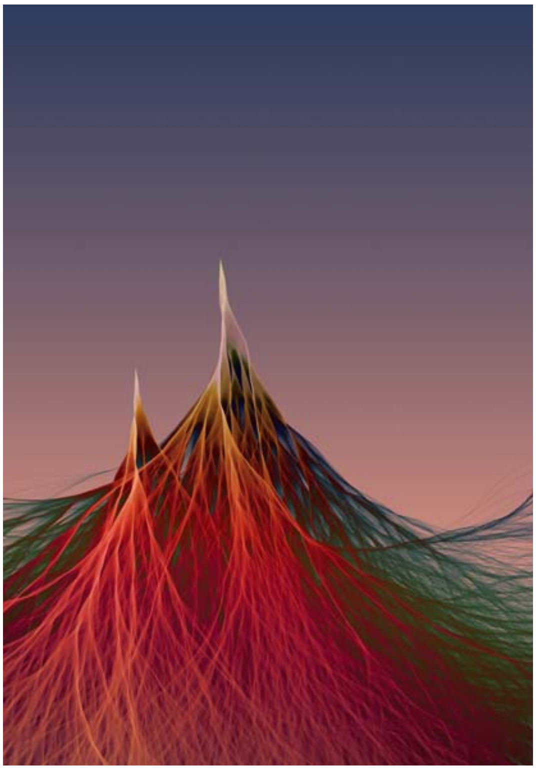
The Hunt for Submarines in Classical Art: Mappings between scientific invention and artistic inspiration



The Hunt for Submarines in Classical Art: Mappings between scientific invention and artistic inspiration

A report to the AHRC's ICT in Arts and Humanities Research Programme

Mike Pringle Rupert Shepherd

Arts & Humanities Research Council

ahds visual arts

The Hunt for Submarines in Classical Art:
Mappings between scientific invention and artistic inspiration

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Cover illustration: Eric J. Heller, *Transport IX*, 2001. See figure 14, page 44.

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1. Introduction

This report stems from a project which aimed to produce a series of mappings between advanced imaging information and communications technologies (ICT) and needs within visual arts research. A secondary aim was to demonstrate the feasibility of a structured approach to establishing such mappings.

The project was carried out over 2006, from January to December, by the visual arts centre of the Arts and Humanities Data Service (AHDS Visual Arts).[1] It was funded by the Arts and Humanities Research Council (AHRC) as one of the Strategy Projects run under the aegis of its ICT in Arts and Humanities Research programme. The programme, which runs from October 2003 until September 2008, aims 'to develop, promote and monitor the AHRC's ICT strategy, and to build capacity nation-wide in the use of ICT for arts and humanities research'.[2] As part of this, the Strategy Projects were intended to contribute to the programme in two ways: knowledge-gathering projects would inform the programme's Fundamental Strategic Review of ICT, conducted for the AHRC in the second half of 2006, focusing 'on critical strategic issues such as e-science and peer-review of digital resources'. Resource-development projects would 'build tools and resources of broad relevance across the range of the AHRC's academic subject disciplines'.[3] This project fell into the knowledge-gathering strand.

The project ran under the leadership of Dr Mike Pringle, Director, AHDS Visual Arts, and the day-to-day management of Polly Christie, Projects Manager, AHDS Visual Arts. The research was carried out by Dr Rupert Shepherd.

The project fell into five sections:
1. Definition of methods
2. Analysis leading to the definition of a number of clearly-defined ICT needs for visual arts research
3. Survey of relevant scientific research into advanced ICT
4. Exercise in mapping needs to technologies
5. Investigation of an exemplary case study resulting from the mapping of technologies to needs

The project's outputs comprise:
1. A report outlining the methods employed, the findings of the survey and analysis, and the mapping between the results of the two main strands
2. A database containing the information gathered during the survey and analysis, and facilitating the mapping between the two
3. A report on the exemplary case study

This report is the first of these outputs. The database and case study can be obtained from the project's website at http://www.vast.ac.uk

[1] http://www.ahds.ac.uk/visualarts/
[2] http://www.ahrbict.rdg.ac.uk/, consulted 18 July 2006.
[3] http://www.ahrbict.rdg.ac.uk/activities/strategy_projects/, consulted 18 July 2006.

1.1. Project aims and objectives

The primary aim of the project was to establish tangible mappings between the needs and/or desires of researchers in the visual arts and the opportunities afforded by technological advances in scientific areas. A secondary aim, achieved by completion of the first, was to demonstrate the feasibility of a structured approach to establishing such mappings. To achieve these aims, the project followed six objectives:

1. definition of a structured method for the project
2. analysis of needs and desires, for ICT technologies, within candidate arenas of visual arts research
3. focused survey of ICT-based technologies
4. creation of a bespoke database populated with the results of objectives 2 and 3
5. mapping exercise to identify areas of common interest
6. reports and exemplar case study based on findings of objective 5

1.1.1. Benefits and interest for the arts and humanities research communities

The project was devised to identify a number of clear ICT arenas that could benefit visual arts research, particularly in respect to the issues and needs of practice-led research. This was achieved by eliciting needs from visual arts researchers and examining technologies that might be available in the sciences. As well as the core information discovered, the project contributes to the wider aims of the AHRC ICT Strategy Projects scheme by demonstrating, through a case study, the broader potential for increased usage of scientific research findings in the arts and humanities. The results of the project are complementary to the findings of the JISC-funded project, *The Digital Picture*,[4] part of another initiative run by AHDS Visual Arts to explore issues relating to the usage of digital images in the visual arts education sector across the entire UK. Findings are presented here to provide a subject-specific complement to the joint AHDS/AHRC ICT in Arts and Humanities survey.

Beyond this, the project's results have relevance for the JISC Arts and Humanities ICT Awareness Programme by helping towards an overview of some of the available tools and resources for arts and humanities research, particularly in visualization methods. It could also contribute towards the programme's aim of developing new methods of collaboration and co-operation. The structured approach used to conduct the project has ensured its compatibility with the AHRC ICT Methods Network, whilst also suggesting ways in which individual projects and overall strategies may benefit from the use of structured methods for developing applications of science-based ICT in the arts and humanities. It offers an example of an extensible method that future research projects, in any of the arts and humanities disciplines covered by the AHRC, could adapt and re-use.

[4] AHDS Visual Arts 2005.

1.2. The project's title

The project's title comes from a hypothetical mapping between imaging ICT and the use of digital images within the visual arts: someone wishing to explore a collection of classical art may benefit from new image-matching[5] techniques developed in military research for the identification of submarine shapes within complex sonar images.

1.3. Context for research

It is well documented that the arts and humanities benefit from scientific advances in ICT imaging technologies. For example, in Content-Based Image Retrieval (CBIR) the arts exploit medical research where technology for retrieving tumour shapes in mammary X-rays also has the potential for finding graphical motifs within digitized paintings. It is also true that the sciences benefit from research in the arts and humanities: the early adoption and subsequent advancement of Virtual Reality technologies, to visualize arts and humanities subjects such as reconstructed archaeological scenes, is one such case.

Such benefits tend to occur serendipitously; but they can provide significant scientific insights, as the following example demonstrates.

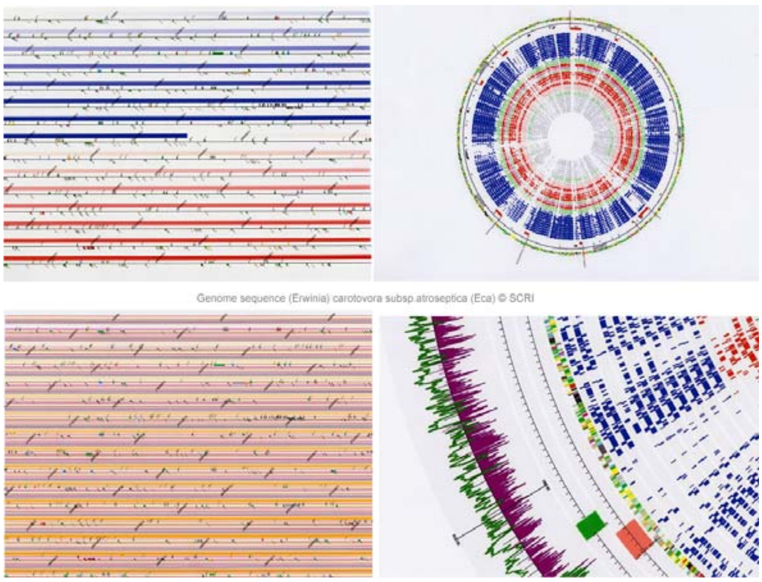

Figure 1. The genome sequence of (Erwinia) carotovora subsp.atroseptica (Eca). © 2006 Elaine Shemilt. Genome sequence © SCRI.

Prof. Elaine Shemilt, a practice-led researcher at Duncan of Jordanstone College of Art and Design, was approached by three genetic researchers, Dr Ian Toth, Dr Leighton Pritchard and Dr Michel Perombelon, from the Scottish Crop Research Institute.[6] Toth and Pritchard use the analytical software Genome Diagram to simultaneously visualise billions of gene comparisons of hundreds of fully sequenced bacterial genomes, including

[5] Image matching is more usually referred to as Content-Based Image Retrieval, or CBIR, which will be the terminology adopted in the rest of this report.
[6] The following information kindly provided by Prof. Shemilt by email, 14 November 2006.

the genomes of animal and plant pathogens (Figure 1). The results of their research have helped to identify the acquisition of foreign DNA by pathogens – potentially representing novel mechanisms involved in disease – and also to trace the evolution of this gene acquisition (and loss) over millions of years.

The scientists asked Shemilt whether she would be interested in producing works of art based upon the images which were being presented by their genome sequencing software. Her first experiments began with a series of prints, where she removed all traces of the relationship between the genome diagram and genome it described, producing a scientific image that was stripped of its contextualizing information. In other words the image, a circular map of genes and their relationship to other bacteria, now represented something essentially invisible that could only be 'seen' in an abstract representation. Shemilt then concentrated on subtleties of colour and tonal variation, focusing on the precision and quantity of visual information and creating a series of etchings, screen prints and animations.

Looking at those prints, from which all contextual material had been removed, the scientists noticed the occurrence of new elements and a very specific event of gene acquisition. Rather than simply identifying genes unique to a pathogen, the screen prints revealed the presence of other genes present in all of the bacteria, possibly representing genes essential to all forms of bacteria. Thus, by simplifying the diagram so that it was reduced to a pattern of tonal variations, Shemilt had re-contextualized the data in such a way that it revealed information that the scientists had completely overlooked. Their scientific approach to the data was systematic and empirical; Shemilt's *artistic* re-interpretation of the scientific data contributed to a new insight.

As a result of this Shemilt, Toth, Pritchard and Perombelon are pursuing a collaborative research project, together with the animator Danny Hill, composer Genevieve Murphy, and soundscape artist David Cunningham. Their project asks:

- Can the collection and visualization of a huge amount of data derived from the scientific study of a genome really enable the production of works of art with high impact and resonance?
- What effects do artistic expressions, communication and methodologies have upon our understanding of complex scientific discovery?

The thread that unifies these two questions is the way that, by de-contextualising scientific data, researchers can obtain a complementary viewpoint to the scientific interpretation. Fine art practice emphasizes subjectivity and ambiguity, whereas science practice attempts to identify objective truths. Despite the contrast between the two approaches, they can be unified because both disciplines thrive on lateral thinking and observation. As well as refining the participants' mechanisms for creative development, this particular collaboration aims to enhance scientific visualisation of complex data, and for this to impact upon scientific understanding and insights.

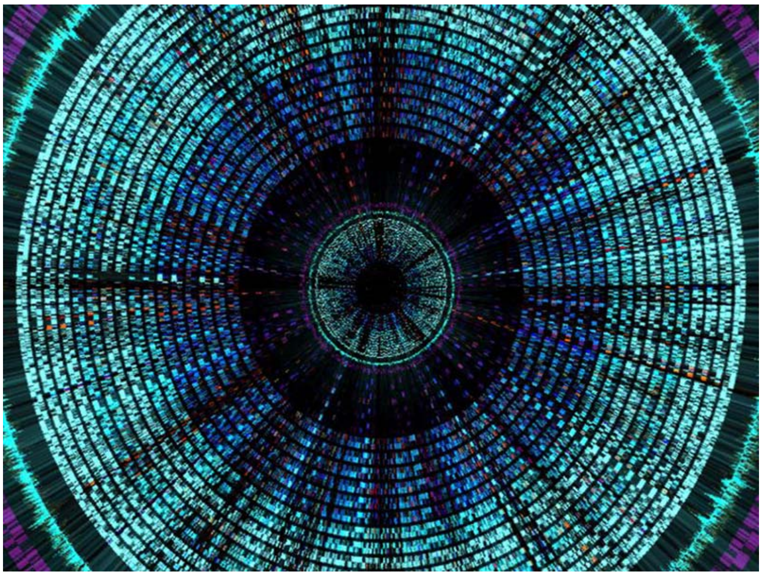

Figure 2. Elaine Shemilt, high-definition wide-screen video animation installed at *Inspiration and Discovery*, Visual Research Centre, Dundee Contemporary Arts, March 2006. © Elaine Shemilt.

Common to both the artists and scientists involved in the project is the use of advanced visualisation tools and the principles of new media. The development of their research will involve the production and analysis of visualizations using print, digital imaging, two- and three-dimensional high-definition animation, and sound and installation (Figure 2 & Figure 3). By using animation to create time-lapse video clips, they will create new dimensions for the expression and interpretation of the data. Their test animations have already shown movement and the uptake and deletion of foreign DNA by bacteria.

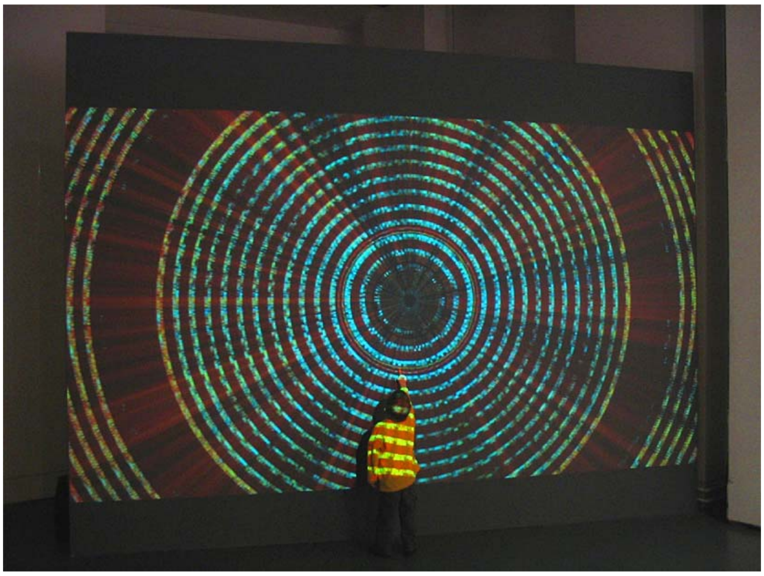

Figure 3. Elaine Shemilt, high-definition wide-screen video animation installed at Inspiration and Discovery, Visual Research Centre, Dundee Contemporary Arts, March 2006. © Elaine Shemilt.

To share DNA, bacteria have to be in close proximity; disease is induced when sufficient bacteria are in close proximity to enable DNA to be shared between them. This idea of a 'tipping point' of bacterial population during disease induction will be explored as an interactive element within an artistic installation as an interactive element. The close proximity of spectators to an object or to one another will trigger a series of visual and aural events reflecting bacterial gene transfer. (The spectators' proximity will be measured using proximity and motion sensing devices.) In this way, the participants hope to relate the idea of the pathogen population-based regulation of pathogenicity genes to a wider audience. Initial animations and music have already been exhibited in the Biopolis Centre in Singapore, and in the Visual Research Centre in Dundee's Contemporary Arts Centre.

As this example suggests, much of the crossover between science and art occurs by fortune rather than design, particularly in the arena of novel ICT-based technologies. This project takes a view that the visual arts could benefit from a more structured and reusable approach to exploring and recording links between focused areas of each sector. Such an approach could extend visual arts research through discovery of ICT technologies that have not yet been exploited within the arts, particularly for areas of practice-led research; and by building on current research in new ways.

1.4. The size of the community and the potential impact of research

The visual arts research community can be divided into practice-led researchers, and those researchers working on the history of the visual arts – historians of art, architecture, design, etc. The size of the community is, inevitably, difficult to estimate, especially as the available statistics are not broken down to a level of detail sufficient to isolate visual arts subjects. In particular, art history and related disciplines are submerged amongst the mass of historians, or even humanities researchers. Similarly, it can be difficult to extract numbers of research students or research-active staff from amongst gross statistics. However, the following figures, all of which relate to the academic year 2004-5 (the last for which statistics are available) may be indicative.

1.4.1. The practice-led research community

Comparison of the total numbers of postgraduate students within the area of 'creative arts and design' who were working on visual arts subjects, with those working on non-visual arts subjects, suggests that approximately 70% of 'creative arts' postgraduates are working on visual arts subjects (the figures are likely to be somewhat inflated by the inclusion of cinematography students) (Table 1).

Subject	Students		
	Full-time	Part-time	Total
Fine art	1,190	1,095	2,285
Design studies	3,030	1,370	4,400
Cinematics & photography	720	600	1,320
Crafts	10	20	30
Others in creative arts & design	455	715	1,170
Total visual arts	5,405	3,800	9,205
Music	1,920	1,520	3,440
Drama	1,110	615	1,725

Dance	90	115	205
Imaginative writing	370	630	1,000
Total non-visual arts	3,490	2,880	6,370
Total creative arts & design	**8,890**	**6,675**	**15,565**
Percentage working on visual arts	61%	57%	59%

Table 1. Postgraduate students of creative arts and design, 2004-5.

Source: http://www.hesa.ac.uk/holisdocs/pubinfo/student/subject0405.htm, consulted 28 September 2006.

This suggests that, of the 275 doctorates awarded in the creative arts and design in 2004-5, perhaps 189 were in visual arts areas.[7] Similarly, assuming that this ratio also holds good for academic staff, then approximately 4,800 of the 6,967.4 FTE staff working in 'design and creative arts' work in visual arts fields.[8] Also, 2,628.6 individuals (FTE, excluding art historians) submitted to the 2001 RAE under the Visual Arts & Media: Practice, History & Theory panel (Table 2).

Subject	Individuals submitting (FTE)
Built Environment	600.5
Art & Design	1,669.5
Communication, Cultural and Media Studies	358.6
Total excluding art historians	**2,628.6**
History of Art, Architecture & Design	346.5
Total	**2,975.1**

Table 2. Individuals submitting to 2001 RAE Visual Arts & Media panel.

Source: Brown et al. 2006, Appendix A2, table 2.2 on p. 70, citing 2001 RAE reports.

1.4.2. *The historical research community*

As mentioned above, however, the initial figures ignore many of those researching in art history and related subjects. Some idea of the number of researchers involved can be gained from the membership of the Association of Art Historians (Table 3). Of the 868 members who gave a precise occupation, roughly 750 are likely to be research-active (the majority of student members of the Association are doctoral candidates). As about 81% of members are UK-based, there are probably about 626 UK-based research-active members of the Association. It should be noted, however, that the Association by no means accounts for all art historians in the UK, and is under-representative in certain areas, notably museums. Staff working in museums and galleries were responsible for over 1,400 publications in the period 2004-5;[9] the importance of the museums sector to academic research has been recognised by the AHRC's decision to award 'analogue

[7] Figure for doctorates from http://www.heas.ac.uk/holisdocs/pubinfo/student/quals0405.html, consulted 28 September 2006.
[8] Figure for academic staff from http://www.hesa.ac.uk/acuk/maninfo/2004-05/staff_fte_0405.xls, column 33, consulted 28 September 2006.
[9] Travers 2006, p. 46.

status' to several leading museums. In comparison, 346.5 individuals (FTE) submitted to the 2001 RAE under the heading of History of Art, Architecture and Design (Table 2).

AAH membership by location	
UK	885
Europe	80
USA	80
Rest of world	36
Unspecified	9
Total	1,090

AAH membership by occupation	Total	UK (estimate)
Academic	308	250
Museum	46	37
Student	417	339
School	13	11
Independent	84	68
Other	166	135
Unaccounted	56	45
Total	1,090	885

Table 3. Membership of the Association of Art Historians, 2005, by location and occupation.

Source: Bulletin of the Association of Art Historians, no. 91, February 2006, p. 4.

1.4.3. *The commercial impact of visual arts research*

Although they ignore visual arts research per se, something of the commercial significance of the visual arts can be gleaned from the Department of Culture, Media and Sport (DCMS)'s bulletin of statistical estimates for the creative industries (Table 4). These figures are necessarily skewed by the coarse breakdown of the different areas: video and film are included alongside photography; music and the performing arts alongside the visual arts; and software and electronic publishing alongside computer games. In addition, many practitioners operate as small businesses which will not find their way into the relevant databases; and the statistics omit any mention of the heritage sector, which has a direct relationship with art history and related subjects. They are nevertheless indicative of the impact the visual arts have on the UK economy. Given these inaccuracies, we might assume that the figures in the 'Total visual-related' column in Table 4 below are, say, twice as high as they should be. Even if this is the case, visual-related industries still contributed more than £15 billion gross value added to the UK economy in 2004, and £4¼ billion of exports. The overall economic impact of museums and galleries (but not other heritage sites such as stately homes, churches or castles) on the UK economy has been estimated at more than £2 billion per year.[10] Well over half a million people were employed in visual-related occupations in 2005, working in more

[10] Travers 2006, p. 47.

than 45,000 businesses. Consequently, developments in visual arts research have the potential to affect the success of 'UK plc' to a significant extent.

	Art & Antiques	Crafts	Design	Designer Fashion	Video, Film & Photography	Music and the Visual and Performing Arts	Software, Computer Games & Electronic Publishing	Total visual-related	Total Creative Industries	Visual-related as % of Creative Industries
Gross Value Added (GVA), 2004 (£ million)	590	n/a	3,900	380	2,300	3,600	20,700	31,470	55,900	56%
% of UK GVA, 2004	0.06%	n/a	0.50%	0.50%	0.30%	0.50%	2.70%	4.56%	7.30%	62%
Exports, 2004 (£ million)	2,200	n/a	550	n/a	940	150	4,700	8,540	13,000	66%
Employment, 2005										
in the Creative Industries	22,900			3,400	51,000	185,300	341,600	604,200	1,045,400	58%
in creative occupations outside the Creative Industries		95,500		112,100	12,800	51,100	255,200	526,700	779,000	68%
Total creative employment	22,900	95,500		115,500	63,800	236,300	596,800	1,130,800	1,824,400	62%
Numbers of businesses in the Creative Industries, 2005	1,700	n/a	n/a	1,400	8,600	29,000	51,200	91,900	117,500	78%

Table 4. How the sector towards which visual arts research is dedicated contributed to the UK economy, 2004/2005.

Note that GVA figures under design are in fact for turnover. Source: DCMS 2006, tables1a & 2-4.

1.5. Dissemination of results

1.5.1. Website

The project website is: http://www.vast.ac.uk . The name VAST is based on an acronym for Visual Arts – Scientific Technologies. The site provides information about the project, and a forum for the dissemination of some of the project's findings and outputs.

1.5.2. Report

One of the project's main deliverables is this report, outlining the project's methods, describing relevant technologies and artistic needs, and producing mappings between them.

1.5.3. Database

As interviews and literature surveys progressed, the technologies and needs were collated in a spreadsheet. Following the development of the conceptual framework to allow for mappings between the two (3.7), the spreadsheet is being converted into a database of technologies and needs, which allows for reports to be generated which identify mappings. This is available on the project website, http://www.vast.ac.uk, and allows scientists and artists hoping to discover opportunities for cross-disciplinary collaborations to upload details of their research and needs and check for likely mappings. Consequently, the project's usefulness will be extended beyond its initial lifetime.

1.5.4. Conferences

In addition, the project's initial findings were presented at the Digital Resources in the Humanities and Arts conference, 2006.[11]

[11] Shepherd 2006.

2. Summary of method, main findings and recommendations

This section provides an overview of the whole project, focusing particularly on the main findings of the various elements of the project, and concluding with a discussion of issues and a number of recommendations that may help to inform future strategies for improving the use of advanced ICT in visual arts research.

2.1. Summary of method employed

The project employed a 'three-pronged attack' (illustrated in Figure 4), based on established methodologies, wherein the following areas were explored in ways appropriate to each:

1. Analysis. Top-down analysis to identify expressed needs/desires of visual arts researchers. The analysis was informed by interviews/email surveys of artist researchers (initially at the University College for the Creative Arts) and augmented with a literature review and the following of new leads based on findings from the interviews/surveys.

2. Survey. Bottom-up survey of the potential benefits of certain ICT technologies employed, primarily, in scientific research. The survey was developed through interviews with representatives of scientific arenas (initially from Cranfield University) and, as in the analysis, augmented by a literature review and the following of new leads based on findings from the interviews.

3. Mappings. Defining innovative uses of scientific technology in the visual arts. Mappings were created by drawing out specific needs of the arts community and linking them, in novel, creative ways, to potential solutions within the scientific domains. This exercise has led the project to identify a list of potentially beneficial areas worthy of further exploration and, subsequently, to a separate description of an exemplar case-study. The case study demonstrates how an identified science-based ICT application can be exploited in a novel way for an arts research project.

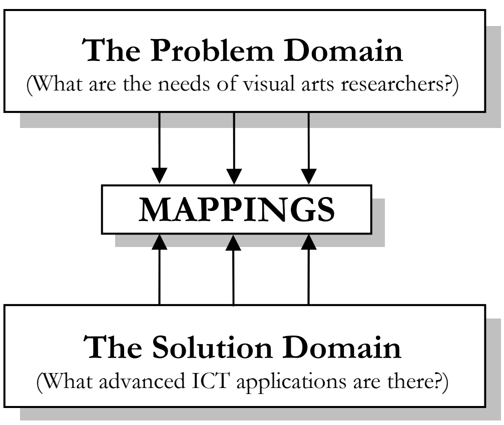

Figure 4. Simplified strategy for mapping ICT applications to visual arts research needs.

2.2. Summary of main findings

This section summarises the main findings from the project

2.2.1. Analysis of the needs of arts researchers

Individual needs, relating to advanced ICT for arts researchers, were elicited through interviews and online surveys. The results were analysed and, where appropriate, grouped together. The following list presents a summary of the needs expressed.

1. Specific needs. Needs that have been identified by researchers in connection with specific interests or projects:
    - Interactive interfaces
    - Viewing images on-screen prior to capture
    - Gigapixel photography
    - Controlling camera movement digitally
    - Generative media
    - Online manipulation and capture of moving images
    - Flexible interactive displays
    - Nano-projection onto living tissue
    - Three-dimensional moving typography

2. Generic needs. Whilst some generic needs may originally have been expressed in terms of specific projects or questions, many of them they have wider applications:
    - Space to share and comment upon ideas and work, including large files
    - Ways of collaborating online with limited infrastructures
    - An easy-to-use facility for creating image-rich online resources
    - Task-specific tools
    - Mixed-reality environments
    - An intuitive haptic interface
    - Seeing below the surface of objects
    - Capturing quantitative data about objects
    - Frame capture
    - Capturing process
    - Capturing images in low light
    - Mapping time
    - Tools for high-quality scanning of digital images
    - New microscopic techniques, including micro-cinematography and animated cell imaging
    - Faster three-dimensional capture
    - Three-dimensional modelling
    - Modelling unconventional forms of vision
    - Modelling non-visual and complex visual properties

- Scalable or animated methods of recording work
- Direct output to industrial tools
- Automated optimisation of images
- Automated image analysis
- Automated incorporation of digital images into databases
- Greater interoperability between file types
- Tools and resources for intensive work with high-definition moving images
- Tools for mapping relationships
- Processing power and exploiting existing resources
- Bulk storage
- Archiving and indexing across multiple removable media
- Annotation of images
- New paradigms for organising archives
- New forms of non-linear interface to websites
- Finding images across multiple collections
- More sophisticated content-based image retrieval
- High-quality presentation of digital images
- Projection onto evanescent surfaces
- More sophisticated presentation software
- Output to multiple types of printer
- Greater and easier access to high-resolution images
- Access to digital reproductions of a broader range of subjects
- More sophisticated searching of collections of digital objects
- The ability to create, use and disseminate personal image collections more easily
- Access to facilities for large-scale digital printing
- Access to technical experts and facilities, and an environment for art/science collaboration
- Personal access to resources
- Pervasive network access
- Training in use of digital images and other digital techniques
- Assistance in processing and presenting digital images
- Keeping the infrastructure up-to-date
- Open content formats
- Preservation of obsolete technologies

2.2.2. Survey of ICT availability/potential

As with the expressed needs, information about advanced ICT technology was elicited from interviews, desk-based research etc., and then condensed into logical groupings. The list in this section outlines the technological applications and processes that were identified as having potential benefit for visual arts research.

1. Collaboration. Collaboration with other individuals, discussion and verbalisation, and the sharing of information and data. The need for high bandwidth network access

was already mentioned in the AHRB's 2003 document on the arts and humanities research landscape.[12]

- The Access Grid
- HP Remote Graphics Software
- CITRIS Gallery Builder
- VidGrid and Mixed Media Grid (MiMeG)
- MITH Virtual Lightbox
- Virtual Vellum

2. Interfaces. Developments in the interfaces between people and machines. This group includes the development of software to focus on specific tasks, rather than presenting an ever-expanding range of functions, as this is – amongst other things – an interface issue.
   - Haptic interfaces
   - Virtual clay
   - VASARI Image Processing Software (VIPS)

3. Capture. The capture of images and of data for digital models, including all forms of imaging technology.
   - Electro-wetting and liquid lenses
   - Charge Injection Devices (CIDs)
   - Functional Electrical Impedance Tomography of Evoked Responses (fEITER)
   - PathMarker
   - Laser capture of three-dimensional objects
   - Volumetric cinematography
   - High-resolution imaging
   - Multi-spectral imaging
   - New infra-red sensors
   - Polynomial Texture Mapping (PTM)
   - Neutron Activation Autoradiography
   - Computed Tomography ('CT scanning')
   - X-ray micro and nano computed tomography
   - Raman microscopy
   - Optical Coherence Tomography (OCT)
   - X-ray Fluorescence (XRF)

4. Modelling. The creation and manipulation of digital models, usually of physical objects but also of more abstract data.
   - Synthetic environments
   - Synthetic wrap
   - Automatic construction of three dimensions from two-dimensional images
   - Visualisation, particularly three-dimensional modelling

[12] AHRB 2003b, ¶ 5.3 on p. 14.

5. Image processing. Various processes applied directly to image files to characterise or alter them (including compression techniques).
   - IIPImage
   - Automated feature extraction
   - Visually Significant Barcodes

6. Video. The ability to work with, store and share uncompressed high-definition video files. As noted by the AHRB in 2003, the growing use of digital media within research, practice and performance 'requires high bandwidth network access, multi-media studios … and film and video suites'. [13]
   - Time-based media

7. Visualisation. The processing of data and digital models to convert them into visual form for presentation and analysis.
   - Physics-based visualisation

8. Processor power. Substantial processor and computing power. The AHRB's research landscape document noted the possibility of exploiting grid technology and large national facilities.[14]
   - Grid computing (and e-Science)
   - Cluster computing

9. Storage. High-resolution image files, and to an even greater extent high-definition video files, require significant amounts of secure storage space.

10. Categorisation/ordering. Ways of categorising and arranging images so that they might be more easily archived, discovered, or presented.
    - Annotation
    - Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH)
    - The semantic web
    - Visual interfaces to data

11. Finding images. The discovery of images for research and incorporation into new works, often by non-text-based means.
    - Content-Based Image Retrieval (CBIR)
    - e-Chase and OpenMKS

12. Display. The presentation of work, whether on-screen, projected, in hard copy (two- or three-dimensional), or in other, less tangible forms.
    - Paper-like displays
    - Rapid prototyping
    - Direct laser fabrication
    - High dynamic range displays
    - High resolution projectors

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[13] AHRB 2003b, ¶ 5.3 on p. 14.
[14] AHRB 2003b, ¶ 5.3 on p. 14.

- Projector calibration
- Evanescent displays
- Volumetric displays

13. Image collections. The production and dissemination to researchers of collections of digital images, and other digital objects, as research material.

14. Access. Access to the tools, equipment, expertise, assistance and people who can enable the development and exploitation of advanced technologies in the visual arts.

15. Sustainability. In addition to those practitioners' needs which might be met by advanced imaging technologies, it must be emphasised that discussions raised many issues which relate to more basic problems. Although these may seem to lie outside the scope of this project, they have a significant impact on practitioners' abilities to sustain their research work. The problems are largely infrastructural, but they reveal a worrying tendency on the part of institutions to fail to provide the assistance and training that their staff need in order to use the digital techniques which are being forced upon them by cultural and technological pressures. They are related to some of the concerns highlighted in the AHDS Visual Arts report on *The Digital Picture*.[15]

2.2.3. Mappings between existing technologies and needs

This section summarises the mappings exercise that the project conducted with the needs and technologies outlined in the previous two sections. The following list indicates areas where the project found potential for novel applications of advanced ICT to meet expressed arts research needs.

1. Collaboration

    - High-end infrastructures. A number of expressed collaborative needs may be met by technologies considered to be 'high-end', i.e. comprehensive, high power, broad bandwidth infrastructures such as VREs and the Access Grid.

      Because of its ability to handle multiple sites and large digital files, the Access Grid's potential in enabling collaborative visual arts research is immense. As Grindley notes,[16] it has significant potential for facilitating detailed discussion of artefacts which may be too fragile to travel. The report on the recent scoping seminar on e-Science in the visual arts also describes the Access Grid's exciting potential, noting that artists want to use the grid as 'an artistic space and see what emerges at the end. A research project could for example - through the use [of] these technologies - lead to a re-conceptualisation of e-science and the grid's future potential.'[17]

[15] AHDS Visual Arts, 2005.
[16] Grindley 2006, p. [7].
[17] Gollifer 2006.

However, there are current obstacles, identified in the report on the recent scoping seminar on e-Science in the visual arts, particularly in regard to the levels of access that HE institutions have to such technologies.[18] Infrastructural problems may be met in part by the increasing specifications of desktop computers, and the use of personal interfaces to the Access Grid rather than full-scale nodes. Other technologies that may prove beneficial for sharing and commenting upon ideas and work include: CITRIS Gallery Builder; VidGrid and Mixed Media Grid (MiMeG); MITH Virtual Lightbox; Virtual Vellum; annotation; e-Chase and OpenMKS, and a number of other existing products.

- Limited infrastructures. Developments in motion-capture technology – particularly live streaming of the point data – may help reduce bandwidth requirements for the distribution of motion-capture based animations, performances etc. over the web; however, rendering would have to be done at the delivery end, and would still place substantial processing demands on the remote computer. But this might be addressed by technologies such as: HP Remote Graphics Software; IIPImage; and Grid computing (and e-Science), notably the Resource-Aware Visualisation Environment (RAVE) project.

2. Interfaces

   - Task-specific tools. One obvious candidate seems to offer one solution to this requirement: VASARI Image Processing Software (VIPS). Whilst VIPS is itself a complex tool, the way that it has been developed and optimised to meet the needs of a comparatively small user-group (imaging scientists working in museums) indicates the kind of focus on specific capabilities that would render task-specific tools useful to particular user communities.

   - Interactive environments. A number of mixed-reality (or augmented reality) technologies exist, including visualisation software, particularly three-dimensional modelling; haptic interfaces; and evanescent displays. Furthermore, intuitive tools exist for interactivity that emulates some of the more traditional modes of arts research; for example, virtual clay and paper-like displays.

3. Capture

   - Seeing below the surface of objects. Those research technologies that involve deeper exploration of artefacts or images include: multi-spectral imaging; new infra-red sensors; neutron activation autoradiography; Computed Tomography; x-ray micro and nano computed tomography; and Optical Coherence Tomography.

   - Capturing quantitative data about objects. As with collaborative research tools, there is also potential for a series of techniques developed in the field of manuscript studies to be of use to art historians, particularly those working on manuscript illumination and on drawings. Such technologies include: laser capture

[18] Gollifer 2006.

of three-dimensional objects; multi-spectral imaging; Polynomial Texture Mapping; Raman microscopy; Optical Coherence Tomography; and X-ray fluorescence.

- Capturing process. Whilst they do not capture process, paper-like displays would enable researchers to present process that has been captured in some way as if it were a drawing or painting – an object hanging on a gallery wall which might be seen to ‘draw’ itself.

- Capturing images in low light. Charge Injection Devices are able to acquire images cumulatively over long time periods, and the image can be read out without clearing the sensor. In addition, individual pixels can be read out as required.

- Mapping time. Charge Injection Devices may also provide a variety of potential ways in which the passage of time may be captured and visualised, as would Polynomial Texture Mapping.

- High-quality scanning of digital images. Advances in high-resolution imaging will almost certainly fulfil this need.

- New microscopic techniques. Such needs, which include facilities for micro-cinematography and animated cell imaging, could be met with: X-ray micro computerised tomography; Raman microscopy; and Optical Coherence Tomography.

- Faster three-dimensional capture. Volumetric cinematography addresses this need, as do Polynomial Texture Mapping and techniques for the automatic construction of three dimensions from two-dimensional images.

- Gigapixel photography. Very high-resolution imaging already exists and is becoming more readily available; it is likely to be only a matter of time before gigapixel technologies emerge.

- Controlling camera movement digitally. Electro-wetting and liquid lenses have the potential to mimic the effects of camera movement.

4. Modelling

    - Three-dimensional modelling. A number of tools may help with this need: Laser capture of three-dimensional objects; automatic construction of three dimensions from two-dimensional images; and visualisation, particularly three-dimensional modelling.

    - Modelling unconventional forms of vision. Visualisation, particularly three-dimensional modelling, has potential for this area.

- Modelling non-visual and complex visual properties. Haptic interfaces; Polynomial Texture Mapping; visualisation, particularly three-dimensional modelling; and physics-based visualisation, all offer solutions for these kinds of needs.

- Scalable or animated methods of recording work. Automatic construction of three dimensions from two-dimensional images; and visualisation, particularly three-dimensional modelling.

5. Image processing

- Direct output to industrial tools. Rapid prototyping; and direct laser fabrication may prove useful.

- Automated image analysis. This need may be met by automatic construction of three dimensions from two-dimensional images; for example, Photo Tourism. This tool was used, in conjunction with digital elevation maps, to reconstruct the point from which Ansel Adams's famous photograph *Moon and Half Dome, Yosemite*, was taken; this suggests a potential application for historians of photography and, possibly, for historians of landscape painting – although the potential 'inaccuracies' in depiction introduced by artists may prove too much for the system. Further technologies for automated image analysis include: visualisation, particularly three-dimensional modelling; the semantic web; and Content-Based Image Retrieval.

- Automated incorporation of digital images into databases. Automatic construction of three dimensions from two-dimensional images is advancing in ways that may help to address this need. One of the most time-consuming aspects of adding images to databases is the entering of suitable metadata. It has been suggested that systems for constructing three-dimensional models from two-dimensional images be used to automatically annotate large collections of images with metadata based upon the images' visual similarity to already-labelled images.[19]

  It has also been suggested that semantic web processes and systems for content-based image retrieval could be used to automatically annotate large collections of images with metadata in the same way as has been proposed for Photo Tourism and similar technologies.

- Greater interoperability between file types. Many developments may help meet this need: PathMarker; synthetic environments; synthetic wrap; visually significant barcodes, which combine two types of data, albeit in physical form; grid computing (and e-Science), specifically the AMUC project; the semantic web; Content-Based Image Retrieval; and e-Chase and OpenMKS increase the interoperability of metadata.

6. Video

[19] Snavely et al. 2006, § 7.2.

- Tools and resources for intensive work with high-definition moving images. Grid computing (and e-Science) clearly has potential for meeting this need. It is worth noting that astronomers have access to grid-based technologies for producing MPEG movies of the sun from observational data via the UK's Astrogrid 'virtual observatory' service.[20]

7. Visualisation

   - Tools for mapping relationships. Physics-based visualisation may be of use in this area.

8. Processor power

   - Processing power and exploiting existing resources. Grid computing (plus e-Science), and cluster computing, clearly offer benefits for processing power and the opportunity for better exploitation of resources.

9. Storage

   - Bulk storage. Grid Computing again offers solutions to this ever present problem.

10. Categorisation/ordering

    These needs may, in part, be addressed by the semantic web.

    - Archiving and indexing across multiple removable media. Existing products may serve this need – Datacatch Librarian is a commercially available product which will automatically catalogue data held on removable media alongside data stored locally, providing a unified search interface for local and removable files.[21]

    - Annotation of images. It has been suggested that systems for constructing three-dimensional models from two-dimensional images be used to automatically annotate large collections of images with metadata based upon the images' visual similarity to already-labelled images. For example, the Photo Tourism system will take annotations applied to one section of a three-dimensional model, and apply them to the same section on all images which also show that section.[22] It has also been suggested that systems for content-based image retrieval could be used to automatically annotate large collections of images with metadata in the same way as has been proposed for Photo Tourism and similar technologies. Furthermore, annotation systems obviously have benefit in this realm, as do e-Chase and OpenMKS.

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[20] See http://wiki.astrogrid.org/bin/view/Astrogrid/MovieMaker, consulted 14 June 2006.
[21] http://www.datacatch.com, consulted 10 August 2006.
[22] Snavely et al. 2006, § 7.2.

- Indicating scale in digital images. MITH Virtual Lightbox may be able to be repurposed for this need.

- New paradigms for organising archives. Several technologies are already pushing the boundaries of this need: PathMarker; physics-based visualisation; visual interfaces to data; and Content-Based Image Retrieval – visual characteristics, such as those generated for Content-Based Image Retrieval, might be used as the organising principle for certain archives of visual material.

- New forms of non-linear interface to websites. Non-linear interfaces can be found in: CITRIS Gallery Builder; PathMarker; physics-based visualisation; and visual interfaces to data. Also, it may be that the necessary routes or links could be generated on-the-fly using text-mining or Semantic Web technologies.

11. Finding images

These needs may, in part, be addressed by the semantic web. Adoption of the recommendations of the *CLIC* report would also make a major contribution towards meeting these needs.[23] Both the *CLIC* report and respondents to the *Digital Picture* consultation emphasised the desirability of harvesting and aggregating image metadata from dispersed collections as the ideal way to meet increasing needs for a unified source of images, a need which OAI-PMH is therefore well-placed to meet.[24]

- Finding images across multiple collections. Grid computing – in the words of the summary of the recent e-Science scoping seminar for visual arts, 'The data grid and the computational grid provide access to large data and the means to analyse it. That doesn't necessarily just mean access to high-resolution images, but opportunities to use multiple images.'[25] The Open Archives Initiative Protocol for Metadata Harvesting and semantic web technologies are also useful here – the latter have already been used in e-Chase and OpenMKS.

- More sophisticated content-based image retrieval. Automatic construction of three dimensions from two-dimensional images; physics-based visualisation – this form of visualisation may also have the potential to work as a navigation aid, perhaps through recording routes through archives or illustrating the search routes one takes. Grid computing (computational grid) also has potential in this area. This was noted in the summary of the recent e-Science scoping seminar for the visual arts: 'This extra computing power would allow people to explore images from all over the globe in much more efficient ways, without the need for the pre-processing or re-rendering of the images.'[26] Further solutions may exist in: cluster computing; e-Chase and OpenMKS; visual interfaces to data; and in advances in

[23] Miller et al. 2006.
[24] Miller et al. 2006, § 3.1 on p. 20, § 5.1.1 on p. 32, § 9.3 on pp. 52-3, § 4.1.2 on pp. 27-9, § 10.6.3 on pp. 60-61, §10.6.5. on pp. 61-2, & App. 11.9.8 on pp. 133-7; and AHDS Visual Arts 2005, § 4.3.2 on pp. 35 & 36-7.
[25] Gollifer 2006.
[26] Gollifer 2006.

Content-Based Image Retrieval – Microsoft are proposing that the point clouds generated by Photosynth could be used for content-based image retrieval, effectively retrieving images which showed the same object, regardless of orientation. They also suggest extending this capacity to deliver automatic tagging of images, something already carried out in the earlier Photo Tourism system.

12. Display

- High-quality presentation of digital images. Quality of images is developing in areas such as: high-resolution imaging (high-quality presentation requires high-quality originals); visualisation, particularly three-dimensional modelling; IIPImage; paper-like displays (avoid need for blackouts); rapid prototyping (three-dimensional facsimiles); high dynamic range displays; high resolution projectors; projector calibration; volumetric displays.

- Projection onto evanescent surfaces. Evanescent displays clearly meet this need.

- More sophisticated presentation software. Virtual vellum; projector calibration can help towards this need, perhaps through incorporation of colour management into PowerPoint.

- Flexible interactive displays. Paper-like displays – the more flexible forms of paper-like display will certainly fulfil the 'flexible' part of this need. 'Writable' technologies such as the Gyricon display may well also be able to function as interactive displays. Evanescent displays may also offer potential.

- 3d moving typography. Haptic interfaces; visualisation, particularly three-dimensional modelling; volumetric displays. It seems likely that this need could be met by a combination of display and modelling technologies.

13. Image collections

- Greater and easier access to high-resolution images. HP Remote Access Software, high-resolution imaging, and IIPImage all offer solutions to this need.

- Digital reproductions of a broader range of subjects. This need may be met in part by visualisation technologies, particularly three-dimensional modelling which gives opportunity for different forms of representation. Also, CITRIS Gallery Builder, the Open Archives Initiative Protocol for Metadata Harvesting, PathMarker, annotation systems, e-Chase and OpenMKS may help to pull collections together or allow more sophisticated searching of collections of digital objects.

- More sophisticated searching of collections of digital objects. This need obviously relates to *finding images* (11, above), but, in terms of increasing sophistication, the Open Archives Initiative Protocol for Metadata Harvesting is an obvious candidate, given its ability to 'join up' collections. Also, the semantic web has relevance here, as do CITRIS Gallery Builder, PathMarker and annotation systems.

- The ability to create, use and disseminate personal image collections more easily. MITH Virtual Lightbox and PathMarker may provide tools to meet this need.

2.3. Discussion and recommendations

This final subsection of the project summary discusses some of the issues that the project has revealed and offers a number of recommendations that may help to inform future strategies for improving the use of advanced ICT in visual arts research.

2.3.1. General observations

Artists, including practice-led researchers, have been exploiting digital technologies almost since their inception, and works of 'new media art' – artworks which involve the use of ICT in their creation or presentation – have become common over the last ten to fifteen years. There is already an established framework for exhibiting and disseminating such works, often via annual exhibitions, prizes and conferences.

However, by its very nature such work uses technologies with which its creators are familiar. Consequently, whilst current practice in new media art may provide useful pointers to the *ways* in which technologies may be of use, the technologies it uses fall outside the scope of this project. *The Hunt for Submarines* was governed by an aim to map researchers' needs to ICT in ways that were, at the time of the project's research, unknown or under-exploited in arts research, or to suggest that new uses of established technologies may meet additional needs. This has been achieved with the identification of over 130 mappings between expressed research needs and known ICT, as summarised in the previous section. Each of these mappings suggests a novel avenue of research.

Such a broad list of mappings, or potential uses of ICT, is indicative of an arts research culture in which the use of technology, while not as widespread, is probably broader in scope than in many other disciplines; art research tends by its nature to have fewer boundaries, and fewer well defined arenas of exploration, than, for example, some of the humanities subjects. Furthermore, this project has discovered that art research, like art itself, has elements of 'counterculture' where one of the key tenets is to explore the unknown, particularly if established barriers, whether cultural, technological, practical (or even moral or ethical) can be pushed. Such a culture naturally lends itself to novel exploration of *anything*, and advanced ICT, with its incessant growth and ever-increasing capabilities, is an obvious candidate for such exploration. However, the desire to push boundaries and retain creativity at the heart of arts research also means that it can be extremely hard to place clear structure or categorisation around technological developments, as anything and everything is considered to be relevant. This can be compounded by the 'subversive' nature of many art disciplines, which seeps into much art research, and often gives the impression of an almost automatic rejection of any formalisation or rigid structure.

For many arts researchers the underlying concern is for the *visual arts* element of their research and, understandably, not always the advancement of ICT except in a limited, localised capacity. To an art researcher the important element of technology (whether access grid node or pencil) is its relationship to art.

Nonetheless, the method used in this project has enabled clear areas of potential arts research to be identified. Some of the mappings may seem obvious but, until now, the art researchers only had aspirational ideas and no awareness of the technologies available. Conversely, the technologists have had access to technology and understanding of previous or existing applications but were unaware of the breadth of applications that art research might bring to their disciplines.

2.3.2. The nature of visual arts research ICT needs

Many of the practice-led needs expressed in this report seem to relate to the properties particular to images, whether still or moving, and their digital equivalents, for example:

- The large file sizes required to capture high-quality images
- The high specifications (and consequently expense) of the equipment required to capture and present high-quality images
- The different purposes, and therefore different kinds of images, stored in different formats, of the artistic and engineering worlds
- File formats for moving images still evolving as processor power increases and displays resolution grows, enabling ever larger images to be used
- The non-verbal nature of images, which leads to problems combined with the verbal nature of most search and retrieval systems

A significant number of such needs could be met in whole or in part by existing tools, either open source or commercially available, though, of course, there is still a necessity for further research and development in order to achieve novel applications.

Art historians' needs also result from the characteristics of images, but perhaps also result from two further factors:

1. Art historians are usually bracketed with the humanities more generally, a field of enquiry which primarily focuses upon verbal rather than visual evidence (there are, of course, exceptions to this)
2. Art history departments tend to be small, and so do not have the resources to employ high-level technical assistance which can focus on specifically art-historical needs (see Table 6 on page 70)

Consequently, research needs which relate to the visual character of the subject are often neglected, particularly if they are expensive. As a result, many of the tools being developed which would prove very useful to art historians have in fact being produced for projects working in other fields, notably the collation of manuscript sources for literature and music – although it should be remembered that the decoration of manuscripts and incunabula is a long-standing and well-defined area of art history.

Despite the fact that many of the needs relate to image properties, researchers' general lack of awareness of the ICT tools that are available suggests that many of the issues blocking take-up of ICT in visual arts research are *cultural* rather than *technological*, and lie within the institutional frameworks within which such research is carried out, and perhaps in a broader, artificial, division between arts researchers and technological domains. It is also clear that issues such as funding, communication, distinctions between research and teaching, and the differing priorities of funding bodies play major roles in the maintenance and/or development of the situation.

2.3.3. The relationship between needs and technologies

Figure 5 shows the number of technologies in each of the project's categories, compared to the number of individual needs in each category. This indicates the degree to which there is a mismatch between technologies and needs. Consequently, the mappings which the project identified do not address all the needs expressed by researchers in the visual arts. The categories with the greatest discrepancies are storage, interfaces, display, collaboration, video and processor power, suggesting that further research may be required in order to identify technologies that might meet needs in these areas.

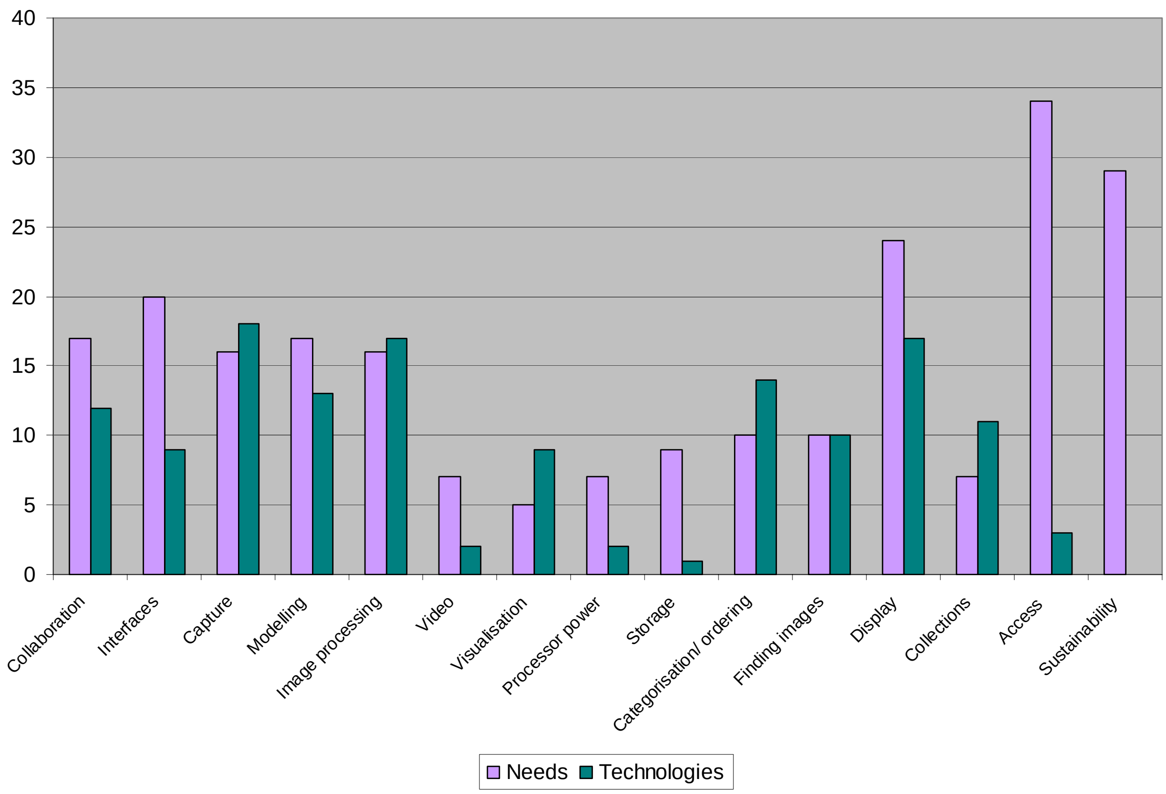

Figure 5. Individual needs and technologies compared, both divided into categories.

Within the general areas identified above, the analysis of arts research needs discovered a number of specific needs for which no obvious ICT solution arose: no mappings. Although the point of creating mappings was to identify future avenues for research, paradoxically, each of these unmapped needs, outlined in the list below, also provides a pointer towards areas of future research:

- Easy-to-use facilities for collaborating in the creating of image-rich online resources
- Frame capture
- Viewing images on-screen prior to capture
- Generative media
- Tools and resources for intensive work with high-definition moving images
- Automated optimisation of images
- Online manipulation and capture of moving images
- Output to multiple types of printer
- Nano-projection onto living tissue
- Access to facilities for large-scale digital printing
- Central resource of equipment
- Personal access to resources
- Pervasive network access

2.3.4. Access constraints

In many of the needs expressed, even where technological solutions may have been identified, research will be impeded because of the difficulties of access: access to the technology itself; access to the required knowledge; and access to appropriate levels of expert help or advice. This is nowhere more apparent than in regard to infrastructural issues, such as those concerning institutional networks. Needs relating to collaboration, three-dimensional capture, modelling, image processing, video, processing power, storage and finding images, are all likely to place high demands on institutional networks and on connections to JANET, and there will therefore be a need to ensure that there is sufficient local infrastructure to support them. Frequently, arts research, based in subject specific art colleges or departments, is isolated from the sorts of ICT environments that, for instance, some of the bigger universities may be able to provide: for example, HATII (Glasgow), CCH (King's College London), HRI (Sheffield), ACDT (Oxford). Various reports have pointed out problems found by researchers in art institutions, whose ICT departments often lack the understanding or capability to support higher-end activities.[27] This leads to a mismatch between the aspirations of researchers and the technological capabilities of their institutions. In order to change this situation, a paradigm shift, or perhaps a step-change, may be required in institutional attitudes to ICT provision, and, inevitably, in the way funds are prioritised or allocated.

Steps forward could be made with relatively simple improvements: one example being in the consideration of the *fitness for purpose* of desk-top computing facilities for art research where the following could easily be achieved:

[27] Huxley et al. 2006, pp. 2 & 10-12; Abbott & Beer 2006, § 6 on pp. 39-40.

- high-resolution, colour-calibrated projectors
- colour-calibration of *all* staff and student monitors
- high capacity graphics and RAM to ensure computers are adequate for the processor-hungry tasks they will be asked to perform
- configuration of machines to run as clusters in idle time for rendering, image characterisation, etc.

Visual arts researchers' current inability to locate experts in particular technologies may be rectified, in part, if Intute follow the recommendation in their recent research community requirements report that they investigate the viability of a national database of researchers.[28] However, this is marked as a long-term project, and there remains a short-term need for a central clearing-house for research collaborations in the field of digital imaging technologies.

2.3.5. Sustainability

Following on from access, the issue of sustainability is relevant: many of the reasons behind lack of access to resources or technologies are underpinned by doubts about sustainability. Institutions, and indeed individual researchers, cannot expend the time, energy or resources to assimilate sophisticated developments in equipment and software (both usually expensive) without reassurance that their use will be sustained beyond a current fixed-term contract or research project life.

Beyond such clear, but problematic, short-term worldviews, a number of associated issues relate to sustainability, all of which need careful consideration, for example:

- researchers need appropriate ongoing training/development in the use of advanced ICT and other digital techniques
- assistance in processing and presenting of digital material should be constantly available
- infrastructure needs to be kept up-to-date
- researchers need to have faith in the longevity and interoperability of standards
- longer term usage of technology might be facilitated through more use of open content formats
- all research materials and outputs must be preserved for future generations
- some obsolete technologies may need to preserved

2.3.6. Recommendations

Each of the needs identified in this project, particularly where mapped to a technology, can be seen to offer a specific, positive area for further research. However, the following list of recommendations takes into account the broader picture that emerged from this project's research, and considers art researchers' ICT needs in the light of what are perceived to be the more pervasive, underlying obstacles to development.

[28] Wilson & Fraser 2006, § 5.2.6-7.

1. Further and more permanent avenues for providing access to resources and expertise should be developed.

2. There is a need for greater sensitivity to specific visual arts needs in *local* infrastructures.

3. Local research support infrastructures should facilitate the research process by providing access to tools, resources and expertise as required, rather than just focusing on administration.

4. Sustainability and preservation of resources and research outputs needs to be considered on a national scale.

5. Specific relationships between elements of art and science communities (following on from initiatives such as e-science) should be encouraged and facilitated.

6. Arts research needs sustained, expanding collections of images: more large-scale projects as well as increased technological capacity for individual contributions, but with an insistence upon interoperability (OAI-PMH) and metadata standards in *all* projects.

7. Active pressure should be placed on government-funded organisations (particularly those with research analogue status) to make large-scale images freely available to researchers.

8. More funding is required for research into, and development of, open-source, user-friendly, task-specific tools which answer specific user needs.

9. The art research community would benefit from a pool of (more expensive) equipment for researchers to borrow/use when required.

There is a need for an ongoing, growing clearing house (dating service) for contacts between visual arts and technological researchers. (The database produced by this project is the first step towards this aim).

3. Full project results

3.1. A note about terminology

The project adopts the vocabulary used in software development, whereby:

- 'top-down' means establishing basic system needs, which are then refined until the requirements have been defined in sufficient detail to enable programming to begin
- 'bottom-up' means starting work by writing or adopting a series of discrete units of code, which are only fitted together near the end of the project

Thus, as far as this project is concerned, 'top-down' means defining user needs regardless of technology, whilst 'bottom-up' means examining technologies in terms of their functionality rather than use.

3.2. Project method

In trying to extend use of ICT, it can be tempting to focus on the known qualities of the technology and to then apply them to problems in a way that gives an impression of providing solutions. Overseen by commonly accepted Project Management procedures and utilising elements of methodologies that are well established in computing information systems engineering , this project avoided such risk through the employment of a 'three-pronged attack'. This strategy is illustrated, in simplified form, in Figure 6.

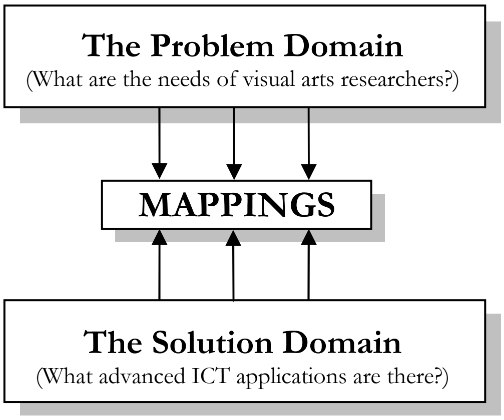

Figure 6. Simplified strategy for mapping ICT applications to visual arts research needs.

The principle of utilising different methodologies for different contexts follows a proposal by Earl.[29] In discussing Information Systems (IS) strategies, he identifies that no single formulation will work, and that a multiple methodology is called for: a 'three-pronged attack', wherein top-down, bottom-up and inside-out methods are each tackled from a perspective that suits their respective needs (illustrated in Figure 7).

Earl suggests that the following three issues need to be addressed:

1. clarification of needs and strategy in IS terms

[29] Earl 1989.

2. evaluation of current IS provision and use
3. innovation of new strategic opportunities afforded by IT

The combination of all three issues creates a comprehensive methodological approach. This basic model illustrates the three areas that need to be addressed when developing strategic visions for the use of ICT, and suggests an appropriate perspective from which each should be approached. Taking this model as its foundation, a bespoke method has been developed for this project, wherein the following three areas were explored in ways appropriate to each:

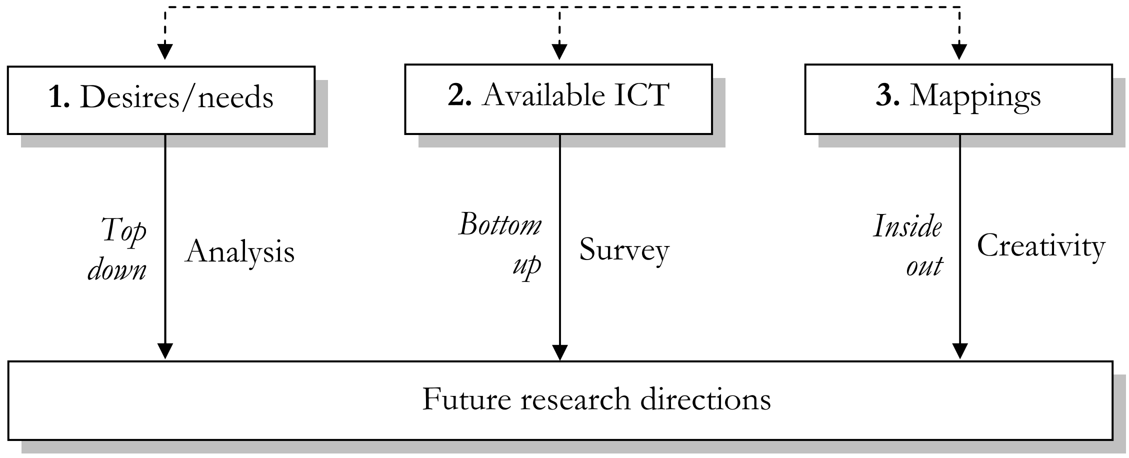

Figure 7. Three-pronged approach modelled on Earl's proposal.

1. Analysis. Top-down analysis to identify expressed needs/desires of visual arts researchers. The analysis was informed by interviews/email surveys of artist researchers (initially at the University College for the Creative Arts) and augmented with a literature review and the following of new leads based on findings from the interviews/surveys.
2. Survey. Bottom-up survey of the potential benefits of certain ICT technologies employed, primarily, in scientific research. The survey was developed through interviews with representatives of scientific arenas (initially from Cranfield University) and, as in the analysis, augmented by a literature review and the following of new leads based on findings from the interviews.
3. Mappings. Defining innovative uses of scientific technology in the visual arts. Mappings were created by drawing out specific needs of the arts community and linking them in novel, creative ways, to potential solutions within the scientific domains. This exercise has led the project to identify a list of potentially beneficial areas worthy of further exploration and, subsequently, to a separate description of an exemplar case-study. The case study demonstrates how an identified science-based ICT application can be exploited in a novel way for an arts research project.

This approach is ideal for studies where the issues involved can be 'soft' or difficult to define, and was augmented by consideration of some of the principles of Soft Systems

Methodology (SSM), which was conceived and developed by Peter Checkland.[30] Checkland makes the valid observation that, in order to understand how change, or novel ideas, can be introduced to a domain, there must first be a coherent overview of the domain, including its strategic or driving desires, its aims for the future and, most importantly, its 'raison d'être' or purpose. To this end, it was imperative for this project that we had an understanding of who our 'target audience' would be, i.e. the visual arts research community, and what their needs, in respect of advanced ICT, might be.

Although the project did not attempt to carry out an SSM implementation, it adhered partially to the notion of establishing a realistic understanding of visual arts research: what it does; how it does it; and why it does it. To fulfil such goals SSM suggests the construction of theoretical models of various aspects of the organisation and comparison of these models with the real-world situations that they represent. In Checkland's words:

> To do systems thinking is to set some constructed abstract wholes (often called 'systems models') against the perceived real-world in order to learn about it. The purpose of doing this may range from engineering (in the broad sense of the word) some part of the world perceived as a system, to seeking or illumination.[31]

The core analysis in this project was primarily concerned with the latter of these aims: illumination, or clarity about what visual arts researchers want or need (described for simplicity throughout this document as *needs*). Checkland states that such analyses, whilst useful for '… debating perceptions of the real world … are not, in fact "valid" or "invalid", only technically defensible or indefensible.'

To ensure the technical defensibility of the results of our analysis, and thus to attain clarity, a number of areas were explored through interviews, discussions and surveys as well as through reference to appropriate literature. This provided what Checkland refers to as a 'situation unstructured' view of the world, revealing perceptions about:

- The context for the research (see section 1.3 above)
- The size of the community and the potential impact of research (see section 1.4 above)
  - The practice-led research community
  - The historical research community
  - The commercial impact of visual arts research
- The relationship between research and practice (see section 3.3.3 below)
- The wider context of ICT in the visual arts (see section 3.3.4 below)
  - Existing collections of new media art
  - Existing events promoting new media art
- The bridge between visual arts, imaging sciences and research (see section 3.3.5 below)

In terms of a 'constructed abstract whole' of the needs of the visual arts research community in respect of advanced ICT, the following abstract list of usage has provided a practical model of the 'situation expressed' on which to build up a picture of needs:

[30] Checkland 1981.
[31] Checkland & Scholes 1990.

- New ways of seeing
- New iconographies
- New ways of presenting their research outputs
- New ways for audiences to interact with their outputs
- New ways of working
- New ways of researching source material and other images

This list can be further clarified if thought about in terms of the AHRB's statement that practice-led researchers

> should, like their colleagues in other subjects and disciplines, regard it as a scholarly obligation to document and to reflect critically on and review their research processes in this way …. This would play the same role as the scholarly apparatus and contextual analysis by which conventional text-based research outputs enable the research to be situated and the research process to be understood.[32]

The methodical approach described above has provided a procedural approach to the issue of identifying practical technological solutions to real needs or desires. If rigidly applied, such an approach does not assume that any suitable applications exist for the particular problem domain under scrutiny, and, consequently, may establish no mappings at all. If this was ever the case, the suggestion would be that the available technology domain offers no suitable solutions for the expressed needs of the problem domain. Nonetheless, in this project the opposite scenario occurred: the visual arts researchers offered up a multitude of needs, many of which seemed to map to potential solutions in the results of the ICT survey.

The project has also taken account of the findings of other AHRC ICT in Arts and Humanities Research Strategy Projects, specifically:

- RePAH: A User Requirements Analysis for Portals in the Arts and Humanities[33]
- Peer Review and Evaluation of Digital Resources for the Arts and Humanities[34]
- Gathering Evidence: Current ICT Use and Future Needs for Arts and Humanities Researchers[35]
- LAIRAH: Log Analysis of Digital Resources in the Arts and Humanities[36]
- ICT Tools for Searching, Annotation, and Analysis of Audiovisual Media[37]

In addition, the project has been overseen using commonly-accepted project management procedures.

The following sections present the results of implementing the method described above.

[32] AHRB 2003a, p. 4.
[33] Brown et al. 2006.
[34] AHRC ICT Strategy Programme 2006.
[35] Huxley et al. 2006.
[36] Warwick et al. 2006.
[37] Marsden et al. 2006.

3.3. Situation unstructured

3.3.1. Context for research

For the details of context, see section 1.3 of this report.

3.3.2. The size of the community and the potential impact of research

For the details of size of community and potential impact see section 1.4 of this report.

3.3.3. The relationship between research and practice

This report focuses on visual arts research; that is, on:

- research with the visual arts as its subject-matter (i.e. art history and related disciplines)
- research conducted through the medium of the visual arts

The latter is usually referred to as 'practice-based' or 'practice-led' research; the precise terminology to be adopted has been the subject of some debate, and is not yet settled, but 'practice-led' will be adopted for the purposes of this report.

It should be noted that the conflation of practice and research is comparatively recent, and is largely the result of developments in the funding of tertiary education within the UK. Specifically, the adoption in 1992 of the Research Assessment Exercise (RAE) as a method of allocating funding to higher education institutions meant that visual arts practitioners were suddenly called upon to submit work which had largely been undertaken within professional and industrial contexts – what had up until then be referred to as 'professional practice' rather than as research.[38] Its relationship to research is still not clearly established. As the Arts and Humanities Research Board (AHRB) has noted, 'practice-led research raises challenging questions about the ways in which research is defined and evidenced'.[39] As a step towards answering these questions, the AHRC has commissioned a review of practice-led research in art, architecture and design, which is due to report imminently.[40] The following discussion, prepared in anticipation of the review, indicates the approach to the matter taken by *The Hunt for Submarines*.

The key issue, according to the AHRB, lies in 'establishing the distinction between creative practice which is the key output of research from that which is not'.[41] At the moment, the AHRC adopts stringent criteria for what constitutes practice-led research, noting that there is 'a distinction between research and practice per se'.[42] These criteria are process-led, rather than defining outputs, and require:

[38] Brown et al. 2004, ¶¶ 3-5 on pp. 1-2.
[39] AHRB 2003b, ¶ 2.2 on p. 3.
[40] See http://aces.shu.ac.uk/ahrc/ahrcreview/, consulted 4 August 2006.
[41] AHRB 2003b, ¶ 4.6 on p. 10.
[42] AHRC 2006, ¶ 80 on p. 19; cf. AHRB 2003a, p. 1: 'The AHRB's starting point is to insist that there is a distinction between creative activities and practice in themselves on the one hand, and research on the other. Not all creative activity and practice, even of the highest quality, constitutes research, and much research in the creative and performing arts involves no such [research] activity at all.'

- a defined series of research questions, issues or problems
- a specific context for the research
- a defined set of research methods[43]

Significantly, practice on its own is considered insufficient to qualify as research:

> The Council would expect … practice to be accompanied by some form of documentation of the research process, as well as some form of textual analysis or explanation to support its position and to demonstrate critical reflection.[44]

The AHRB stated that practice-led researchers

> should, like their colleagues in other subjects and disciplines, regard it as a scholarly obligation to document and to reflect critically on and review their research processes in this way …. This would play the same role as the scholarly apparatus and contextual analysis by which conventional text-based research outputs enable the research to be situated and the research process to be understood.[45]

In short, to be considered as research, practice must also be accompanied by a verbal rationalisation of the questions being addressed, their context, and the methods used to address them. The specification that documentation should be verbal seems initially to have been adopted for purely pragmatic reasons, related to the 1992 and 2001 Research Assessment Exercises, which also required such documentation.[46] Thus, the visual arts community found themselves faced with 'the challenge of articulating intellectual frameworks for research activities that were largely focussed on object-based outputs and visual language'.[47] Yet it remains unclear how such verbal documentation can realistically be provided within a community which, in many cases, has deliberately eschewed verbal means of communication. The uneasy relationship between verbal documentation and non-verbal practice would seem to be indicated by the notable drop in practice-based research outputs submitted to the art and design panel of the 2001 RAE, in favour of purely text-based submissions (notably journal articles and conference papers).[48]

Such clearly defined research questions might seem to preclude flexibility in research projects, even if the progress of the research would seem to demand them. However, the AHRB (as it then was) noted in 2003 that

> the specifications may well change during the course of the research project itself. Changes of this kind arise from the very nature of the research process in all disciplines, but they might be thought to be particularly marked in research whose creative outputs cannot be so tightly defined in advance without undermining the very creativity which makes them valued.[49]

In recognising this problem, and in emphasising the importance of process to its concept of practice-led research, the AHRC accepts that such flexibility in relation to the original research questions should not disqualify a project from counting as research. However, the question remains of how research might be judged which does not succeed in answering the research questions initially proposed, even though such failure can itself lead to disciplinary development. This is a particular concern in the current competitive

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[43] AHRC 2006, ¶ 79 on p. 19; the AHRC's current criteria were prefigured in AHRB 2003a.
[44] AHRC 2006, ¶ 80 on p. 19.
[45] AHRB 2003a, p. 4.
[46] For 1992, see Brown et al. 2004, ¶ 3 on p. 1; for 2001 and the pragmatic adoption of this requirement by the AHRB, see AHRB 2003a, pp. 3-4.
[47] Brown et al. 2004, ¶ 3 on p. 1.
[48] Brown et al. 2004, ¶ 6 on pp. 2-3.
[49] AHRB 2003a, pp. 2-3.

funding environment, where researchers' previous 'success' influences their chance of securing subsequent funding.

Furthermore, the AHRC makes it clear that practice-led research

> should bring about enhancements in knowledge and understanding in the discipline, or in related disciplinary areas. This requirement excludes research to provide content, for example, if a film-maker wanted to make a film about refugees, the research questions should be about the process of making the film, not about the experience of the refugees. … the proposed work should aim, *through … practice*, to illuminate or bring about new knowledge and understanding *in the discipline*.[50]

They clearly state that '[w]ork that results purely from the creative or professional development of an artist, however distinguished, is unlikely to fulfil the requirements of research.'[51] This is problematic: the precise distinction between work which illuminates a specific artistic discipline, and work which is purely a manifestation of professional development, seems particularly unclear.

Yet Brown, Gough and Roddis have argued that such an attitude may be mistaken, and that it conflates '*practice-led* research (a methodological approach) with *applied research* (a type of knowledge)'.[52] This, they argue, lies behind the visual arts community's continued scepticism about the AHRC's criteria for defining practice-led research. They claim that 'the scholarship of applied research in art and design is just as relevant as … is the scholarship of other types of research in the arts and humanities although evidenced differentially'.[53]

Instead, Brown, Gough and Roddis propose that practice-led research as understood by the AHRC should be re-labelled 'scholarly research', and placed at one end of a broad spectrum of practice-led research, with applied research at the other end. Their proposed tentative typology of practice-led research encompasses:[54]

- <u>Scholarly Research</u> – 'Creates intellectual infrastructure' – 'Compiles the resources, methods, tools and models used in Pure, Developmental and Applied research in that field.'
- <u>Pure Research</u> – 'Asks key questions' – 'Uncovers issues, theories, laws or metaphors that help to explain why things operate as they do, why they are as they are, or, why they appear to look the way they do.'
- <u>Developmental Research</u> – 'Tests relevant issues' – 'Contests and tests existing hypotheses/theories originally. … Focuses, in general, on how things are done by (a) generating useful metaphors for organising insight (b) developing specific theories that can be used to predict the future in specific situations.'
- <u>Applied Research</u> – 'Solves specific problems' – 'Examines specific cases systematically. Creates new or improved artefacts, products, processes, materials, devices, services, or, systems of thought and ways of seeing. Applies outcomes from Pure and Developmental research to a specific context or project where long-term economic, social and/or cultural benefits are a direct objective. … The methods and tools evolved to deliver these results are often transferable to other contexts.'

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[50] AHRC 2006, ¶ 85 on pp. 20-21 & ¶ 86 on pp. 21-2 (original emphasis).
[51] AHRC 2006, ¶ 85 on pp. 21; see also ¶ 86 on p. 22.
[52] Brown et al. 2004, ¶ 10 on p. 4 (original emphasis).
[53] Brown et al. 2004, ¶ 10 on p. 4.
[54] For this and the following quotations, see Brown et al. 2004, ¶¶ 11-13 on pp. 4-5 and table.

It should be noted by those sceptical of the 'research' component of 'applied research' in the visual arts that it is directly analogous to the majority of scientific research, which also focuses on specific solutions to specific problems, and creates new products, processes, materials, devices, etc.

Given the continued debate as to what, exactly, constitutes 'practice-led research', the current project has adopted Brown, Gough and Roddis's more inclusive model, and considers it to include the full spectrum, from scholarly research, through pure and developmental research, to applied research.

3.3.4. The wider context of ICT in the visual arts

Visual arts research involving the use of advanced (or cutting edge) ICT is a reflection of a wider arts culture: artists have been involved with digital technologies since Michael Noll and Charles Csuri began producing computer-generated artworks in the late 1950s.[55] Works of 'new media art' – artworks which involve the use of ICT in their creation or presentation – have become common over the last ten to fifteen years.[56] There is already an established framework for exhibiting and disseminating such works, often via annual exhibitions, prizes and conferences. This is a rapidly-evolving field, and the following examples are purely indicative, and make no attempt at being comprehensive or up-to-date.

Some existing collections of new media art

- äda'web[57]
- Computer Arts, Contexts, Histories, etc. (CACHe) (Birkbeck, University of London)[58]
- The Database of Virtual Art (Humboldt Universität)[59]
- The Fondation Daniel Langlois[60]
- The Inter-Society for the Electronic Arts (ISEA) archive[61]
- Net_Working[62]
- PVA Media Lab are currently planning to produce a 'LabCulture archive' of artist projects produced during residencies from 1997 to 2005[63]
- Rhizome[64]

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[55] Gere 2002, p. 99; for the evolution of computer art in the 1950s and 1960s more generally, see pp. 64-5, 76 & 98-103.
[56] For a summary of some of the ways in which digital technologies and artistic practice have converged, see Gere 2002, pp. 109-11 & 193-5. For an indication of the extent to which this has taken place, see, for example, the list of links relating to *Intersections of Art, Technology, Science and Culture* compiled by Stephen Wilson at http://userwww.sfsu.edu/~infoarts/links/wilson.artlinks2.html (consulted 9 March 2006).
[57] http://www.adaweb.com, consulted 19 December 2006.
[58] http://www.bbk.ac.uk/hosted/cache/, consulted 19 December 2006.
[59] http://www.virtualart.at, consulted 19 December 2006.
[60] http://www.fondation-langlois.org, consulted 19 December 2006.
[61] http://www.isea-web.org/eng/archiveupdate.html, consulted 19 December 2006.
[62] http://www.dshed.net/networking/, consulted 19 December 2006.
[63] http://www.pva.org.uk/rtt/archive.htm, consulted 19 December 2006.
[64] http://www.rhizome.org, consulted 19 December 2006.

- Tate Online's Net Art site[65]
- Turbulence[66]

Whilst not a collection of new media art, the Curatorial Resource for Upstart Media Bliss (CRUMB), based at the University of Sunderland, provides a resource for anyone hoping to 'exhibit' new media art;[67] whilst the project Archiving the Avant-Garde: Documenting and Preserving Digital Media Art, based at the Berkeley Art Museum and Pacific Film Archive, aims to address some of the problems involved in preserving these kinds of work.[68]

Some existing events promoting new media art

- The art exhibitions at the Computers in Art and Design Education (CADE) conferences (ArCade I-IV, GAMUT and BitStream)[69]
- The annual Digital Resources in the Humanities and Arts (DRHA) conferences[70]
- The FutureSonic festival[71]
- The International Symposium on Electronic Art[72]
- The Prix Ars Electronica[73]
- The art exhibitions at the annual Special Interest Group for Computer Graphics (SIGGRAPH) International Conference and Exhibition on Computer Graphics and Interactive Techniques[74]

3.3.5. Bridges between visual arts, sciences and research

Clearly, within such a context of advanced ICT use in the arts, there is also evidence of a parallel growth in relevant art/science crossover research in educational arts institutions. Some organisations provide funding for such collaborations, for example The Wellcome Trust's Sciart programme, which funded 'experimental, collaborative arts projects investigating biomedical science and its social contexts'.[75] The programme's work is being continued under the aegis of the Trust's new Arts Awards.[76] The following list presents just a few examples of places where successful collaboration exists:

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[65] http://www.tate.org.uk/netart/, consulted 19 December 2006.
[66] http://www.turbulence.org, consulted 19 December 2006.
[67] http://www.crumbweb.org, with a trial new site currently available at http://crumb.sunderland.ac.uk/%7Eadmin/beta/; both consulted 19 December 2006.
[68] http://www.bampfa.berkeley.edu/about_bampfa/avantgarde.html, consulted 19 December 2006.
[69] http://www.cade.ac.uk, temporarily unavailable on 19 December 2006.
[70] http://www.drh.org.uk, consulted 19 December 2006.
[71] http://www.futuresonic.com, consulted 19 December 2006.
[72] http://www.isea-web.org, consulted 19 December 2006.
[73] http://prixars.aec.at, consulted 19 December 2006.
[74] Follow links to the different conferences from http://www.siggraph.org, consulted 19 December 2006.
[75] Sciart ran from 1996 to 2006, supporting 124 projects to a value of £3 million: http://www.wellcome.ac.uk/node2530.html, consulted 4 January 2007.
[76] http://www.wellcome.ac.uk/node2580.html; see also the Trust's People Awards (http://www.wellcome.ac.uk/node2510.html) and Society Awards (http://www.wellcome.ac.uk/node2540.html). All sites consulted 4 January 2007.

- The Banff New Media Institute.[77]
- The Centre for Fine Print Research at the University of the West of England, Bristol.[78] The centre has carried out research on
  - Reviving the collotype process and integrating it with digital technology (collotypes carry many advantages for the preparation of very high quality and archivally-stable prints; as they reproduce continuous ones without screening, they can print any number of layers of colours without any interference patterns).[79]
  - The use of rapid prototyping techniques to produce modern photo ceramic relief images, updating a 19th-century technique which combined relief with toned glazes to produce the effect of a three-dimensional photograph on a ceramic tile.[80]
  - Quantifying existing methods of processing digital images and developing imaging and colour systems to expand the capabilities of digitally-based printing for the fine arts.[81]
  - Developing a method for printing digitally-generated imagery onto traditional underglaze tissue for applying images to ceramics.[82]
- Culture Lab Newcastle at the University of Newcastle, which aims to facilitate collaboration across disciplinary boundaries, including between artists and scientists.[83]
- Fine Art, Science and Technology in the UK (fast-uk), 'an artist-led organisation dedicated to promoting and encouraging artists that use digital or electronic technologies in some part of their practice.'[84]
- Institute of Digital Art and Technology (i-DAT) at the University of Plymouth.[85] I-DAT 'aims to define and establish new fields of practice and critical discourse in the context of emergent technologies and cultural forms, new scientific paradigms, and new media art - telematic, interactive, generative, architectural, technoetic, performative, sonic, transgenic, transmedia.'[86]
- RapidformRCA, a rapid prototyping centre at the Royal College of Art.[87]
- The Slade Centre for Electronic Media in Fine Art.[88]

In addition, the AHRC-funded Methods Network provides advice and information for researchers in the arts and humanities interested in using advanced ICT in their research.[89]

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[77] http://www.banffcentre.ca/bnmi/, consulted 22 December 2006.
[78] http://www.cfpr.uwe.ac.uk/, consulted 14 December 2006.
[79] http://amd.uwe.ac.uk/cfpr/index.asp?pageid=1095 and http://amd.uwe.ac.uk/cfpr/index.asp?pageid=1104, both consulted 19 December 2006.
[80] http://amd.uwe.ac.uk/cfpr/index.asp?pageid=1170 and http://amd.uwe.ac.uk/cfpr/index.asp?pageid=1139, both consulted 19 December 2006.
[81] E.g. http://amd.uwe.ac.uk/cfpr/index.asp?pageid=1092, http://amd.uwe.ac.uk/cfpr/index.asp?pageid=1093, and http://amd.uwe.ac.uk/cfpr/index.asp?pageid=1109, all consulted 19 December 2006.
[82] http://amd.uwe.ac.uk/cfpr/index.asp?pageid=1172, consulted 19 December 2006.
[83] http://www.ncl.ac.uk/culturelab/, consulted 19 December 2006.
[84] http://www.fastuk.org, consulted 12 January 2007.
[85] http://www.i-dat.org/go/home, consulted 14 December 2006.
[86] http://www.i-dat.org/go/about, consulted 14 December 2006.
[87] http://www.rca.ac.uk/pages/getinvolved/rapid_prototyping_facilities_509.html, consulted 19 December 2006.
[88] http://www.scemfa.org, consulted 19 December 2006.
[89] http://www.methodsnetwork.ac.uk, consulted 30 January 2007.

However, it is important to note that, sources of funding aside, the opportunities for collaboration can seem to be limited to particular institutions. Access to these resources is much more difficult for researchers who are not already affiliated with those institutions.

Whilst many of the individuals involved in the activities mentioned above have been, and continue to be, amongst the earliest adopters of emerging technologies, the results of the questionnaire carried out for this project suggest that even the most technologically-sophisticated researchers remain frustrated at technical limitations and the difficulty of keeping abreast of new developments. Consequently, *The Hunt for Submarines* has been directed to the needs of all researchers, regardless of whether or not they currently use digital technologies in their work. The project was designed to map researchers' needs to digital imaging technologies which are unknown or under-exploited in current artistic practice/research, or to suggest that new uses of established technologies may meet additional visual arts research needs.

3.4. Situation expressed

Since many individuals have already made extensive use of advanced ICT in their practice, teaching and research, a brief examination of some of the uses of ICT in the broader art world which underpins UK research is necessary to establish the ways in which artists, and thus art researchers, can exploit imaging ICT. The project used the following abstractions to think about applications of technology:

- New ways of seeing
- New iconographies
- New ways of presenting their research outputs
- New ways for audiences to interact with their outputs
- New ways of working
- New ways of researching source material and other images

This section provides some examples of uses which fall into each of these categories.

It is important to note that digital imaging may play only a small part in the creation of artworks. For example, the curators of the first ArCade exhibition specifically called for 'prints which at some stage in their production involve the use of computers', rather than 'computer prints'; they also suggested the terms 'computer mediated' or 'computer assisted'.[90] Dorothy Simpson Krause has proposed the word 'tradigital' 'to describe works that bridge traditional and digital worlds'[91] – for example, Jessica Maloney's *Someone, somewhere, sometime*, which involved scanning, manipulating and re-scanning an image which was then incorporated into a weathered wooden box to which other physical objects had also been added.[92]As Maloney's work suggests, whilst much digital work continues to focus on purely mechanical or optical output (inkjet or laser prints onto conventional or photographic paper), more traditional materials are still being used in conjunction with digital technologies. For example, Hans Dehlinger exhibited *Bird*

[90] Braybon 1997, p. 36. This has been continued in subsequent ArCade exhibitions: see, e.g., Gollifer 2001.
[91] Gollifer 2000, p. 234.
[92] Exhibited at SIGGRAPH 2002. Eber 2002, p. 228 & figs 6-8.

Facing Left (Figure 8), a plotter drawing using a gel pen, at SIGGRAPH 2004.[93] ArCade IV (the fourth UK Open International Exhibition of Electronic Prints) included works created manually, photographically or digitally and produced in a variety of media, including encaustic and graphite.[94]

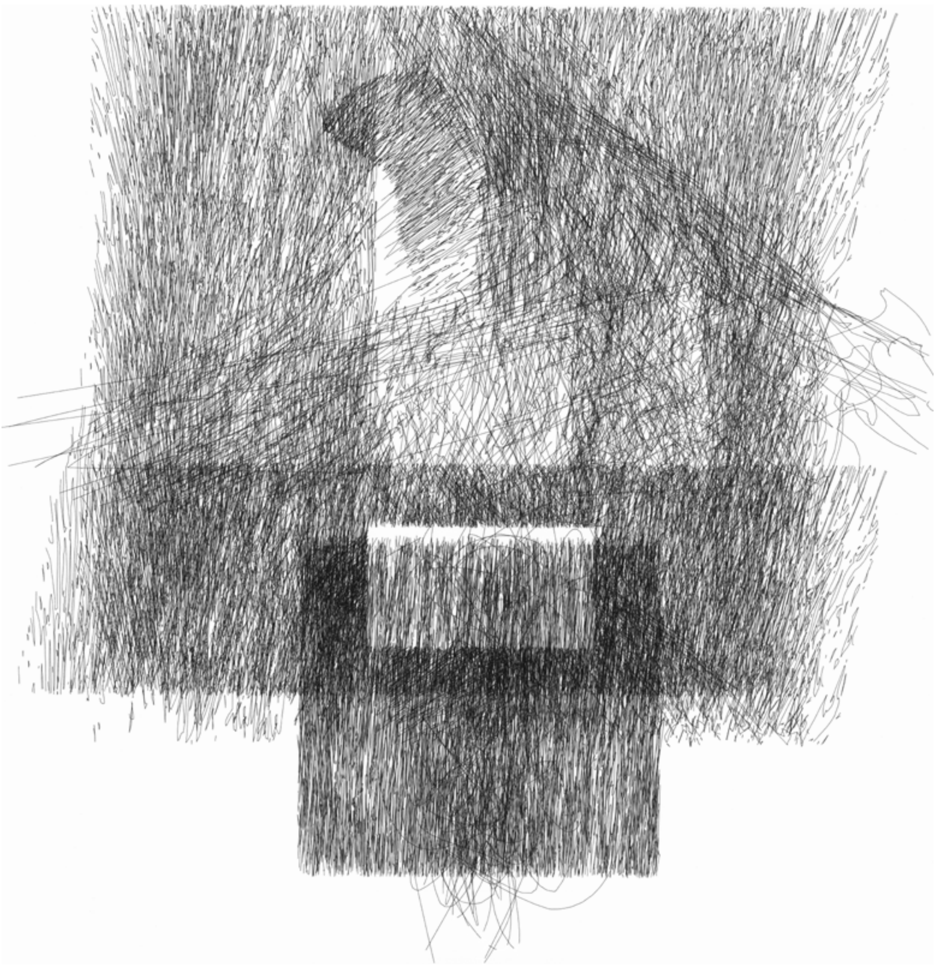

Figure 8. Hans Dehlinger, *bird_facing_left*, 2003, gel-pen on paper, 50 cm x 60 cm. © Hans Dehlinger (dehling@uni-kassel.de).

3.4.1. Seeing

By 'new ways of seeing', we mean the ability to see in ways not previously available – for example by using different electro-magnetic spectra, or different forms of radiation. The imaging technologies can be conceived as prostheses, extending the abilities of human vision into the previously invisible.

[93] Gollifer 2005, p. 105.
[94] Gollifer 2004.

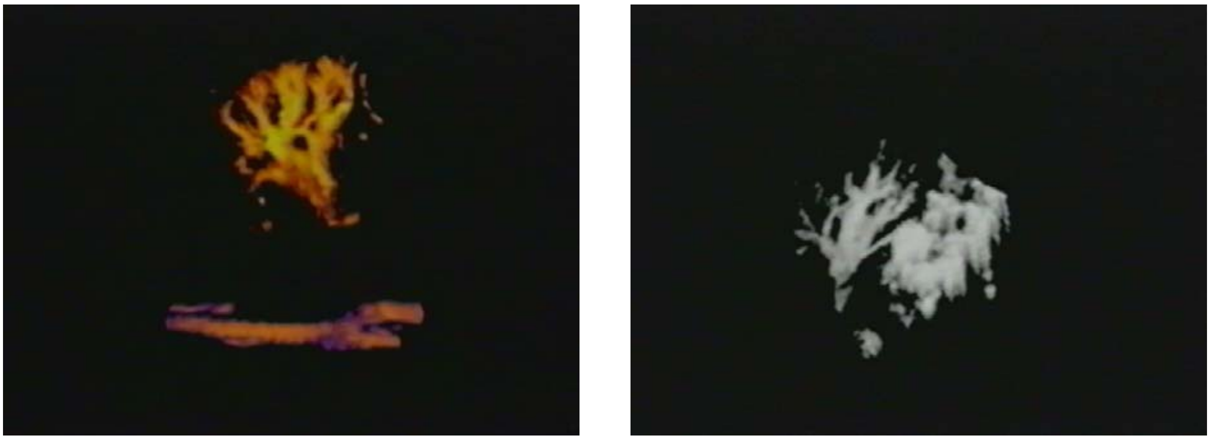

Figure 9. Wendy Kirkup, *Echo*, 2000, video stills. © Wendy Kirkup.

These are perhaps most obvious in the field of medical imaging, which has been used by several artists. In *Echo*, for example, Wendy Kirkup created a 'technological "body atlas"' of herself using advanced ultrasound techniques, presented as a projection accompanied by Doppler ultrasound recordings of the sound of the circulation of the artists' blood (Figure 9). Advanced medical imaging techniques made possible a large-scale, site-specific multimedia installation.[95] The fact that such techniques are necessarily processed by computers means that, by altering rendering settings, images can easily be produced which emphasise aesthetic, rather than diagnostic, aspects of the image.[96]

Some devices, rather than allowing us to see within apparently opaque objects, as ultrasound does, allow us to see things at hitherto unimaginable magnifications. Claire Davies has used an atomic force microscope to create *Wonderland*, an animated work based upon the contours of a flower petal at 100 nm intervals.[97] According to Davies, 'I was inspired by the beauty of what no human is able to see without the aid of technology and wanted to make that visible.' In other words, the imaging technology is here being used to see beyond the normally visible.

Alternatively, digital technology might allow us to see motion in different ways. To take a comparatively straightforward example, in digital slitscan photography, an image is captured along a series of narrow lines, rather than across a broad field of view all at the same time (in the same way that a scanner captures a single line of data at a time, not an entire page). If the camera is static, moving objects will appear blurred due to the time required to capture the entire image. However, if the camera moves at the same speed as the object being photographed, the object is captured clearly and the background becomes a blur. The effect is similar to using a long exposure and a tracking shot in analogue photography, often used in sports photography to give an impression of movement and dynamism – but also an unavoidable by-product of slow lenses and emulsions. The digital camera makes the technology much easier to use, and less

[95] http://www.locusplus.org.uk/kirkup.html, consulted 20 February 2006.
[96] Fung 2006a, Fung 2006b. Fung's technique exploits the improved imaging provided by recently-developed multi-detector X-ray CT scanners and the greater processing power offered by modern computers.
[97] Performed at the National Glass Centre, Sunderland on 2 March 2006. See http://www.avfest.co.uk/06/thursday2.php (consulted 27 February 2006).

dependent upon the photographer's steady hand and smooth movement. To take just one example, Ansen Seale, in *Evergreen*, used digital slitscan photography with a moving camera to photograph a long freight train in the U.S., producing a 66-inch panoramic giclée print (Figure 10).[98]

Figure 10. Ansen Seale, *Evergreen*, digital slitscan photograph. © Ansen Seale, http://ansenseale.com.

Digital imaging can also reveal time in unfamiliar ways. Susan Collins uses very slow image capture – usually at the rate of about 1 pixel per second – to draw images over long periods of time (Figure 11). The change of light as the day and night pass are incorporated into the image as lines of pixels of varying intensity and colour, although the underlying scene remains visible behind the incidental effects of the passage of time.[99]

Figure 11. Susan Collins, *Glenlandia*, 19 August 2005, 09:53 am. © Susan Collins 2005.

[98] Exhibited at SIGGRAPH 2005. Eber 2005, p. 160 & figs 8-9.
[99] See, for example, the ongoing work *Glenlandia*, http://www.susan-collins.net/glenlandia, and *The Spectrascope*, http://www.susan-collins.net/spectrascope, both consulted 14 December 2006.

3.4.2. Iconographies

As we are able to see the previously invisible, so the different things we see, along with the visual characteristics of the new ways of seeing, come to form new visual languages, and to begin to carry their own meanings. New iconographies and ways of carrying meaning are established.

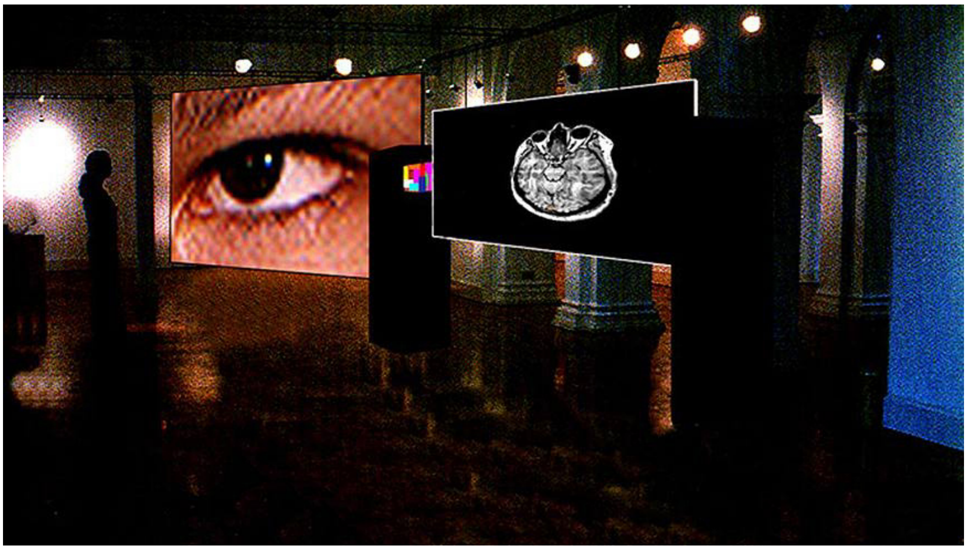

Figure 12. Chris Meigh-Andrews, *Mind's Eye*, site-specific 5-channel video installation at the Hot Bath Gallery, 1997. © Chris Meigh-Andrews.

Once again, the most obvious examples make use of medical imaging techniques. Chris Meigh-Andrews used functional Magnetic Resonance Imaging (fMRI) scans directly in *Mind's Eye*, a video installation which he exhibited in 1997. The scans were recorded as he responded to a visual stimulus, which was also displayed in the installation (Figure 12).[100] Heather Elliott-Famularo also used MRI scans in a series of works she exhibited at SIGGRAPH 2005. These combined photographic images of herself with MRI scans of her mother's brain – the end results resembled ultrasound images of foetuses in wombs (Figure 13).[101] Thus, two imaging iconographies were combined, exploiting the associations of both. Scanning electron microscope (SEM) images of pinopods, microscopic protrusions which appear in the lining of the womb for two days in each menstrual cycle, were the inspiration for several recent works by Adinda van 't Klooster.[102] Whilst pinopods were discovered in rats in 1959, their function in humans is still debated, although it is suspected that they may play a role in the implantation of embryos in the womb. In *States of Receptiveness*, the pinopods – which can only be seen in the still images produced by the SEM – formed the basis of a 10-minute projected video animation, emphasising the cyclical nature of life. In *Receptive Mo(nu)ment*, van 't Klooster cast forms based on pinopods in red jesmonite, which were then incorporated into the womb-like installation in the crypt of Gloucester Cathedral – a particularly appropriate

[100] Exhibited at the Hot Bath Gallery, June-July 1997: Meigh-Andrews 2001, p. 112.
[101] Eber 2005, pp. 153-8 & figs 1-2. Marilène Oliver also used MRI scans in her *Family Portrait* (2003): Oliver 2004.
[102] See http://www.livinggloucester.co.uk/histories/cathedral/artist_in_residence/adinda/ and http://www.axisweb.org/atATCL.aspx?AID=549 (consulted 16 March 2006).

site for a work which again referred to the cyclical nature of life, as it was once used to store the bones of deceased monks.

Figure 13. Heather Elliott-Famularo, *ACQ: E3 (and me)*, 2003, inkjet print on backlight film, fluorescent lights, wood and plexiglass, 16.5 x 18.5 x 4 inches.

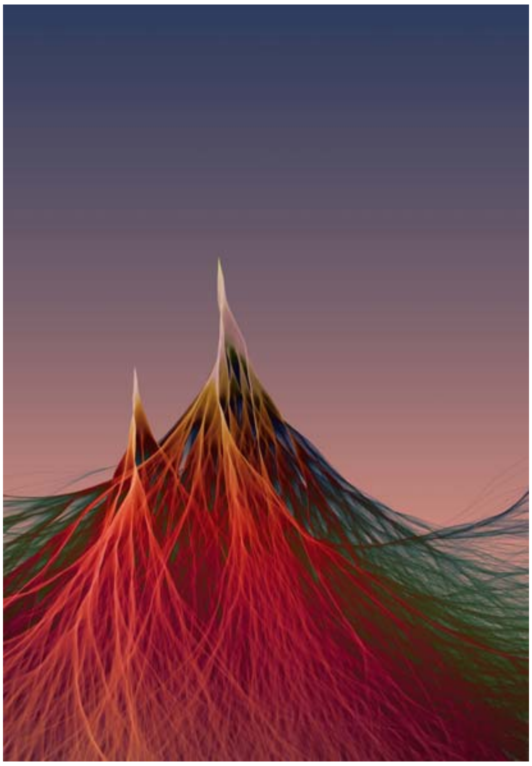

Figure 14. Eric J. Heller, *Transport IX*, 2001. © 2001 Eric J. Heller.

Transport IX renders electron flow paths in a two dimensional electron gas (2DEG). It is based on accurate simulation of electron flow patterns for electrons riding over a bumpy landscape such as encountered in a 2DEG. The electrons have more than enough energy to ride over any bump or hill they encounter. In fact the deflection is so weak at each hill that several hills (not shown) are encountered before much noticeable change of direction occurs. The concentrations of electron flow which result, a kind of channelling or branching, were unexpected and have implications for small electronic devices of the future.

Other subjects may also produce new iconographies, such as particle physics: Eric Heller's *Transport IX* is an abstract print on photographic paper, representing the paths of electrons followed for a short time (Figure 14).[103] Julian Voss-Andreae bases his sculptures on the forms of three-dimensional protein models.[104] Alternatively, raw digital data in its most straightforward form might itself become a subject for display: Kate Pemberton's *Tracert* uses traditional techniques and materials – silk cross-stitch – to depict the screen display following the typing of a DOS `tracert` command (Figure 15). Pemberton combines the techniques associated with traditional samplers, which would often include symbols representing emotional events, with a modern representation of the connection between the artist at her computer and her website (www.endfile.com).[105] The simple alphanumeric readout is itself a way of depicting the time and space traversed by the digital signals produced by the command.[106] A similar conceit, but on a much grander scale, seems to lie behind recent performances by Ryoiji Ikeda (*C^4I* and *data.matrix* (working title)), which include transformations of landscape images into a series of different graphical and numerical visualisations of the data which the landscapes contain.[107] Philip Van Loocke has recently described a system which uses generative techniques to render binary information as a series of trees and flowers.[108]

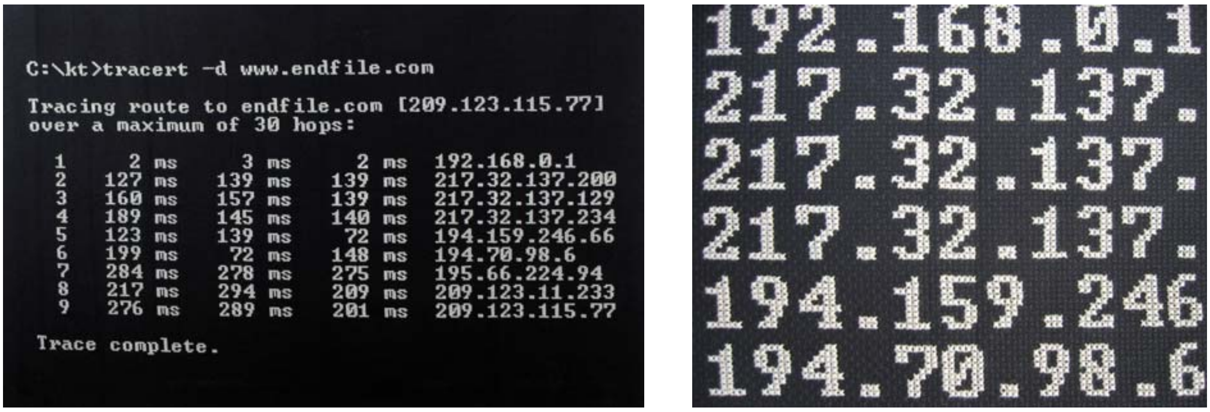

Figure 15. Kate Pemberton, *Tracert* (whole work and detail), aida and embroidery silk. © Kate Pemberton, http://endfile.com.

As Pemberton's work suggests, these new iconographies need not be restricted to new media works; indeed, they can have an impact in craft-based practice as well. In the early 2000s, Hilary Carlisle produced a program to create non-repeating patterns for transfer to textiles using newly-developed techniques for inkjet printing onto fabric.[109] Digitally-generated imagery may also play in role in printmaking. Traditionally, printmakers

[103] Exhibited at SIGGRAPH 2004. Gollifer 2005, p. 100.
[104] Voss-Andreae 2005.
[105] Information provided by Kate Pemberton by e-mail, 11 January 2007.
[106] Exhibited at SIGGRAPH 2005. Eber 2005, pp. 158-160 & figs 5-6.
[107] Performed at the sage, Gateshead, on 3 March 2006. See http://www.avfest.co.uk/06/friday3.php (consulted 27 February 2006).
[108] Van Locke 2006.
[109] Carlisle 2001.

established a set of linear and tonal conventions for the process of depiction of forms and shades, based upon the capabilities of the different surfaces (plate, block, stone) and techniques at their disposal; the constraints and possibilities of these conventions have in turn stimulated their practice and shaped the visual languages of printmaking. George Whale sought to create a new set of conventions or constraints for the digital age, using algorithms to create their components. In effect, he was aimed to construct a new visual vocabulary for printmaking.[110]

3.4.3. Presenting

New technologies can lead to new ways of disseminating works. The video of Wendy Kirkup's *Echo*, mentioned above (Figure 9), was broadcast simultaneously via satellite between the Hunterian Museum in Glasgow and the International Centre for Life in Newcastle-upon-Tyne, and projected live on a large scale.[111]

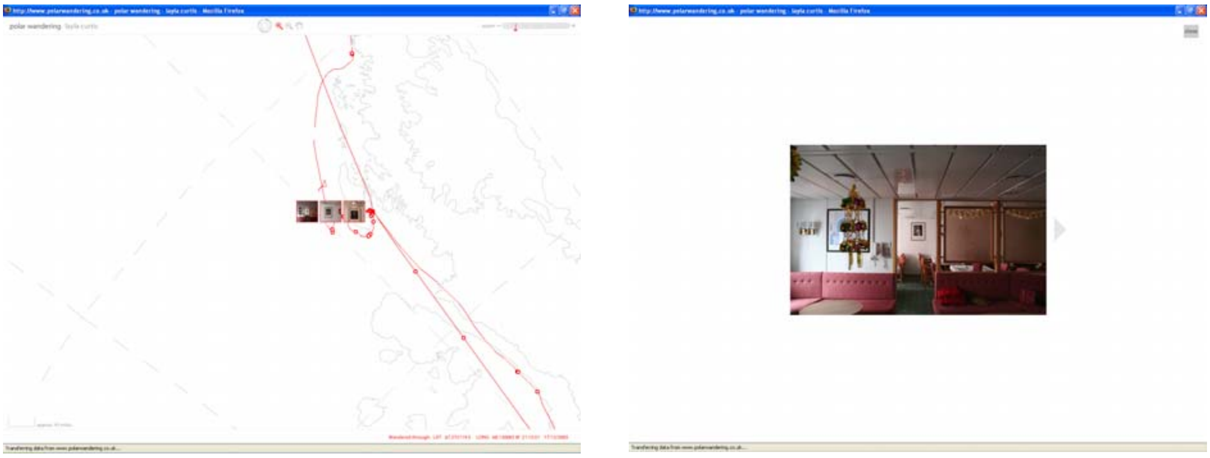

Figure 16. Layla Curtis, *Polar Wandering*, 2005/6. http://www.polarwandering.co.uk (screenshots taken 11 January 2007).

In some cases, the work exists only in digital form. Layla Curtis's *Polar Wandering* exists only on the web, in the form of an animation incorporating various media within a GPS drawing (Figure 16).[112] Similarly, works may be preserved in digital form: the performance of Chris Burden's *Ghost Ship*, the voyage of an un-manned 28-foot sailing boat from Fair Isle to Newcastle-upon-Tyne under autonomous control, is still available through its documentation, which takes a fairly similar form to *Polar Wandering*.[113] The work is now presented as a website, incorporating a timeline which in turn drives a map of the boat's position, accompanied by its compass heading and speed and the wind

[110] Whale 1997.
[111] http://www.locusplus.org.uk/kirkup.html, consulted 20 February 2006; the project was supported by the Arts Council, Locus+ and Siemens. Although created for the Hunterian and the International Centre for Life, the piece has subsequently been exhibited elsewhere: see http://www.sitegallery.org/live_art/view.php?id=55 (exhibited March 2001; site consulted 20 February 2006).
[112] http://www.polarwandering.co.uk, consulted 21 February 2006. Layla Curtis was awarded the 2005 Artists and Writers Fellowship Award, a joint partnership between the British Antarctic Survey and Arts Council England's International Artists Fellowships Programme; the project was developed in collaboration with Locus+.
[113] http://www.ghostship.org.uk/flash.htm, consulted 20 February 2006.

speed and direction. In addition, a series of still images and video clips illustrate the boat's progress, as well as the process of its creation. Whilst the project is itself an example of technological innovation underlying a creative project, its significance for this project lies in its use of straightforward imaging technologies to document and preserve the work.

More advanced technologies for presentation were explored by Jonathan (Jo) Fairfax, who received a NESTA Dream Time fellowship in 2003 to work on holographic film, where movement from frame to frame is dictated by the viewer's position.[114] However, the final work, *Dream Time*, used more conventional techniques – virtual reality headsets and a rotating chair – to create a series of virtual environments for the audience.[115]

3.4.4. Interacting

The notion that viewers might interact with works of art has been a commonplace in the western tradition since at least antiquity: one need only recall the legend of Pygmalion, or Pliny and Lucian's accounts of the man who fell in love with Praxiteles's Cnidian *Venus*, embracing the statue, so that 'a stain betrays this lustful act'.[116] More recently, Duchamp's *Bicycle Wheel* of 1913 relied upon the viewer to set the wheel in motion to achieve its full effect.[117] But digital technologies have provided practice-led researchers with a much greater variety of ways in which viewers can interact with art works. To take one, canonical example: Char Davies's *Osmose*, first created in 1995, is an immersive virtual reality environment (Figure 17). The viewer's movement through the environment is controlled by their rate of breathing and slight shifts in their balance (Figure 18).[118] Much of the work's impact derives from the inter-relationship between a thoroughly corporeal act (breathing) and the translucent, virtual environment.

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[114] http://www.nesta.org.uk/ourawardees/profiles/3040/ (consulted 21 February 2006 via Google's cached version of the page).
[115] http://www.24hourmuseum.org.uk/leicester/events/EDR33567.html. *Dream Time* was displayed at the City Gallery, Leicester, from January to March 2006.
[116] For Pygmalion, Ovid, *Metamorphoses*, X.243-97; for the Cnidian *Venus*, Pliny, *Naturalis historiae*, XXXVI.iv.21; Lucian, *Imagines*, 4; quoting from the Loeb edition of Pliny, translated by D.E. Eichholz.
[117] See the discussion of Duchamp's 1951 recreation of the lost original, in the Museum of Modern Art, New York, on the Museum's website at http://www.moma.org/collection/browse_results.php?object_id=81631, consulted 19 December 2006.
[118] http://www.immersence.com/osmose/index.php, consulted 19 December 2006.

Figure 17. Char Davies, *Subterranean Earth*, *Osmose*, 1995. Digital still image captured during immersive performance of the virtual environment *Osmose*.

Figure 18. Immersant in breathing vest during immersive performance of the virtual environment *Osmose*, 1995. Char Davies.

3.4.5. Working

Digital imaging technologies can also lead to new ways of producing work. For example, the use of digital techniques to aid the design process is increasingly commonplace. These can take various forms, such as the computerised tool developed by Ian Kelly to aid the design of colour combinations.[119] Based upon techniques developed in evolutionary computing, the tool presents the designer with a series of possible colour combinations. In its most basic form, once one of these combinations is selected, a new set of possible combinations is produced which have evolved from specific aspects of the first set. In a more sophisticated form, the designer uses a new first stage to set some general characteristics from which the tool then evolves possibilities. Here, the computer is used to aid in the generation of ideas – in this case, colour schemes.

Work has been done at Manchester Metropolitan University and the University of Huddersfield on the application of plug-in tools for simulation software to the design of textiles and clothing.[120] The aim was to see if available software tools could successfully re-create the characteristics of textiles effectively enough for the virtual textiles to be used as part of the design process. Whilst the published results were ultimately disappointing – the tools available in 2003 were simply not capable of modelling the fabrics' behaviours to a high enough standard – the research is an interesting example of how virtual modelling might be applied to a subject which is traditionally very tactile. The computer allows practitioners to assess the potential of particular materials in particular contexts, without having to create a physical work. Similarly, work in the Visual and Information Design Centre of Coventry School of Art and Design has examined the use of three-dimensional modelling of products coupled with texture mapping to produce quick, three-dimensional models from sketch designs.[121] The resulting models are used either to assess the concepts presented in the sketches, or as the basis for further three-dimensional elaboration.

Digital imaging technologies also present practitioners with a variety of tools they can use. Whilst image-manipulation software such as PhotoShop is an obvious example, there are many other examples: Layla Curtis's *Polar Wandering*, mentioned above, is but one of many works produced using GPS tracking devices to produce drawings as the artist moves across the globe.[122] In Curtis's case, the device recorded the artist's journey from London to Antarctica; other media – photos, videos, sound recordings and text – were then embedded into the resulting 'drawing' to create a 'complex data map'.[123]

Tracey Bowen describes how some artists feel that the software they use can become 'an electronically mediated Other who retained some element of control over the manipulation process…. a form of collaborator'.[124] In the case of Alison Mealey's work, the software is fundamental to the creation of the work. Working with the *Unreal*

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[119] Kelly 1997.
[120] Taylor, Unver & Worth 2003.
[121] Owen, Tovey & Dekker 1997.
[122] For the emerging genre of GPS drawing, see Jeremy Wood's continuously evolving *GPS Drawing* website, http://www.gpsdrawing.com, consulted 13 December 2006.
[123] http://www.polarwandering.co.uk, consulted 21 February 2006.
[124] Bowen 2003, p. 223.

Tournament games engine, Mealey has used it to generate solid architectural forms from the 'negative' spaces which make up different levels;[125] to generate 'maps' of the areas in the game actually used by players, which in turn form the basis of interventions in the real world;[126] and finally, by instructing the engine's artificial intelligence robots, setting them off to play a game, and logging their positions, to actually create the traces which make up the finished 'drawing'.[127] In other words, although following basic instructions from the artist, the work itself is created by the games engine. In re-working an existing game, Mealey has adopted the practices of the games modding community for artistic ends.

Digital images may provide the raw material on which artists work. As CGI artists develop characters for films, they work through a series of texture maps to provide 'skin' for the characters. Donna Tracy uses the early, discarded texture maps as the basis for her own works, subjecting them to further transformations.[128] As imaging technologies develop, so they can be applied to forms of practice previously considered impossible to create digitally: for example, rapid prototyping techniques have been used to create sculptures, such as the works of Keith Brown and Carlo Séquin exhibited at SIGGRAPH 2003 (Figure 19).[129]

Figure 19. Keith Brown, *Geo_01*, 2003, burnished bronze cast from a 3D Systems ThermoJet wax 3D print. © Keith Brown.

Not all artistic practice is directed towards the creation of a finished piece of work. Many artists also teach, and digital images have proved useful in this sphere, too. Kelly, discussing his tool for the design of colour combinations mentioned above, suggested that it might have a role in teaching colour design through practical experience.[130] A similar course has been followed by Catherine Stones at the University of Bradford,

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125 *Monolith* (2004): http://www.alisonmealey.com/monolith.htm, consulted 17 March 2006.
126 *Marked* (2004): http://www.alisonmealey.com/marked.htm, consulted 17 March 2006.
127 *UnrealArt* (2005): http://www.alisonmealey.com/unrealart.htm, http://www.unrealart.co.uk, and http://alison.organised.info/unrealart/history/Project.swf, all consulted 17 March 2006.
128 Martin 2005.
129 Eber 2003, p. 244 & figs 10-11; for rapid prototyping, see appendix 2.10.2 below.
130 Kelly 1997, pp. 110-11.

where a web-based tool has been developed using a combination of existing technologies (Macromedia Flash and ColdFusion, Microsoft Access) to aid in the practical teaching of colour theory in typographic design.[131] Students are given a basic section of text and a palette of colours, and asked to try various combinations, marking those they thought worked well, and choosing a final layout. The system allowed the tutor and the students to examine the processes by which the different colour combinations had been tried and, eventually, selected. In capturing process, it allowed students to analyse their assumptions and ways of working.

In the current age of the internet and the world-wide web, the ability of digital technologies to bridge geographical distance, allowing for collaborations between individuals across the globe, is unavoidable. They have been used to facilitate long-distance collaboration in the creation of digital work since at least 1994/5, when the University of Plymouth collaborated with a number of institutions in the UK and on the Continent as part of the Atlantis InterArc EC Research Programme.[132] Although this project focussed on production of an electronic publication, it used shared screen and simultaneous voice communications in a way that might also be relevant to artistic practice. More recent developments have seen the emergence of the Access Grid, with its capacity for real-time transmission of high-bandwidth, low-latency transmission of large video and audio files.[133] Whilst still underdeveloped in UK artistic practice, the Access Grid has formed the basis for a series of collaborations organised under the umbrella of MARCEL (Multimedia Art Research Centres and Electronic Laboratories), described as 'a permanent broadband interactive network and web site dedicated to artistic, educational and cultural experimentation, exchange between art and science and collaboration between art and industry'.[134]

But recent cultural developments have also had an impact on how artists view collaboration in the digital age. Michela Ledwige is releasing the raw material for her short film *Sanctuary* on the internet, with the intention that visitors to the site can re-cut the film and produce their own works. This is based on the paradigm of 'modding' computer games.[135]

3.4.6. Researching

Whilst this project never intended to conduct a broad survey into use of ICT amongst arts researchers, it is worth noting here that they can be characterised by the frequency with which they carry out certain kinds of activity online, as shown in Table 5 and Figure 20.

[131] Stones 2003.
[132] Honeywill *et al.* 1995.
[133] See appendix 2.1.1.
[134] http://www.mmmarcel.org/about.htm, consulted 21 July 2006.
[135] Silverman 2006; see http://www.modfilms.com, consulted 21 July 2006.

Activity	Frequently (%)	Occasionally (%)	Frequently + occasionally (%)	Never (%)
Read primary texts	80	17	97	3
Read secondary literature	83	17	100	0
Use free online resources	70	30	100	0
Study images	70	23	93	7
Study performances	47	33	80	20
Carry out creative work	33	33	66	33
Carry out collaborative work	28	55	83	17
Maintain web pages	28	38	66	34

Table 5. Most popular online activities amongst arts researchers.

Source: Intute research community requirements survey, 2006 - raw data provided by James A.J. Wilson, private communication, 13 September 2006.

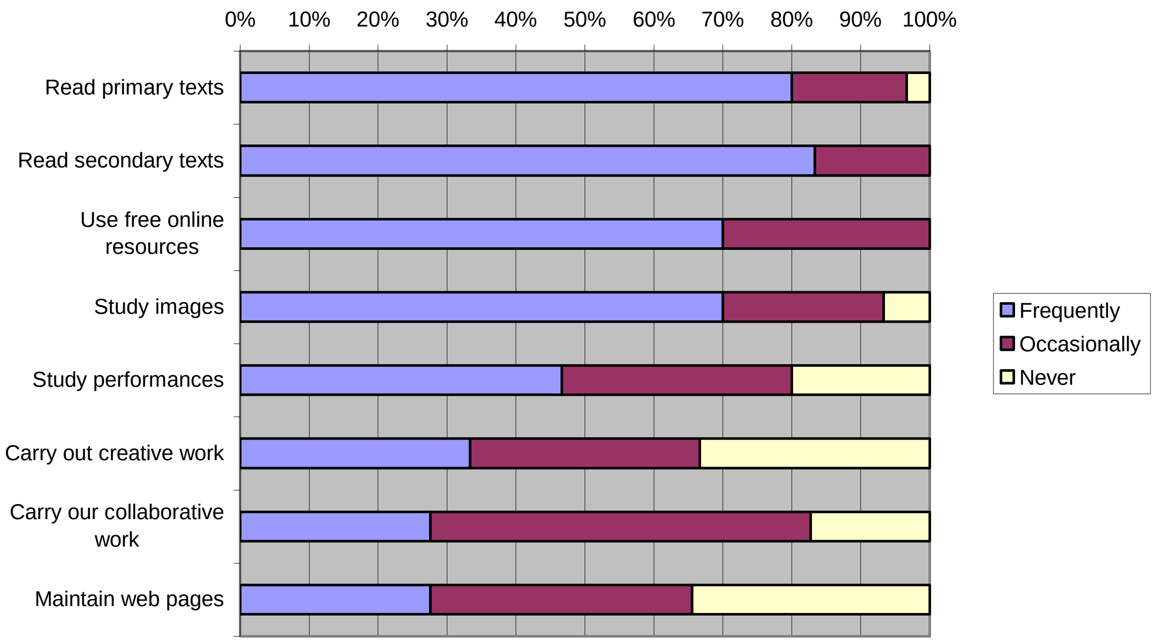

Figure 20. Most popular online activities amongst arts researchers (based upon Table 5).

Although these activities are widespread (as indicated by the figures above), they essentially remain hidden, seldom revealing themselves explicitly in research outputs. But they are often fundamental to the process of research, and, with more than 80% of arts respondents to Intute's research community survey reading primary and secondary texts online 'frequently', and 70% studying images online frequently, they are very nearly ubiquitous. Yet this is not always a sophisticated process: one of the findings of *The Digital Picture* was that Google Images was likely to be the most used method for finding images.[136]

[136] AHDS 2005, § 4.3.2 on p. 38 and § 5.1 on p. 40.

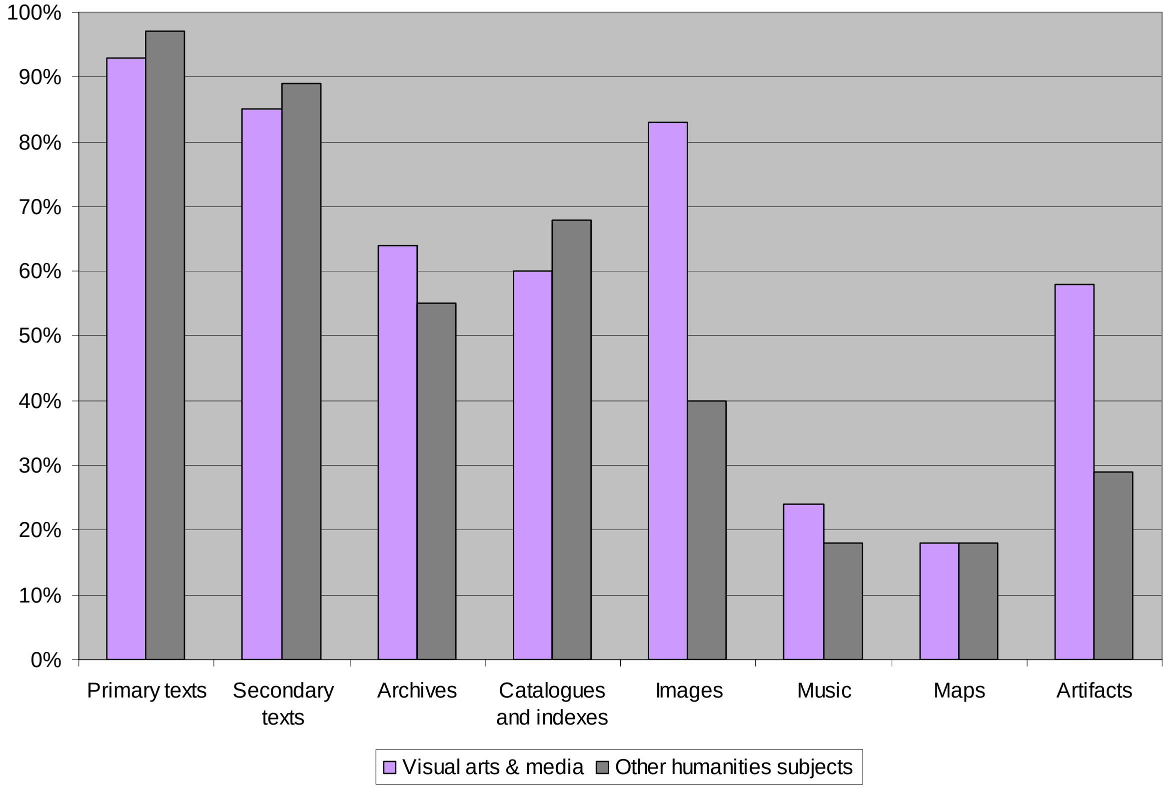

Figure 21. Percentages of humanities researchers considering analogue resources important.

Source: Huxley et al. 2006, table 15 on pp. C: 5-8.

According to the *Gathering Evidence* report, primary texts, secondary texts and then images form the most important analogue research resources for visual arts researchers (Figure 21). When we turn to digital resources (Figure 22), the pattern changes slightly: databases come first, then primary and secondary texts and images, in that order, followed closely by catalogues and indexes. There may also be some confusion between 'primary texts' and images in responses to the *Gathering Evidence* questionnaire: it should be remembered that, for the majority of visual arts researchers, images are the 'primary texts' of their research. The importance of databases and catalogues is likely to be related to the use of these formats for the delivery of digital images.

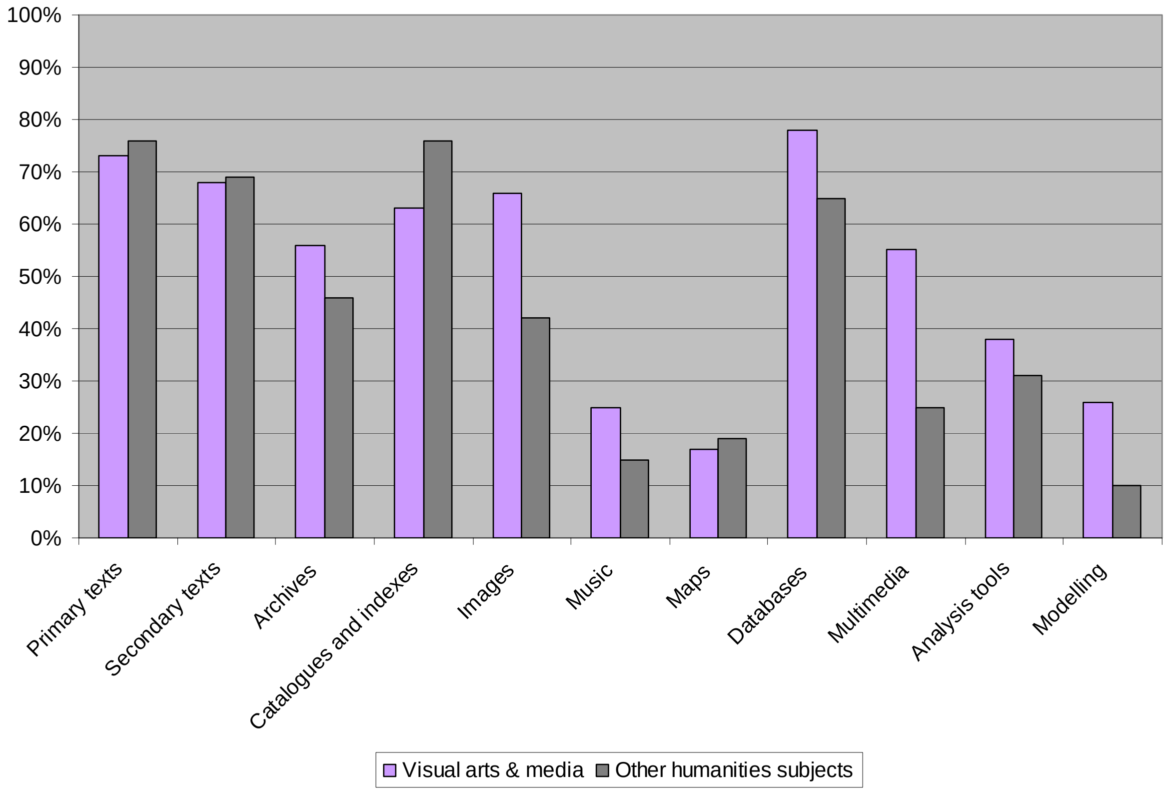

Figure 22. Percentage of humanities researchers considering digital resources important.

Source: Huxley et al. 2006, table 15 on pp. C: 5-8.

Compared to other humanities research fields, visual arts researchers place a much greater emphasis on the importance of analogue images and artefacts and, to a lesser degree, archives and music (Figure 21). Of the digital research resources (Figure 22), the difference between visual arts and other humanities researchers is most marked by the former's preference for multimedia and images. They are also markedly more likely to rate modelling and archives as important and, to a lesser extent, music and tools for analysis.

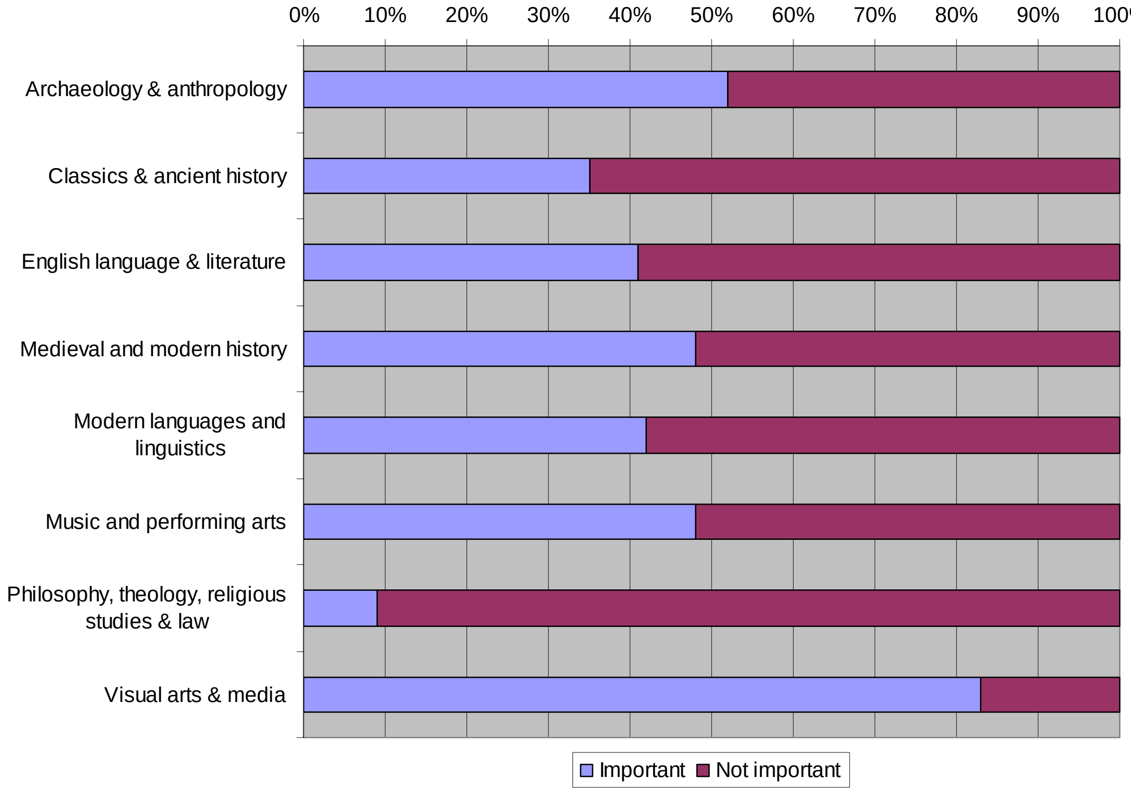

Figure 23. Attitudes of different humanities subject areas to analogue images, expressed as percentage of responses in each subject area.

Huxley et al. 2006, table 15 on pp. C: 5-8 & table 6 on p. C: 2.

When we focus our attention upon images, it becomes clear how much more significant analogue images are for visual arts researchers than for other disciplines: 83% of visual arts and media researchers rated them as 'important', compared to only 52% of archaeologists and anthropologists, the next highest rating (Figure 23). Curiously, more researchers in English language and literature rated digital images as 'important' than did visual arts researchers (78% compared to 66%; seeFigure 24). Once again archaeology and anthropology came the next highest after the visual arts, but by a much narrower gap: 64% considered digital images 'important'. In their preference for analogue over digital images, visual arts researchers echo a more general preference in the humanities for the analogue.[137] The authors of the *Gathering Evidence* report have also suggested that some humanities researchers focus their research upon the 'materiality' and physical form of resources.[138]

[137] Huxley et al. 2006, p. 7.
[138] Huxley et al. 2006, p. 7.

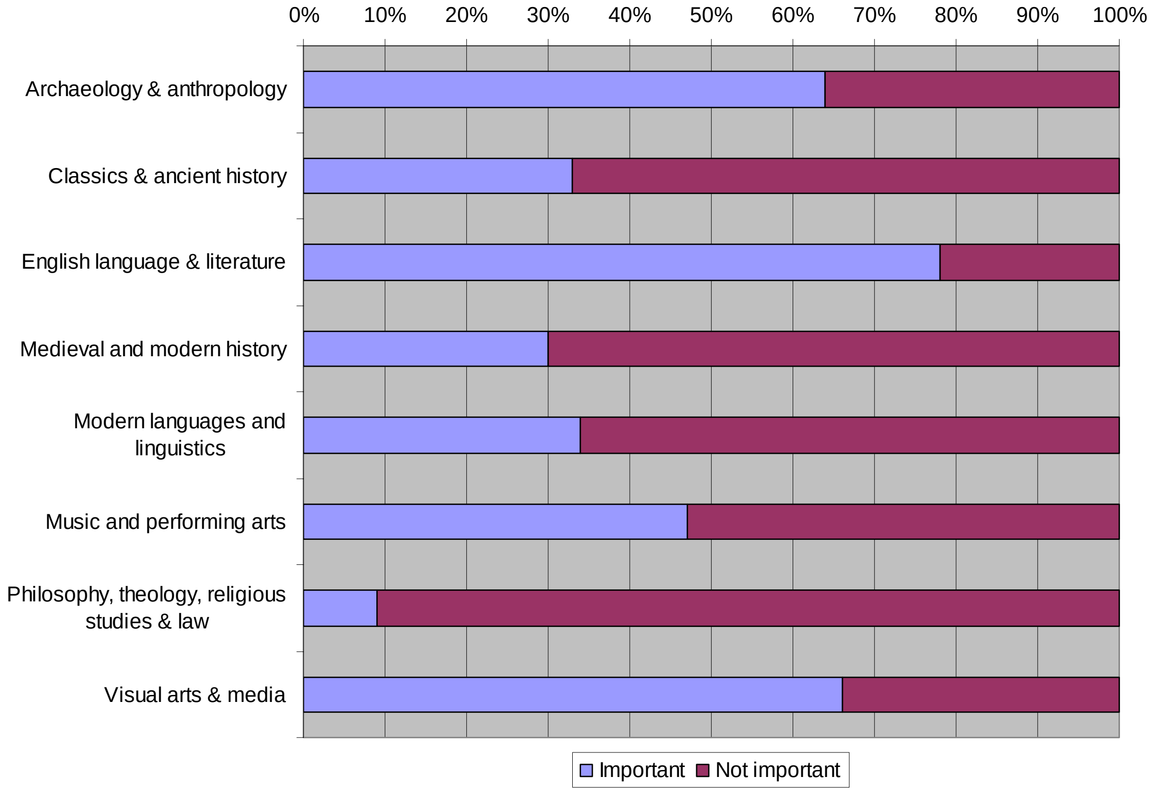

Figure 24. Attitudes of different humanities subject areas to digital images, expressed as percentage of responses in each subject area.

Huxley et al. 2006, table 15 on pp. C: 5-8 & table 6 on p. C: 2.

This leads one to consider whether the emphasis placed by both visual arts researchers and archaeologists and anthropologists upon images – whether digital or analogue – might relate to the importance placed by both disciplines on artefacts as subjects for research (Figure 25): 79% of archaeologists and 58% of visual arts researchers rated them as 'important', compared to 28% of historians, the next most likely discipline to work with artefacts. Artefacts are often complex objects which are not easily reducible to verbal descriptions or characterisations, and images remain the easiest way to disseminate information about them.

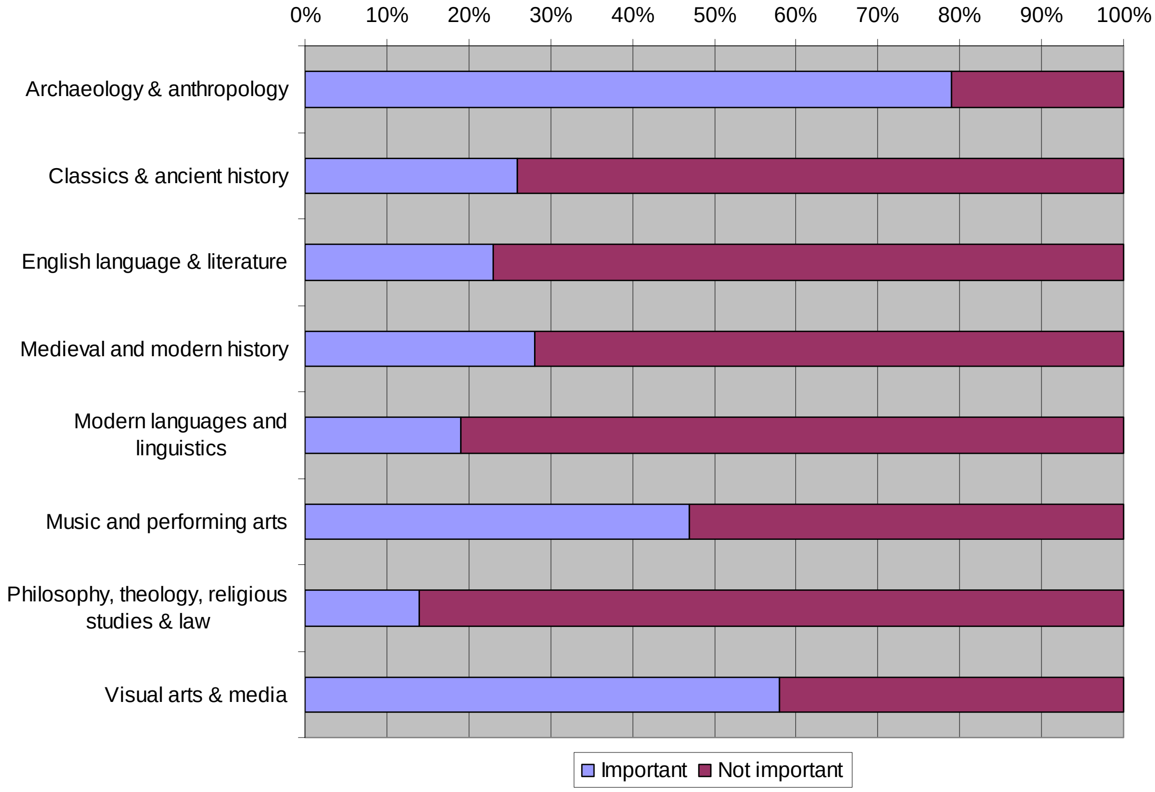

Figure 25. Attitudes of different humanities subject areas to artefacts, expressed as percentage of responses in each subject area.

Huxley et al. 2006, table 15 on pp. C: 5-8 & table 6 on p. C: 2.

When it comes to the creation of research resources, visual arts researchers are generally slightly less likely than other humanities researchers in general to create digital resources. There are two exceptions to this: visual arts researchers are significantly more likely to create digital images, and to re-use or re-package existing products (Figure 26). Once again, they share their preference for images with archaeologists and anthropologists.[139]

[139] Huxley et al. 2006, p. 7.

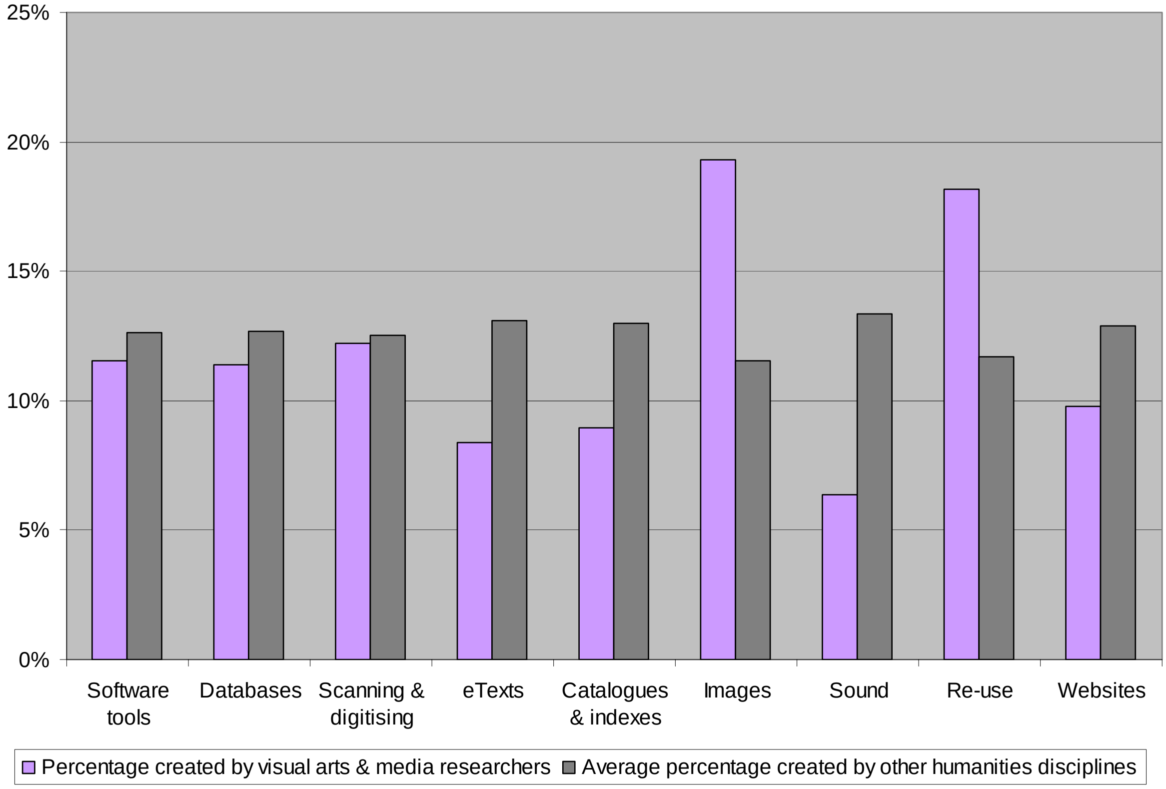

Figure 26. Percentage of digital resources created by humanities researchers in different subject areas. Source: Huxley et al. 2006, table 16 on p. C: 8.

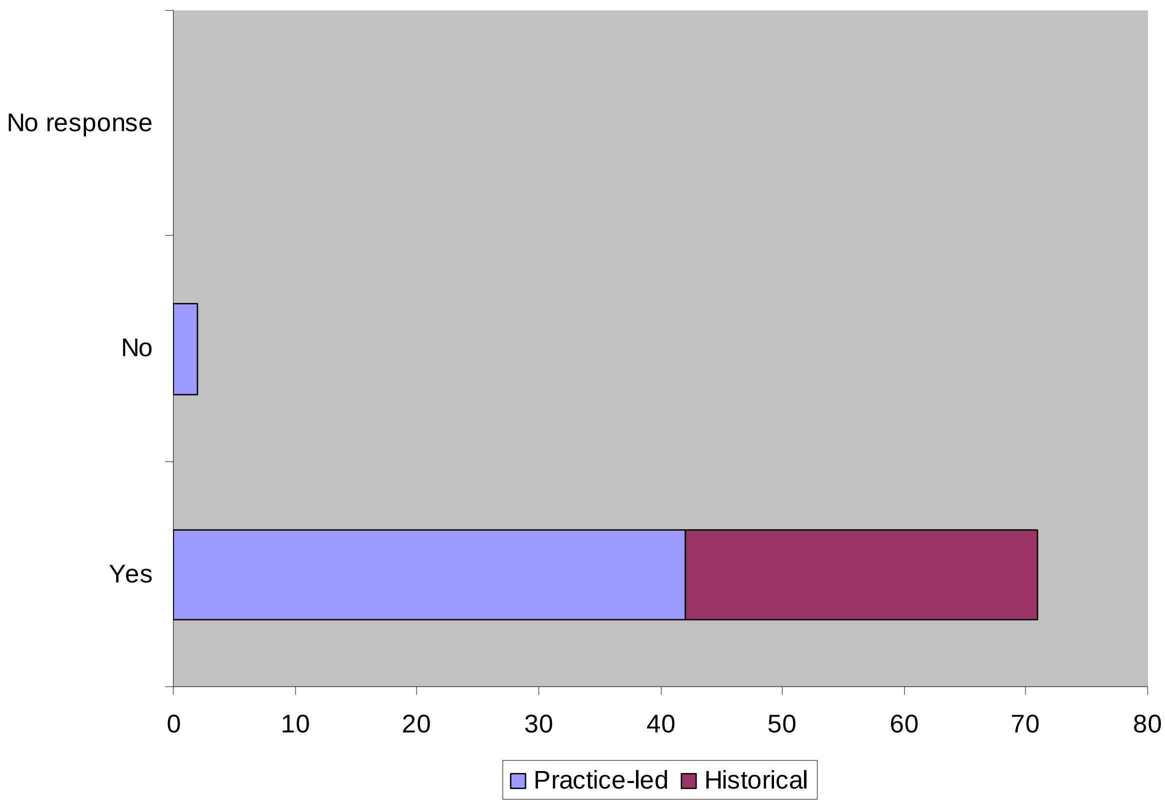

Figure 27. Respondents to project survey who use digital imaging in their practice and/or research.

A snapshot of ICT use amongst visual arts researchers is also provided by the results from the survey conducted for the current project – with the caveat that the sample was self-selecting, and is likely to be biased in favour of those who are already committed to the use of ICT in their research and practice (see Appendix 3). Thus, of the 73 respondents, all but 2 said they used imaging ICT in their research; both those who did not use imaging ICT were practice-led researchers, representing just under 5% of that group (Figure 27).

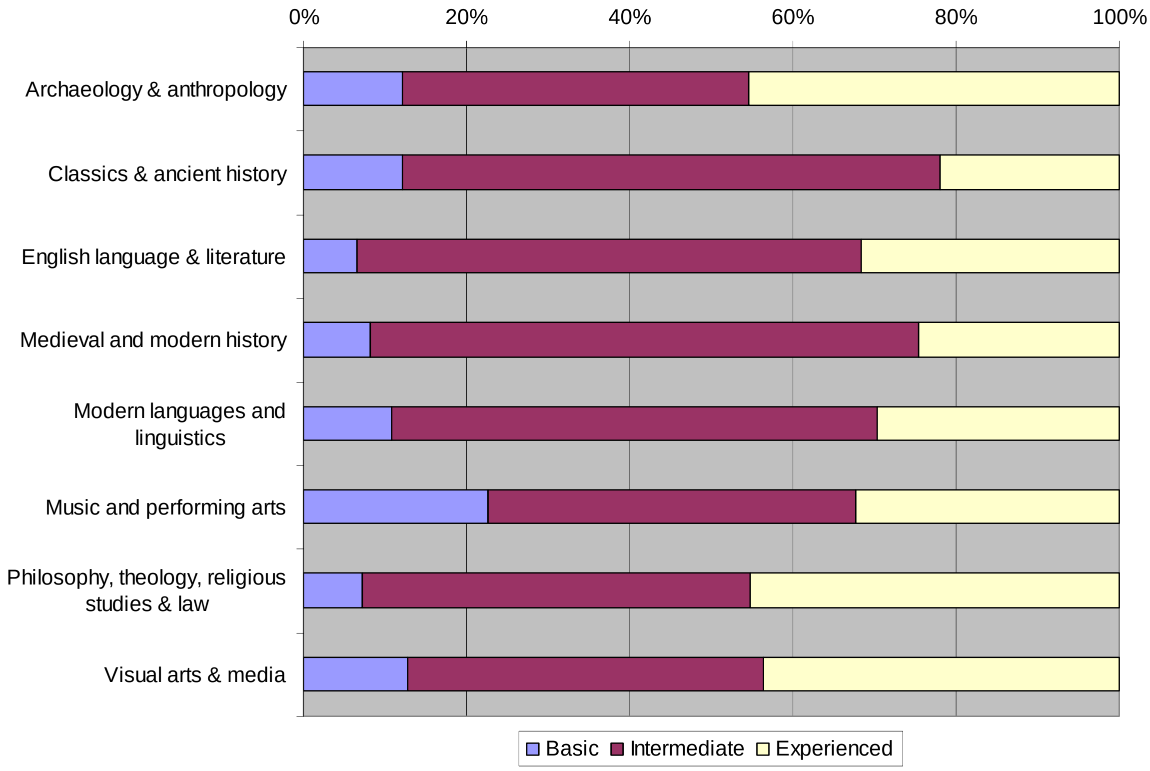

Figure 28. Level of skill in ICT, expressed as a percentage of researchers in each subject area.

Source: Huxley et al. 2006, table 19 on p. C: 9.

These results are supported by the *Gathering Evidence* report, which notes that, by and large, researchers in the visual arts and media consider themselves to be relatively advanced users of ICT: 44% told the *Gathering Evidence* survey that they were 'experienced' users, and a further 44% that they were 'intermediate' (Figure 28). The only subject areas where more researchers considered themselves to be experienced ICT users were archaeology and anthropology, and the area comprising philosophy, theology, religious studies and law. In both cases, there was a negligible difference in proportions compared to the visual arts, with 45% in each subject area defining themselves as experienced. However, these reflect researchers' self-definitions; and the authors of *Gathering Evidence* note that even these 'experienced' users often describe a lack of expertise and consequent need for support and training.[140] Visual arts researchers, along with archaeologists and anthropologists, are amongst the researchers most aware of

[140] Huxley et al. 2006, p. 9.

developments in humanities computing provision – but in both cases, the numbers remain small, between a third and a quarter of researchers.[141] Their main sources of information in this area are serendipity and personal contacts.[142]

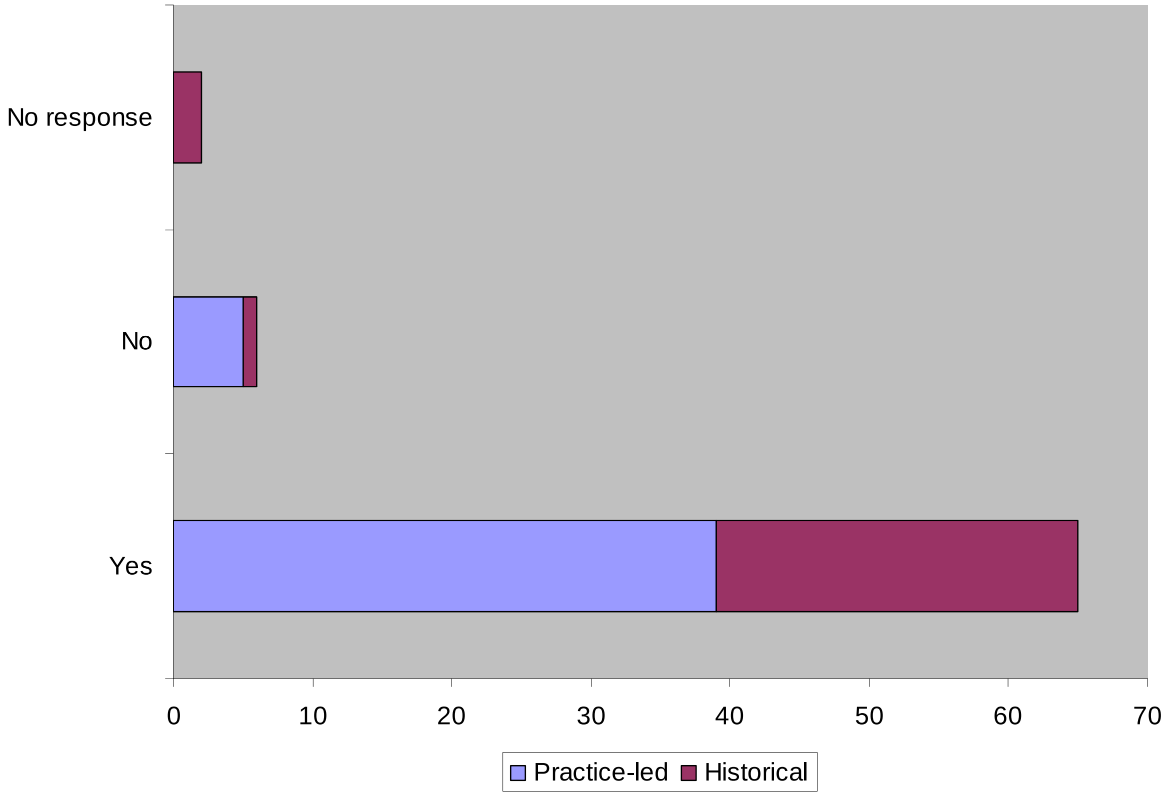

Figure 29. Respondents to project survey who stated that there were things they wished they could do that they could not.

[141] Huxley et al. 2006, pp. 9-10 & table 21 on p. C: 10.
[142] Huxley et al. 2006, p. 10.

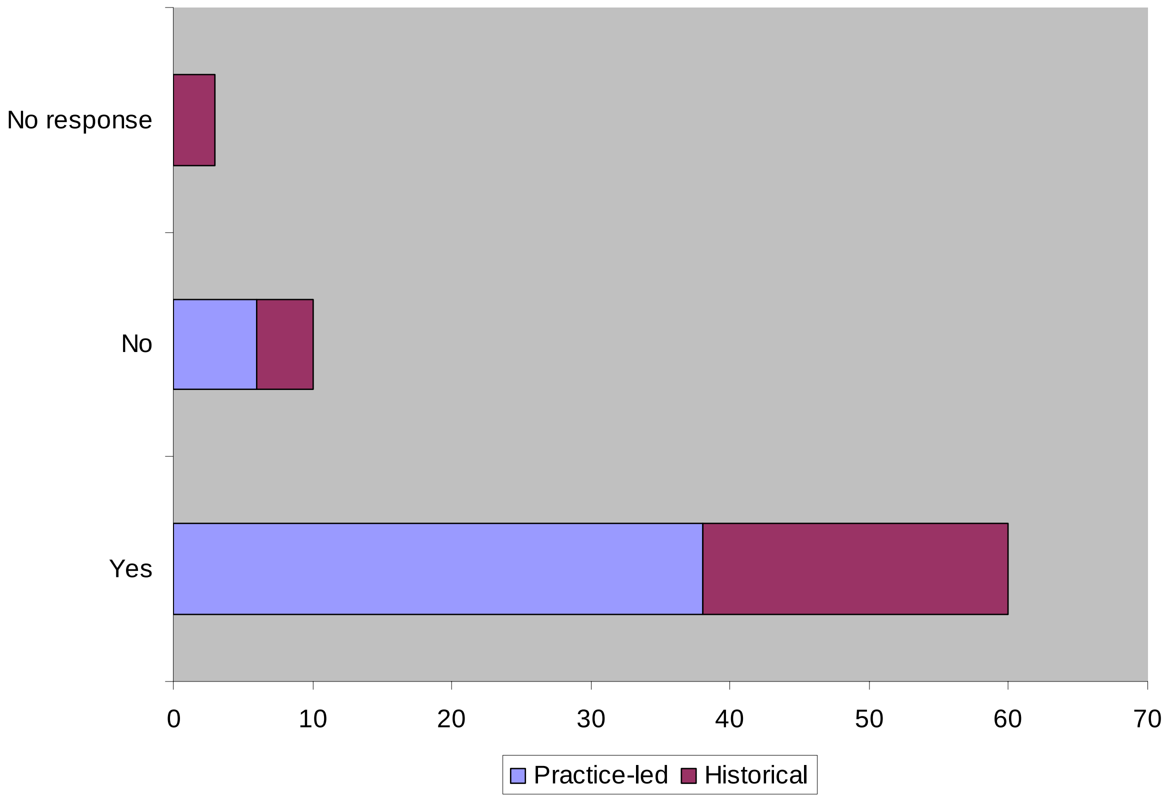

Figure 30. Respondents to project survey who thought that digital technologies might help them do things they could not currently do.

Yet, despite their avowed expertise, visual arts ICT users are also clearly frustrated: 65 (89%) respondents to this project's survey stated that there were things that would like to do in their research that they could not do at the moment (Figure 29), and 60 (82%) thought that digital technologies could help them (Figure 30). A slightly higher proportion of historical researchers than of practice-led (90% as opposed to 89%) expressed this frustration (Figure 31), although the historical researchers were less optimistic that ICT could help fulfil their needs (76%, as opposed to 86% of practice-led researchers – see Figure 32).

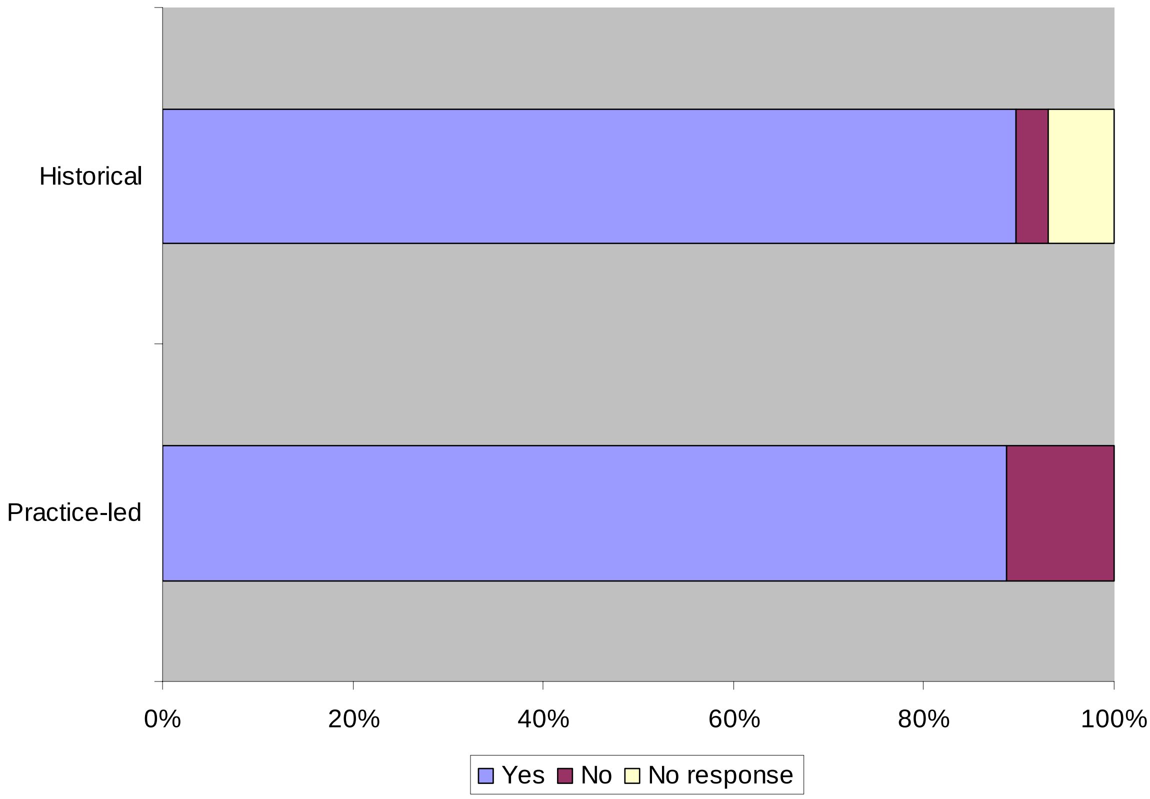

Figure 31. Respondents to project survey who stated that there were things they wished they could do that they could not, as percentages of each discipline.

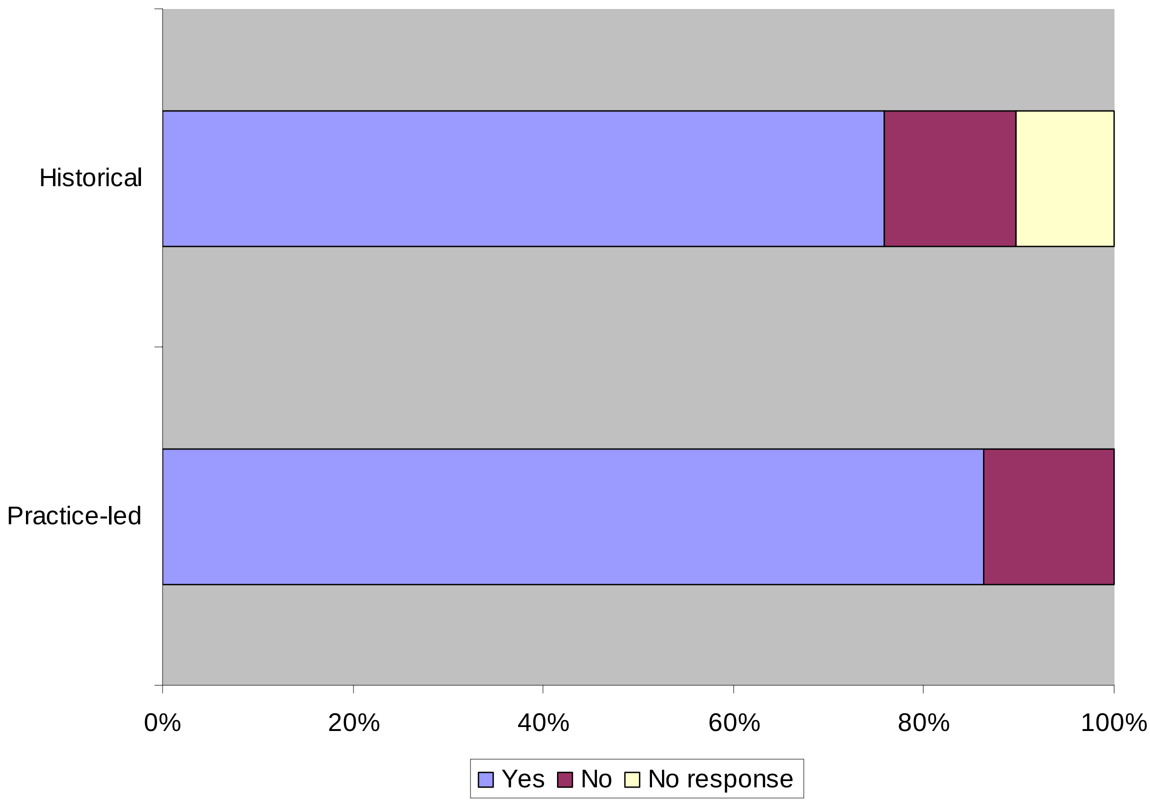

Figure 32. Respondents to project survey who thought that digital technologies might help them do things they could not currently do, as percentages of each discipline.

As revealed by Figure 33, the technologies used by these researchers are many and varied, and the following figures represent an attempt to categorise a great range of disparate and unstructured responses. They are dominated by technologies for the creation of images, used by 50 respondents, 68% of total), followed by processing and manipulation of images (30 respondents, 41% of total), then display technologies (20 respondents, 27% of total) and means of finding images (15 respondents, 21% of total). Other technologies were used by 5 respondents or fewer (under 7% of total). However, as shown in Figure 34, the technologies used differ according to the researcher's discipline: only practice-led researchers stated that they used interface and modelling technologies, or that they wrote code. On the other hand, historical researchers tended to describe very general image use, and dominated the use of technologies for organising and cataloguing, and for finding, images. Use of display technologies and creation of images more-or-less reflected the proportions of practice-led and historical researchers in the overall sample, whilst other technologies were dominated by practice-led researchers, with only a few historical researchers using them.

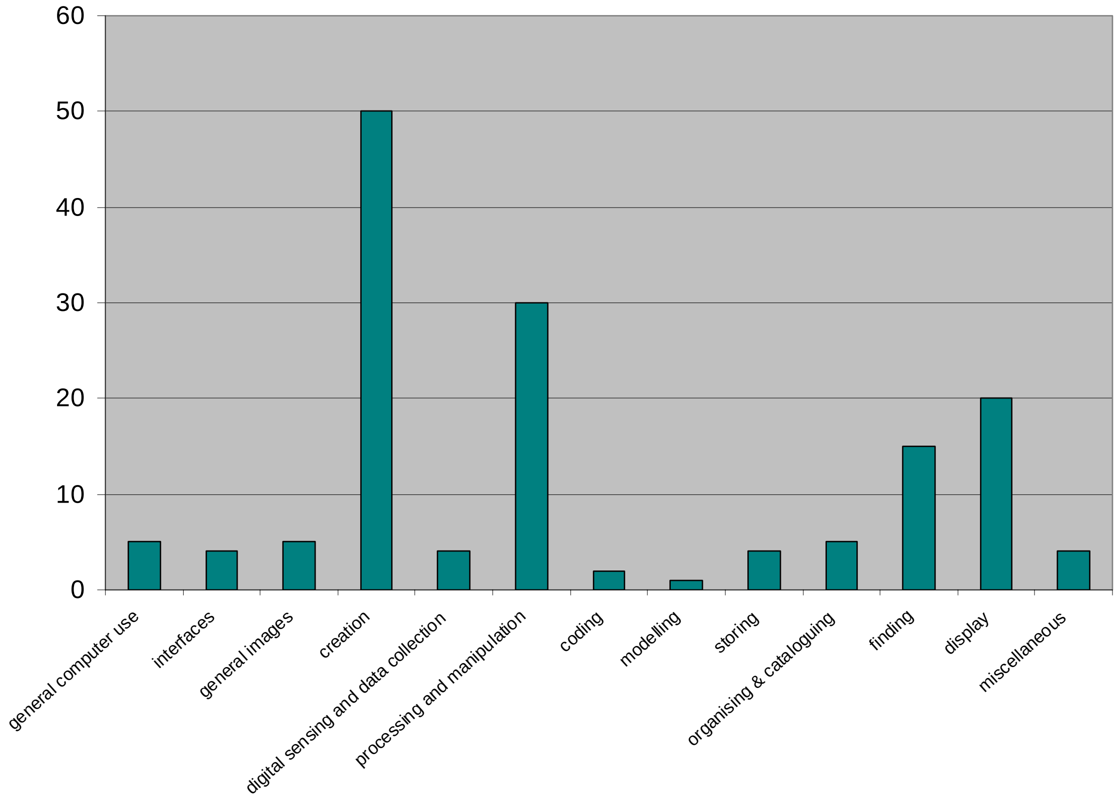

Figure 33. Technologies used by survey respondents.

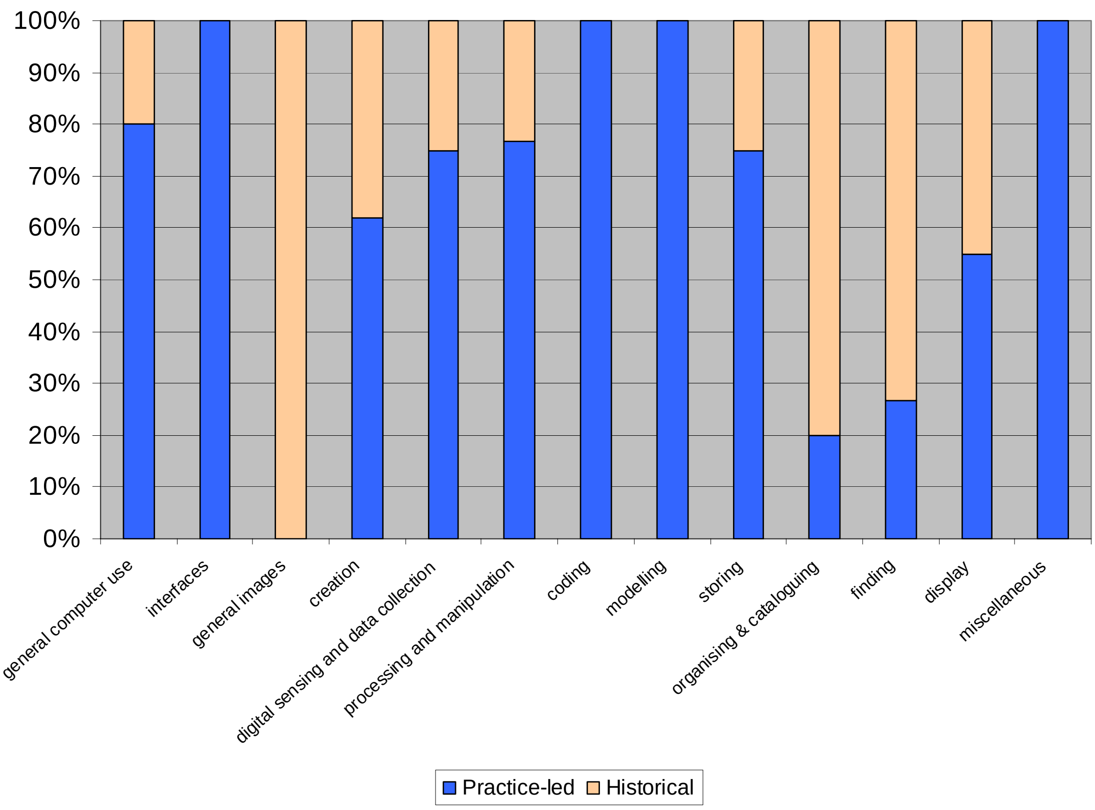

Figure 34. Percentages of technologies used by the two disciplines of survey respondents.

Clearly, digital images now play a major role in the work of most visual arts researchers, reflected in the *Digital Picture*'s finding that 86% of their respondents felt that the increase of digital images in visual arts education had had an impact on them.[143] In this, they reflect arts and humanities researchers more generally – 57% of those responding to the *Gathering Evidence* consultation reported that ICT had had a 'highly significant' impact on the way they conducted research, rising to 98% who believed it had had some impact. For visual arts scholars, though, the proportion describing a 'significant impact' on their research rises to 75%.[144]

3.5. Potential uses of ICT in arts research

New media art is, by definition, concerned with new *media* – that is, the technology is used as the medium (or media) in which research is done. But, as some of the examples above suggest, this is only one way in which ICT may be of use to artists and practice-based researchers: there are many others. For example, ICT may be used to:

- present or display research outputs created in traditional media for portfolios, exhibitions, etc.
- categorise, sort, and deliver representations of outputs created in any medium
- aid research-informed teaching

[143] AHDS Visual Arts 2005, § 4.2.1 on p. 11.
[144] Huxley et al. 2006, p. 12.

- capture the research process as an aid to analysis, further research, teaching or presentation

Any of these uses – and others – are of equal interest to this project.

3.6. ICT – definitions

Similarly, ICT is an extremely broad area, even if we simply focus on technologies that are primarily concerned with images. These extend far beyond the obvious field of digital photography using visible light to cover subjects such as the digital creation, processing and display of images, or methods of visualization which are based upon digital technologies. And, of course, there is no requirement that the images be born digital, or that they be restricted to the visible spectrum.

In addition, whilst this project intended to focus on new technologies, many of the technologies that may be of innovative use to researchers are actually a mixture of novel and well-established techniques. Thus, signals from newly-developed sensors might be subjected to Fourier Transforms for a number of reasons, such as the removal of regularly-occurring artefacts or, in the form of the related Discrete Cosine Transform, as one of the fundamental components of JPEG image file compression.[145] Consequently, Fourier transforms (themselves long-established mathematical functions) have been used in digital imaging for a number of years. The issue is not so much one of absolute novelty, as that a technology should not previously have been exploited in artistic practice or research.

3.7. Categorisation

As information on needs and technologies was assembled, an ad hoc conceptual framework was evolved to enable broad matches to be made between the two. The categories derived in this process have been used to draw up the rough statistics discussed in sections 4.1, 5.1 and 7.1 below, and have been used to produce broad mappings between needs and technologies in the project database (1.5.3). The categories used in the project are:

3.7.1. Collaboration

Collaboration with other individuals, discussion and verbalisation, and the sharing of information and data. The need for high bandwidth network access was already mentioned in the AHRB's 2003 document on the arts and humanities research landscape.[146]

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[145] http://en.wikipedia.org/wiki/Fourier_transform; http://en.wikipedia.org/wiki/Discrete_cosine_transform; http://en.wikipedia.org/wiki/JPEG, all consulted 19 July 2006.

[146] AHRB 2003b, ¶ 5.3 on p. 14.

3.7.2. Interfaces

Developments in the interfaces between people and machines. This group includes the development of software to focus on specific tasks, rather than presenting an ever-expanding range of functions, as this is – amongst other things – an interface issue.

3.7.3. Capture

The capture of images and of data for digital models, including all forms of imaging technology.

3.7.4. Modelling

The creation and manipulation of digital models, usually of physical objects but also of more abstract data.

3.7.5. Image processing

Various processes applied directly to image files to characterise or alter them (including compression techniques).

3.7.6. Video

The ability to work with, store and share uncompressed high-definition video files. As noted by the AHRB in 2003, the growing use of digital media within research, practice and performance 'requires high bandwidth network access, multi-media studios … and film and video suites'. [147]

3.7.7. Visualisation

The processing of data and digital models to convert them into visual form for presentation and analysis.

3.7.8. Processor power

Substantial processor and computing power. The AHRB's research landscape document noted the possibility of exploiting grid technology and large national facilities.[148]

[147] AHRB 2003b, ¶ 5.3 on p. 14.
[148] AHRB 2003b, ¶ 5.3 on p. 14.

3.7.9. Storage

High-resolution image files, and to an even greater extent high-definition video files, require significant amounts of secure storage space.

3.7.10. Categorisation/ordering

Ways of categorising and arranging images so that they might be more easily archived, discovered, or presented.

3.7.11. Finding images

The discovery of images for research and incorporation into new works, often by non-text-based means.

3.7.12. Display

The presentation of work, whether on-screen, projected, in hard copy (two- or three-dimensional), or in other, less tangible forms.

3.7.13. Image collections

The production and dissemination to researchers of collections of digital images, and other digital objects, as research material.

3.7.14. Access

Access to the tools, equipment, expertise, assistance and people who can enable the development and exploitation of advanced technologies in the visual arts.

3.7.15. Sustainability

In addition to those researchers' needs which might be met by advanced imaging technologies, it must be emphasised that discussions raised many issues which relate to more basic problems. Although these may seem to lie outside the scope of this project, they have a significant impact on researchers' abilities to sustain their research work. The problems are largely infra-structural, but they reveal a worrying tendency on the part of institutions to fail to provide the assistance and training that their staff need in order to use the digital techniques which are being forced upon them by cultural and technological pressures, and which will enable them to research more effectively and efficiently. They are related to some of the concerns highlighted in the AHDS Visual Arts report on *The Digital Picture*.[149]

[149] AHDS Visual Arts, 2005.

4. Needs

This section presents the results of the top-down analysis to identify needs and desires, as expressed by visual arts researchers. The analysis was informed by interviews and email surveys of artist researchers (initially at the University College for the Creative Arts) and augmented with a literature review and the following of new leads based on findings from the interviews and surveys. These needs are extensive: as the *Gathering Evidance* report noted,

> The use of images (and other digitised material such as sound) appear problematic at several levels, including difficulties in access, standards, storage, manipulation/analysis, copyright issues and cost of re-use (this latter particularly for images).[150]

4.1. Analysis of needs

Individual needs expressed during interviews and in responses to the survey were assessed and, where necessary, grouped together with similar needs. These are listed in appendix 1 below. Once a reasonable number of needs had been established, these were assigned to a series of broad functional groups (see 3.7 above) in order to provide a structure for mapping to technologies. The relevant groups are listed with each need, and it is apparent that many needs may fall into several categories at once. This suggests that they will be addressed by a range of technologies, rather than any single solution.

4.1.1. *The nature of images and visual arts research*

Many of these needs seem to be the direct results of properties particular to images, whether still or moving, and their digital equivalents:

- The large file sizes required to capture high-quality images
- The high specifications (and consequently expense) of the equipment required to capture and present high-quality images
- The use of images for different purposes, and therefore the use of different kinds of images, stored in different formats, in the engineering world as opposed to the arts world
- The constant evolution of file formats for moving images as processor power increases and display resolution grows, enabling ever larger images to be used
- The non-verbal nature of images, which leads to problems when combined with the verbal nature of most search and retrieval systems

Historical researchers' needs also result from these characteristics of images, but perhaps also result from two further factors:

- Historical researchers are usually bracketed with the humanities more generally, a field of enquiry which primarily focuses upon verbal rather than visual evidence (there are, of course, exceptions to this)

[150] Huxley et al. 2006, p. 2.

- Art history departments tend to be small, and so do not have the resources to employ high-level technical assistance which can focus on specifically art-historical needs (Table 6).[151]

Subject	Departmental Size by Staff Numbers				Total No. of Departments
	50+	30-50	10-30	1-10	
History of Art, Architecture & Design			14	25	39
Built Environment	1	1	29	6	37
Art & design	5	12	35	19	71
Communication, Cultural & Media Studies			15	23	38
Totals	**6**	**13**	**93**	**73**	**185**

Table 6. Size of visual arts departments, 2001.

Source: Brown et al. 2006, Appendix A2, table 2.2 on p. 70, citing 2001 RAE reports.

Consequently, research needs which relate to the visual character of the subject tend to be neglected, particularly if they are expensive. As a result, many of the tools being developed which would prove very useful to art historians have in fact been produced for projects working in other fields, notably the collation of manuscript sources for literature and music – although it should be remembered that the decoration of manuscripts and incunabula is a long-standing and well-defined area of art history.[152] As Neil Grindley notes, art historians

> deal with a particularly rich, diverse and highly visual body of material as the focus of their research and analysis. Presently, the technological response to the complex questions that arise from the study of that material is - for the most part - fragmentary, inadequate and poorly coordinated.[153]

Practice-led and art-historical researchers share certain characteristics with arts and humanities researchers more generally. Several of these have been identified by the recent RePAH report:[154]

- Knowledge-gathering processes in the arts and humanities are reiterative and typically open-ended.
- Researchers prefer to deal with particulars, qualities and complication, which means that categorised, pre-structured information is not always ideal for their needs. Researchers may prefer to establish their own ontological structures.
- Arts and Humanities research is still mainly defined at an individual level, and often not well-understood beyond the particular individual in question. It is usually loosely structured.

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[151] Whilst true of research-active units in the arts and humanities more generally (Brown et al. 2006, § 4.1.3 on p. 23), this is particularly the case of art history departments, which are nearly all small (under 10 researchers) or medium-sized (10-30 researchers) rather than large (over 30 researchers): see Brown et al. 2006, Appendix A2, table 2.2 on p. 70, citing 2001 RAE reports.

[152] See, for example, work on the Archimedes Palimpsest, http://www.archimedespalimpsest.org; Virtual Vellum, http://www.shef.ac.uk/hri/projects/projectpages/virtualvellum.html; the Digital Archive of Medieval Music (DIAMM), http://www.diamm.ac.uk; the Online Chopin Variorum Edition (OCVE), http://www.ocve.org.uk; all consulted 18 September 2006.

[153] Grindley 2006, p. [1].

[154] Brown et al. 2006: see §§ 2.3.1-2 on pp. 7-10, § 2.3.4 on p. 11, § 4.1.3 on p. 23, & §4.2 on pp. 24-5.

- There is a relative lack of 'mutual dependence' among Arts and Humanities researchers, and a degree of 'task uncertainty' in their research.
- The arrangements for collaborative research and disseminating research results are personalized, localized and decentralized. Informal communication depends on individual groups and specific social networks.
- There is sometimes an underlying 'counter-culture' which is suspicious of conformism and authority. The RePAH project encountered this most noticeably in Arts disciplines, where they found that research agendas were often articulated in terms of 'diametrical difference' to prevailing trends.
- Arts and Humanities researchers want access to information, irrespective of the medium in which it is available.
- There is less emphasis on communicating work-in-progress and more emphasis on formal ways of disseminating information.

In addition, the recent ICT Strategy report on tools for use with audio-visual media has isolated a series of basic processes adopted by humanities researchers as they go about their work.[155] These are:

- Accessing
- Searching and collecting
- Annotation
- Transcription
- Analysis
- Presentation

With the possible exception of transcription, these processes are also applied by visual arts researchers; and this formulation is reflected in the categories adopted by this project, outlined in 3.7 above.

4.1.2. *The relative importance of different needs*

Whilst these statistics are to some extent arbitrary, it is worth noting the number of different needs which fall into the various categories. Although the questionnaire produced 73 responses, there are significantly more individual needs, 163 in all (of which 3 were outside the project's scope, producing a total of 160). This is due to several needs appearing in any one questionnaire response, and to the addition of needs emerging from interviews, personal knowledge, participation in workshops, etc.

[155] Marsden et al. 2006, pp. 2-3 & fig. 1.

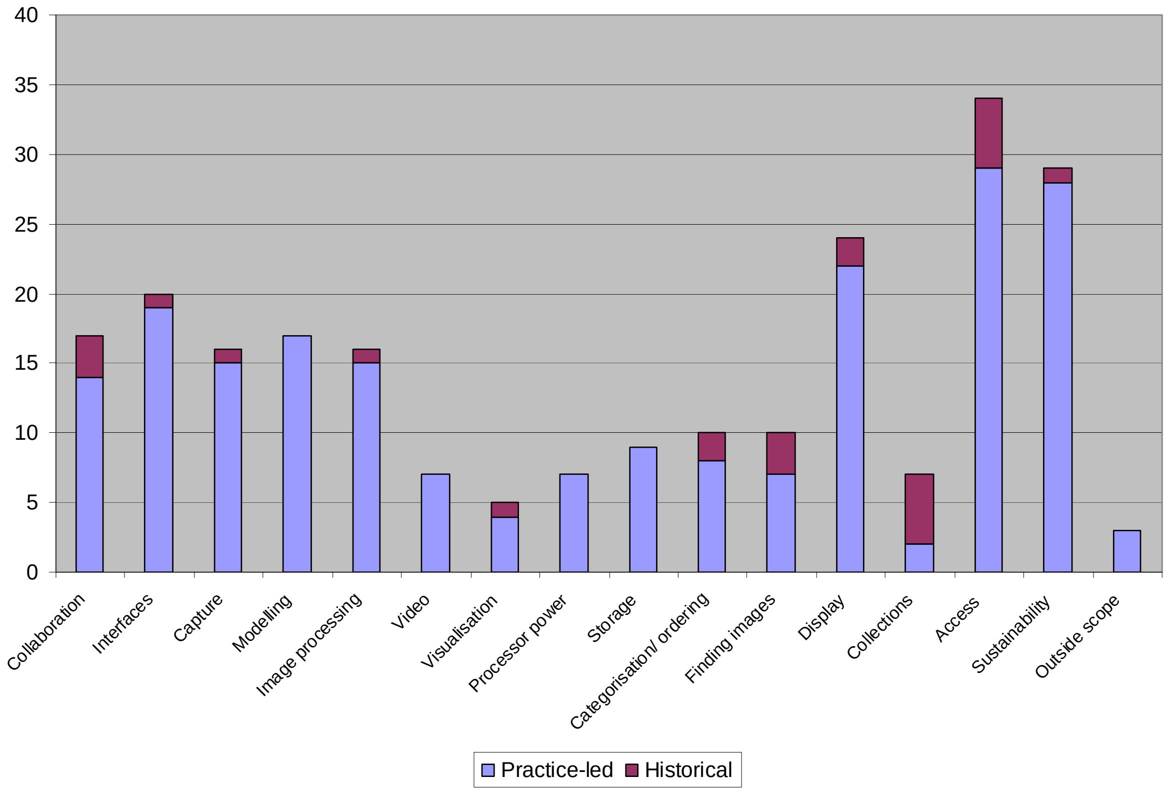

Figure 35. Individual needs expressed by visual arts researchers, divided into categories.

Figure 35 illustrates how the individual needs are divided between the working categories established for the project; this gives an idea of the areas in which there is most demand. It should be noted that needs often fall into more than one category. These are broken down in Figure 35 between those expressed by practice-led researchers (44 out of 73, or 60 % of respondents) and those expressed by historical researchers (29 out of 73, or 40%), as the needs of the two sections of the community differ quite substantially. Figure 36 and Figure 37 show the individual figures for each section of the community on their own, for the sake of clarity.

From these, it emerges that the most significant needs are related to issues of access and sustainability, followed by needs related to the display of images and to interface issues. The least significant lie in the areas of visualisation, video, processor power and storage. Whilst needs surrounding image collections are not a major feature, they should not be discarded: together with access, they form one of the largest categories amongst historical researchers, perhaps reflecting their greater need for structured data and more formal apparatus surrounding the images they use. Finding images and collaboration were also significant needs for historical researchers, whilst there was no demand for modelling, video or storage.

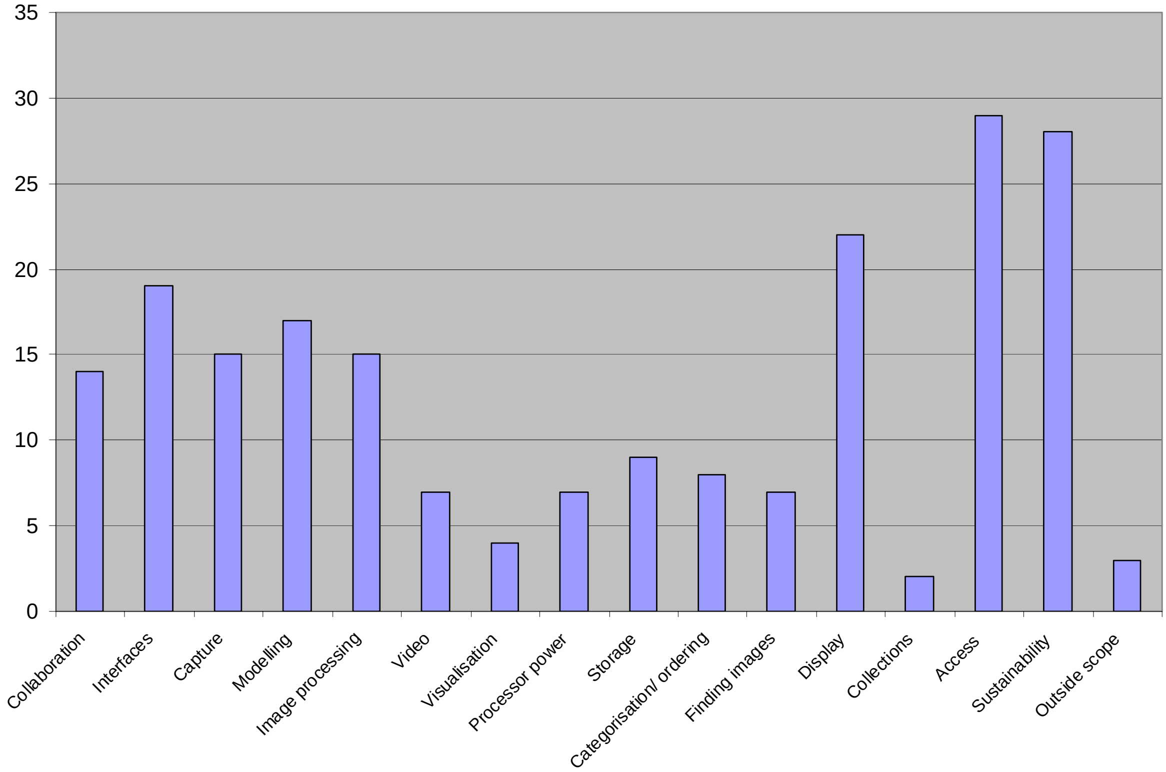

Figure 36. Individual needs expressed by practice-led researchers, divided into categories.

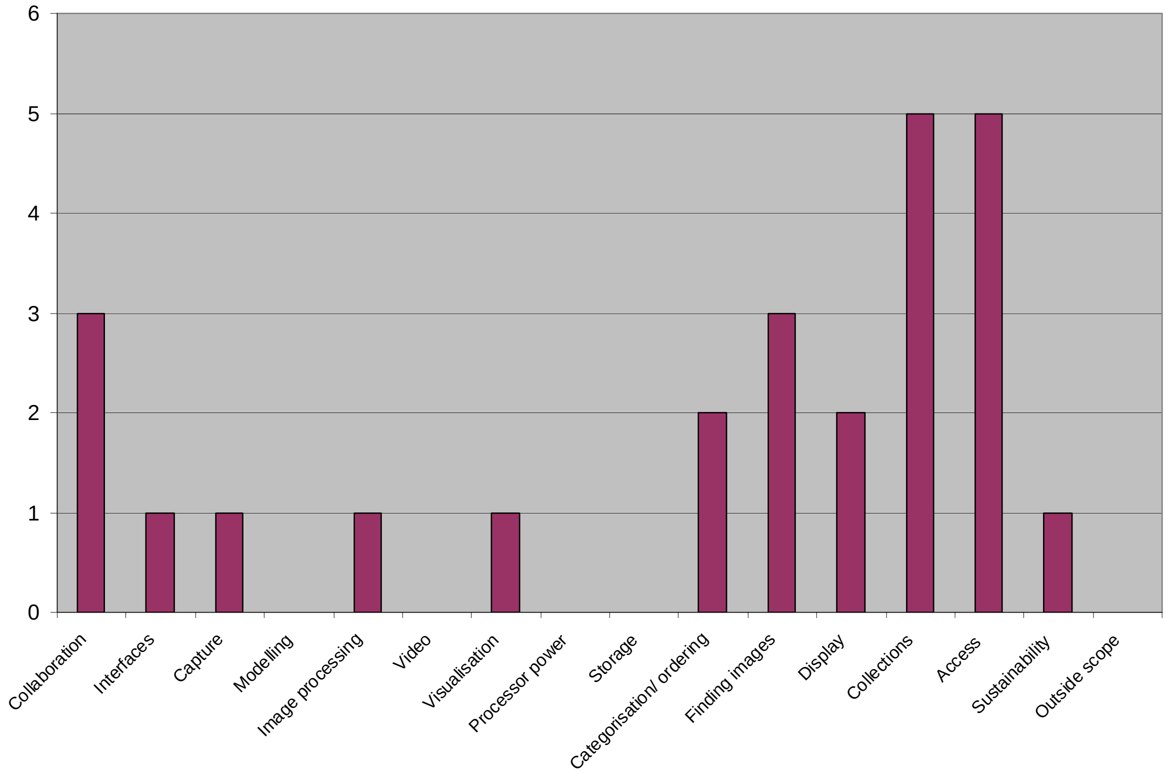

Figure 37. Individual needs expressed by historical researchers, divided into categories.

Individual needs were then compared with each other and similar needs were grouped together. Of these needs, 9 seem to have little potential application beyond specific research projects or interest (‘specific needs’), and 52 are of more general interest (‘generic needs’). Again, one need may fall into more than one category. Figure 38 takes the consolidated generic needs, and indicates how many needs fall into each of the project’s categories. Once consolidated, the emphasis has shifted slightly – sustainability is now the most significant issue, followed by capture, then access. Interfaces, image processing, categorisation/ordering and display are also significant needs, whilst video, visualisation and processor power are the categories that show the fewest separate needs. However, Figure 35 remains the best guide to the relative demand for technologies in each category.

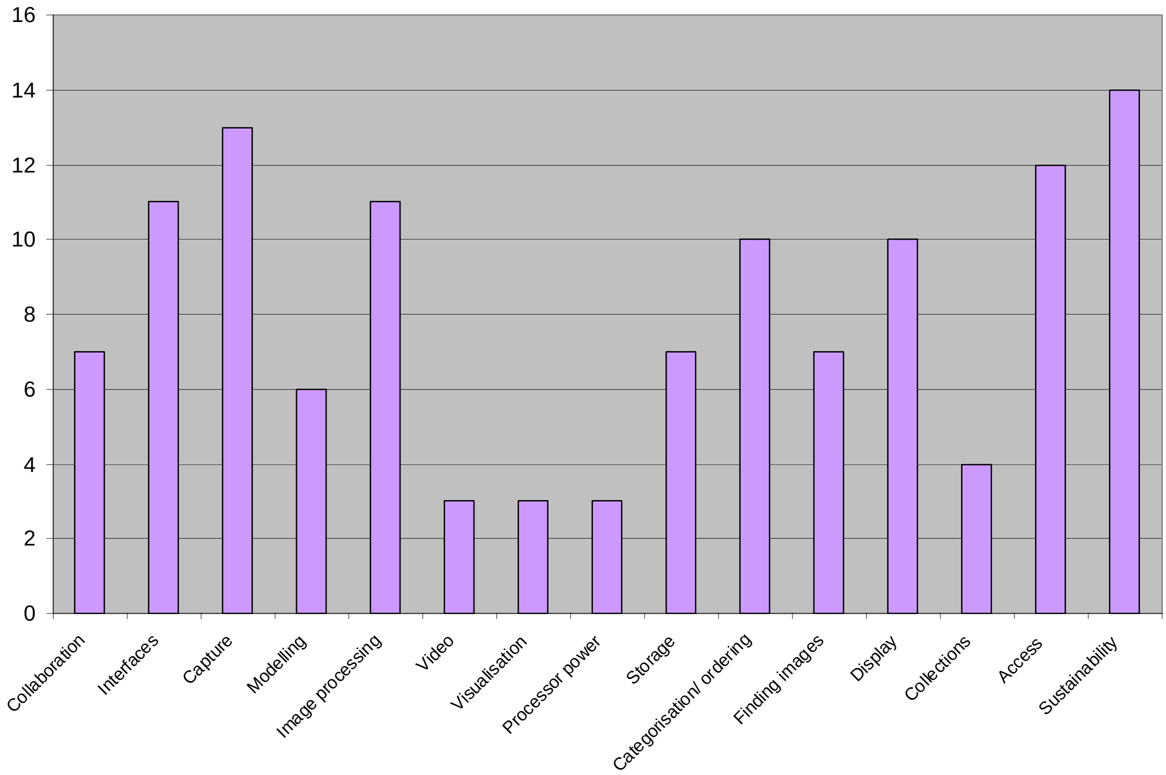

Figure 38. Generic visual arts research needs, divided into categories.

5. Technologies

This section relates to the bottom-up survey of the potential benefits of certain ICT technologies employed, primarily, in scientific research. The survey was developed through interviews with representatives of scientific arenas (initially from Cranfield University) and, as in the analysis, augmented by a literature review and the following of new leads based on findings from the interviews.

5.1. Survey of technologies

Individual technologies discovered during interviews and in desk-based research were assessed and described. Forty-eight relevant technologies were discovered, and they are listed in appendix 2 below. They were assigned to the same broad functional groups as the needs, in order to facilitate the process of mapping needs to technologies. Figure 39 shows the relative numbers of technologies in each category. (It should be noted that, like needs, technologies often fall into more than one category.) It is clear that technologies relevant to capture, image processing and display dominate, followed by categorisation and ordering, modelling, and collaboration. The project has been least successful in finding technologies related to video, processor power and storage. The scarcity of technologies relating to access and sustainability should not be surprising, as these are more institutional issues than technological ones.

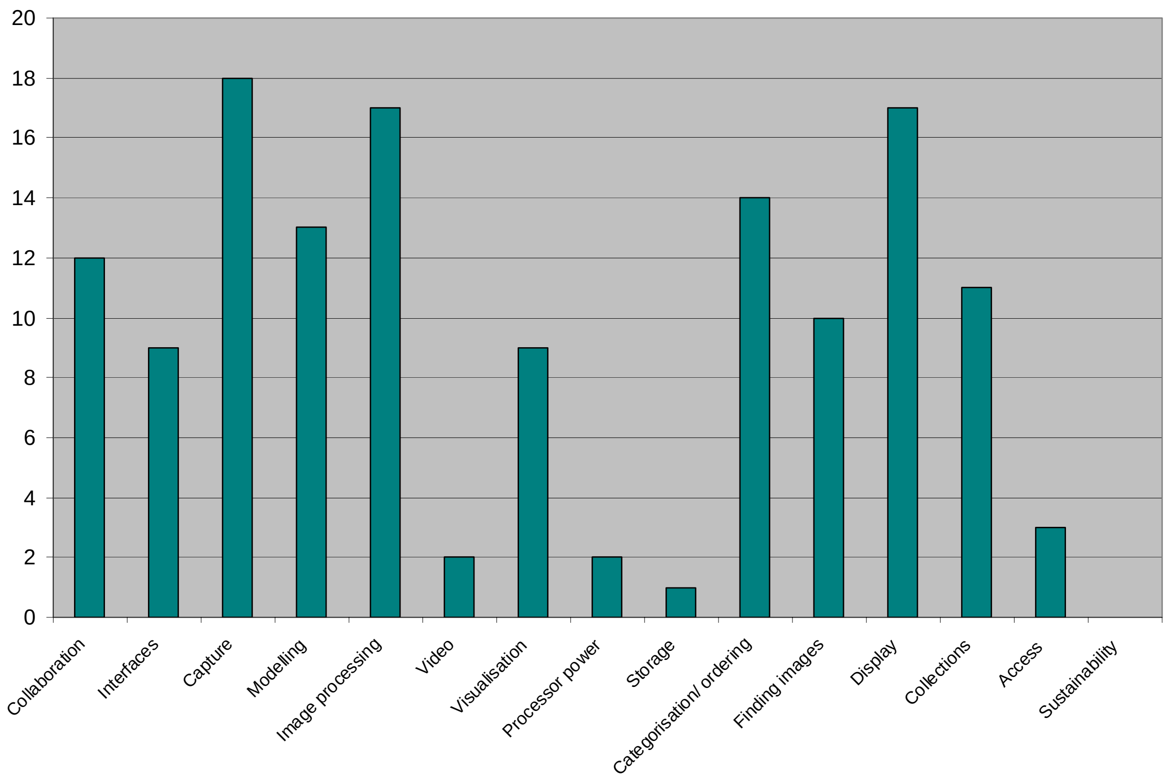

Figure 39. Technologies, divided into categories.

6. Mappings between existing technologies and needs

This section presents the mappings between need and technologies, defining innovative uses of scientific technology in the visual arts. Mappings were created by drawing out specific needs of the arts community and linking them in novel, creative ways, to potential solutions within the scientific domains.

The details of the individual needs and technologies are defined and discussed in detail in appendixes 1 and 2, respectively. This section of the report presents the mappings themselves.

6.1. Collaboration

These needs may well be met by technologies which include VREs and the Access Grid.

Such systems are likely to place high demands on institutional networks and connections to JANET, and there will therefore also be a need to ensure that there is sufficient local infrastructure to support them.

6.1.1. Space to share and comment upon ideas and work, including large files (1.2.1) ↔ Access Grid (2.1.1)

Because of its ability to handle multiple sites and large digital files, the Access Grid's potential in enabling collaborative visual arts research is immense, although the technology is still temperamental, and requires the constant presence of a technician to maintain connections and troubleshoot during a session. But, as Grindley notes, it has significant potential for facilitating detailed discussion of artefacts which may be too fragile to travel:

> In the context of art history where the primary materials of study are scattered worldwide and in many cases cannot be moved, it is significant that wherever a network connection can be obtained, perhaps wirelessly in a gallery space in front of a fragile early renaissance altarpiece, then the Access Grid offers the possibility of turning that occasion into an inclusive and highly interactive meeting of scholars.[156]

The report on the recent scoping seminar on e-Science in the visual arts also describes the Access Grid's exciting potential:

> What we bring as artists is creativity, innovation, imagination. We want to imagine the access grid, to engage with it, to sit with creative computer scientists and use it as an artistic space and see what emerges at the end. A research project could for example - through the use [of] these technologies - lead to a re-conceptualisation of e-science and the grid's future potential.[157]

However, there are current obstacles, identified in the report on the recent scoping seminar on e-Science in the visual arts:

> The key issue is access, so although there are now a number of UK HE institutions that have invested in grid technology resources, we know little about them or how they are being used. … we need to make the contacts to make things happen. There need to be opportunities to engage

[156] Grindley 2006, p. [7].
[157] Gollifer 2006.

in an ongoing dialogue between the technical and IT departments, to encourage the best use of these new technologies with artists/academics.[158]

Infrastructural problems may, however, be met in part by the increasing specifications of desktop computers, and the use of personal interfaces to the Access Grid rather than full-scale nodes.

6.1.2. Space to share and comment upon ideas and work, including large files (1.2.1) ↔ CITRIS Gallery Builder (2.1.3)

The CITRIS Gallery Builder combines a series of three-dimensional virtual spaces with the ability for multiple researchers to interact with each other and digital objects; clearly, such interactions are likely to include collaboration.

6.1.3. Space to share and comment upon ideas and work, including large files (1.2.1) ↔ VidGrid and Mixed Media Grid (MiMeG) (2.1.4)

VidGrid and MiMeG have been developed with the explicit purpose of allowing researchers to collaborate in the analysis of digital video, and to annotate specific sections of the video. However, the system currently relies on videos being circulated to participants before a collaborative session. Further tools for collaborative annotation of video are discussed in the recent AHRC Strategy report on audio-visual media.[159]

6.1.4. Space to share and comment upon ideas and work, including large files (1.2.1) ↔ MITH Virtual Lightbox (2.1.5)

The application version of the Virtual Lightbox allows remote users to view and manipulate the same image set in real time. If combined with voice communication (voice over IP, or an Access Grid session (2.1.1)), then it could prove a useful tool for collaborative work on images.

6.1.5. Space to share and comment upon ideas and work, including large files (1.2.1) ↔ Virtual Vellum (2.1.6)

Like the MITH Virtual Lightbox (2.1.5), the Virtual Vellum viewer allows remote users to view and manipulate the same image in real time. The viewer is already configured to run within an Access Grid (2.1.1) session.

[158] Gollifer 2006.

[159] Marsden et al. 2006, § 3.3.3 on pp. 32-4.

6.1.6. *Space to share and comment upon ideas and work, including large files (1.2.1) ↔ Annotation (2.8.1)*

The various annotation technologies discussed in appendix 2.8.1 should, with development, allow researchers to annotate images, videos, etc., and share their annotations with other users. By building upon annotations, a dialogue can emerge, and annotation becomes a form of collaboration. But, as noted in the appendix, the full list of desirable features has not yet been implemented in a single application.

6.1.7. *Space to share and comment upon ideas and work, including large files (1.2.1) ↔ e-Chase and OpenMKS (2.9.2)*

Imminent versions of OpenMKS should include the facility for researchers to create, share and modify collections of images ('lightboxes'), and annotate their contents, in order to facilitate collaboration.

6.1.8. *Space to share and comment upon ideas and work, including large files (1.2.1) ↔ Existing products*

Online collaboration has already been the subject of some work, and there are existing implementations. For example, VisitorsStudio is an open online area with a web-based interface in which artists can 'chat, mix and upload audiovisual files to participate in the creation of new work'. The system will work over a dialup connection, and requires the Flash plugin (v.6 or higher).[160] The Omnium project has been developing commercial software intended to 'support creative practice that relies heavily on interaction with visual materials'.[161] They offer a suite of products as well as a hosting service; the most relevant to this need is probably Omnium Studio, which includes various communication technologies (message boards, discussion forums, live chat), tools to display and collaboratively mark up work in progress, and the ability to store large working files. However, the software is offered under an institutional site licence, and this may make it difficult to set up ad hoc communities.

6.1.9. *Ways of collaborating online with limited infrastructures (1.2.2)*

Developments in motion-capture technology – particularly live streaming of the point data – may help reduce bandwidth requirements for the distribution of motion-capture based animations, performances etc. over the web; however, rendering would have to be done at the delivery end, and would still place substantial processing demands on the remote computer.

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[160] http://www.furtherstudio.org; quoting from http://www,furtherstudio.org/home_images/VS_presentation.pdf, both consulted 8 December 2006.
[161] http://www.omnium.edu.au/project/; quoting from http://www.omnium.edu.au/assets/downloads/omnium_studio.pdf, both consulted 22 November 2006.

6.1.10. *Ways of collaborating online with limited infrastructures (1.2.2) ↔ HP Remote Graphics Software (2.1.2)*

HP's Remote Graphics Software carries out all rendering on the server, meaning that only the display pixel information has to be transmitted over a network to a remote user's client machine. When combined with efficient compression techniques, this allows high-level visualisations to be run over narrow bandwidth networks.

6.1.11. *Ways of collaborating online with limited infrastructures (1.2.2) ↔ IIPImage (2.5.1)*

IIPImage was developed to serve large images very quickly over comparatively narrow bandwidth networks. It therefore has the potential to aid collaboration with researchers who only have access to limited bandwidth.

6.1.12. *Ways of collaborating online with limited infrastructures (1.2.2) ↔ Grid computing (and e-Science) (2.7.1)*

Whilst grid computing is primarily concerned with high-performance systems, the Resource-Aware Visualisation Environment (RAVE) project uses grid technologies to distribute high-level visualisations in manners appropriate to the remote client's capabilities, including processor power, display size and bandwidth. At the same time, it gives remote clients access to the server's more extensive rendering power.

6.2. Interfaces

6.2.1. *Task-specific tools (1.3.1) ↔ VASARI Image Processing Software (2.2.3)*

Whilst VIPS is itself a complex tool, the way that it has been developed and optimised to meet the needs of a comparatively small user-group (imaging scientists working in museums) indicates the kind of focus on specific capabilities that would render task-specific tools useful to particular user communities.

6.2.2. *Task-specific tools (1.3.1): additional recommendations*

The issue here is less one of technologies, and more one of access to expertise (see 6.14). Meeting this need will require development work, probably focussed in two directions:

- reconfiguring large, existing programs to run as the back-ends of a series of small, discrete front-end components focussed on specific tasks
- developing small, task-specific tools from scratch

In both cases, the emphasis should be on solid user-needs analysis and careful interface design, including easy installation on a range of common platforms. Such tools should be published as open source software wherever possible. It is likely that these needs will best be funded directly, rather than rely on ad hoc partnerships between developers and researchers.

6.2.3. *Mixed-reality environments (1.3.2) ↔ Haptic interfaces (2.2.1)*

Haptic interfaces have the potential to add the sense of touch to mixed-reality environments, although they are still relatively crude – but expensive – technologies.

6.2.4. *Mixed-reality environments (1.3.2) ↔ Visualisation, particularly three-dimensional modelling (2.4.4)*

High-level visualisation technologies already rely on tools like three-dimensional displays and motion-tracking when displaying and manipulating data; these are already forms of mixed-reality environment, and could be developed to meet the more specific needs of practice-led researchers.

6.2.5. *Mixed-reality environments (1.3.2) ↔ Evanescent displays (2.10.7)*

Evanescent displays are explicitly intended to merge digital outputs with the real world to create mixed realities.

6.2.6. *An intuitive haptic interface (1.3.3) ↔ Virtual clay (2.2.2)*

Virtual clay technologies were developed to mimic the effects of modelling clay in a purely digital realm; consequently, they are intended to exploit the intuitive, manual intelligence which is the focus of this need.

6.2.7. *Interactive interfaces (1.1.1) ↔ Visualisation, particularly three-dimensional modelling (2.4.4)*

High-level, large-scale visualisation systems, with their use of motion-tracking, digital 'wands' and other devices, are effectively interactive interfaces.

6.2.8. *Interactive interfaces (1.1.1) ↔ Paper-like displays (2.10.1)*

Some paper-like displays – particularly the Gyricon rotating ball display – can be written on as if they were paper. If combined with touch sensitive technologies, then they have the potential to become more interactive, whilst continuing to exploit the advantages paper-like displays have over conventional CRT, LCD and LED technologies.

6.3. Capture

6.3.1. Seeing below the surface of objects (1.4.1) ↔ Multi-spectral imaging (2.3.8)

The infra-red section of the electromagnetic spectrum, often used in multi-spectral imaging, can penetrate many pigments that are opaque in visible light.

6.3.2. Seeing below the surface of objects (1.4.1) ↔ New infra-red sensors (2.3.9)

Infra-red imaging has long been used to see through many pigments that are opaque to visible light; these technologies allow clearer and more detailed infra-red images to be captured more quickly whilst limiting the object's exposure to infra-red radiation.

6.3.3. Seeing below the surface of objects (1.4.1) ↔ Neutron activation autoradiography (2.3.11)

Neutron-activation autoradiography provides a way of discovering the substances used to create a painting, whether they lie on the surface or are concealed by subsequent paint layers. Although originally an analogue, film-based technique, it seems likely that it can be improved if combined with digital image capture and manipulation technologies.

6.3.4. Seeing below the surface of objects (1.4.1) ↔ Computed Tomography (2.3.12)

Computed tomography is an x-ray technique specifically intended to produce three-dimensional images of the interiors of objects.

6.3.5. Seeing below the surface of objects (1.4.1) ↔ X-ray micro and nano computed tomography (2.3.13)

X-ray micro and nano computed tomography combine the penetrative capabilities of computed tomography with high levels of microscopic magnification, allowing three-dimensional images to be captured of the interiors of microscopic samples.

6.3.6. Seeing below the surface of objects (1.4.1) ↔ Optical Coherence Tomography (2.3.15)

When using infra-red illumination, optical coherence tomography has the ability to penetrate many materials that are opaque in visible light, producing two- or three-dimensional images of the interiors of small samples.

6.3.7. Capturing quantitative data about objects (1.4.2)

As with collaborative research tools, there is also potential for a series of techniques developed in the field of manuscript studies to be of use to art historians, particularly those working on manuscript illumination and on drawings.

6.3.8. Capturing quantitative data about objects (1.4.2) ↔ Laser capture of three-dimensional objects (2.3.5)

Laser capture is a well-established technique for capturing precise volumetric data about objects, although its main uses are currently in industry and surveying (including archaeological surveying). Whilst it can capture to a very fine resolution, the larger the object that is being captured, the coarser the resolution. When used in the scientific examination of artworks, for example, it has been much more effective when used on small panel paintings than when used on large-scale wall paintings.

6.3.9. Capturing quantitative data about objects (1.4.2) ↔ Multi-spectral imaging (2.3.8)

Multi-spectral imaging can produce very precise information about the spectral response of objects, often sufficient to identify the materials used.

6.3.10. Capturing quantitative data about objects (1.4.2) ↔ Polynomial Texture Mapping (2.3.10)

When combined with imaging techniques that can record changes in objects under different conditions, polynomial texture mapping can enable the combination of separate images of the same object in ways that can isolate particular areas of change. When combined with technologies such as multi-spectral imaging or neutron activation autoradiography, this would facilitate the isolation of particular areas of an object with similar characteristics – perhaps incorporating the same pigment.

6.3.11. Capturing quantitative data about objects (1.4.2) ↔ Raman microscopy (2.3.14)

Raman microscopy captures very precise spectral information about the Raman radiation emitted by small samples. This can be used to identify the materials contained within the sample.

6.3.12. Capturing quantitative data about objects (1.4.2) ↔ Optical Coherence Tomography (2.3.15)

Unlike infra-red imaging (6.3.2), optical coherence tomography can produce precise measurements of the depths at which particular changes in the composition of an object occur – in other words, it can produce virtual cross-sections without the need to remove samples from the object.

6.3.13. Capturing quantitative data about objects (1.4.2) ↔ X-ray fluorescence (2.3.16)

X-ray fluorescence generates precise spectral data about the sample under investigation, allowing its component substances to be identified.

6.3.14. Capturing process (1.4.4) ↔ Paper-like displays (2.10.1)

Whilst they do not capture process, paper-like displays would enable researchers to present process that has been captured in some way as if it were a drawing or painting – an object hanging on a gallery wall which might be seen to 'draw' itself.

6.3.15. Capturing images in low light (1.4.5) ↔ Charge Injection Devices (2.3.2)

Charge injection devices perform much better with long capture times than do the more common charge-coupled devices (CCDs); it is also possible to read the output from the device without removing the data, allowing an image to be continually assessed until the correct exposure has been reached. However, such devices would not meet a need for fast image capture in low light (e.g. hand-held photography).

6.3.16. Mapping time (1.4.6) ↔ Charge Injection Devices (2.3.2)

Charge injection devices are able to acquire images cumulatively over long time periods, and the image can be read out without clearing the sensor. In addition, individual pixels can be read out as required. This provides a variety of potential ways in which the passage of time may be captured and visualised.

6.3.17. Mapping time (1.4.6) ↔ Polynomial Texture Mapping (2.3.10)

Given a series of time-lapse still images of a scene, polynomial texture mapping can be used to generate images of the scene at points between the instants when the stills were captured. The technology also allows viewers of the image to arbitrarily select any particular still or intermediate image, effectively giving them the ability to move time forwards or backwards as required.

6.3.18. *Tools for high-quality scanning of digital images (1.4.7) ↔ High-resolution imaging (2.3.7)*

High-resolution imaging technologies can help meet the need for high-quality scanning, at least in terms of capture resolution.

6.3.19. *New microscopic techniques, including micro-cinematography and animated cell imaging (1.4.8) ↔ X-ray micro and nano computed tomography (2.3.13)*

X-ray micro computerised tomography combines the ability of computed tomography to produce three-dimensional images of the interiors of objects with the ability to resolve down to microscopic levels, approximately 150-250 nm (i.e., half the wavelength of visible light).

6.3.20. *New microscopic techniques, including micro-cinematography and animated cell imaging (1.4.8) ↔ Raman microscopy (2.3.14)*

Raman microscopy combines microscopic resolution with ability to capture spectrographic data which allows for the identification of specific substances.

6.3.21. *New microscopic techniques, including micro-cinematography and animated cell imaging (1.4.8) ↔ Optical Coherence Tomography (2.3.15)*

Optical coherence tomography combines the ability to capture three-dimensional sections through objects with microscopic resolution (in the area of 15-20 μm).

6.3.22. *Faster three-dimensional capture (1.4.9) ↔ Volumetric cinematography (2.3.6)*

Volumetric cinematography enables capture of detailed three-dimensional data (up to 0.1 mm resolution) at cinematic frame rates. However, in its current from it requires a large grid of cameras, and the object being captured needs to be coated with a fluorescent paint; it can only capture dry surfaces.

6.3.23. *Faster three-dimensional capture (1.4.9) ↔ Polynomial Texture Mapping (2.3.10)*

Polynomial texture mapping needs only a limited number of exposures (the National Gallery use twenty-four) from which to interpolate a three-dimensional structure. Replacing existing incandescent light sources with LED or flash illumination should help further speed up capture times.

6.3.24. Faster three-dimensional capture (1.4.9) ↔ Automatic construction of three dimensions from two-dimensional images (2.4.3)

Techniques for constructing three-dimensional models from two-dimensional images have been developed to work with existing images – in other words, as long as the images are already available in digital form, the capture time is zero. (Photo Tourism has been demonstrated using images downloaded from Flickr.) In addition, because they do not rely on detailed knowledge of camera position, the two-dimensional images required to create the model can potentially be captured from scratch very quickly. However, as noted in appendix 2.4.3, this technology is still very processor-intensive; for the moment, it is likely to require access to significant processor power to run effectively. But there are also technologies which may be able to address this need: see 6.8 for relevant mappings.

6.3.25. Gigapixel photography (1.1.3) ↔ High-resolution imaging (2.3.7)

Whilst high-resolution imaging is currently only capable of producing images in the low hundreds of megapixels, capture technologies continue to evolve, and the techniques for using micro- and macro-positioning to extend the effective size of sensors are already well-established.

6.3.26. Controlling camera movement digitally (1.1.4) ↔ Electro-wetting and liquid lenses (2.3.1)

By varying the voltage used to control a liquid lens around its circumference, the lens's focal point can be moved in three dimensions, rather than the single dimension required for focussing. This means that the lens can be made to pan and tilt optically, rather than physically.

6.4. Modelling

As noted in appendix 2.4, many of the technologies mentioned in this section are still very processor-intensive; for the moment, they are likely to require access to significant processor power to run effectively. However, there are also technologies which may be able to address this need: see 6.8 for relevant mappings.

6.4.1. Three-dimensional modelling (1.5.1) ↔ Laser capture of three-dimensional objects (2.3.5)

Laser capture is an established technology for capturing objects of various sizes in three dimensions. It continues to be under-used in visual arts research.

6.4.2. Three-dimensional modelling (1.5.1) ↔ Automatic construction of three dimensions from two-dimensional images (2.4.3)

The technologies discussed under this heading have all been developed with the explicit aim of constructing three-dimensional digital models.

6.4.3. Three-dimensional modelling (1.5.1) ↔ Visualisation, particularly three-dimensional modelling (2.4.4)

As suggested in 6.4.1, there are a number of well-established technologies used for the three-dimensional modelling of data and objects. However, it is not always easy for visual arts researchers to secure access to them – see also 6.14 below.

6.4.4. Modelling unconventional forms of vision (1.5.2) ↔ Visualisation, particularly three-dimensional modelling (2.4.4)

Although not normally used in this way, there is no reason why existing visualisation and modelling technologies cannot be manipulated to model unconventional forms of vision – assuming that those forms of vision can be properly characterised.

6.4.5. Modelling non-visual and complex visual properties (1.5.3) ↔ Haptic interfaces (2.2.1)

Haptic technologies – although currently still crude – are expressly designed to model non-visual properties relating to touch.

6.4.6. Modelling non-visual and complex visual properties (1.5.3) ↔ Polynomial Texture Mapping (2.3.10)

Polynomial texture mapping provides a flexible way of storing various viewing parameters (e.g. focal point or depth of focus) within an image file, and allowing the viewer to manipulate them.

6.4.7. Modelling non-visual and complex visual properties (1.5.3) ↔ Visualisation, particularly three-dimensional modelling (2.4.4)

Existing visualisation technologies, currently under-used by visual arts researchers, are designed to model a variety of properties, either visual or non-visual. The only requirement is that those properties can be captured and characterised.

6.4.8. Modelling non-visual and complex visual properties (1.5.3) ↔ Physics-based visualisation (2.6.1)

Physics-based visualisation provides a means of visualising the strength of relationships or similarities between different data.

6.4.9. Scalable or animated methods of recording work (1.5.4) ↔ Automatic construction of three dimensions from two-dimensional images (2.4.3)

Techniques for automatically constructing three-dimensional models from two-dimensional images have the potential to combine general views with detailed depictions of parts of an exhibition or installation in the models they construct.

6.4.10. Scalable or animated methods of recording work (1.5.4) ↔ Visualisation, particularly three-dimensional modelling (2.4.4)

Rather than rely on conventional still photography or video, existing two- and three-dimensional visualisation techniques may provide more suitable methods for recording and reproducing physically-complex works such as installations.

6.5. Image processing

6.5.1. Direct output to industrial tools (1.6.1) ↔ Rapid prototyping (2.10.2)

Rapid prototyping has been developed to allow objects to manufactured directly from digital files, without any requirement for re-tooling, etc. However, there are restrictions to the materials from which the object can be made, and its maximum size. Most rapid prototyping machines use the task-specific STL file format, although this can be generated from many CAD programs.

6.5.2. Direct output to industrial tools (1.6.1) ↔ Direct laser fabrication (2.10.3)

Direct laser fabrication is a rapid prototyping (6.5.1) technique which can produce objects in solid metals, direct from digital files.

6.5.3. Automated image analysis (1.6.3)

As noted in appendix 2.4, many of the technologies mentioned in this section are still very processor-intensive; for the moment, they are likely to require access to significant processor power to run effectively. However, there are also technologies which may be able to address this need: see 6.8 for relevant mappings.

6.5.4. *Automated image analysis (1.6.3) ↔ Automatic construction of three dimensions from two-dimensional images (2.4.3)*

These technologies can be used to analyse certain aspects of images automatically. For example, Photo Tourism was used, in conjunction with digital elevation maps, to reconstruct the point from which Ansel Adams's famous photograph *Moon and Half Dome, Yosemite*, was taken; this suggests a potential application for historians of photography and, possibly, for historians of landscape painting – although the potential 'inaccuracies' in depiction introduced by artists may prove too much for the system.

Potential uses suggested by the developers of the technique for constructing three-dimensional models from a single view include:[162]

- the development of tools which clarify the relationship between perspective constructions and finished paintings
- assessing the levels of individual artists' concerns with perspectival accuracy
- identifying departures from strict perspective constructions and analysing possible reasons for them
- exploring the relationships between the viewpoints defined by perspective constructions and those which are available to spectators in the paintings' original locations
- setting paintings within virtual reconstructions of their original locations

The system can also be used to measure the relative sizes of objects within images, providing indications of relative scale; and it can make objects shown in extreme foreshortening much clearer, possibly enabling the more detailed examination of details within the image.

6.5.5. *Automated image analysis (1.6.3) ↔ Visualisation, particularly three-dimensional modelling (2.4.4)*

Well-captured three-dimensional models inherently contain significant qualities of data about the physical shape of an object, which is capable of being analysed by suitable software tools.

6.5.6. *Automated image analysis (1.6.3) ↔ Content-Based Image Retrieval (2.9.1)*

Content-based image retrieval relies upon the automatic analysis of images' visual characteristics in order to quantify the degree of similarity between different images. Recent research has suggested that such forms of analysis may be able to aid in the attribution of works of art.

[162] Criminisi et al. 2003, p. 31.

6.5.7. Automated incorporation of digital images into databases (1.6.4) ↔ Automatic construction of three dimensions from two-dimensional images (2.4.3)

One of the most time-consuming aspects of adding images to databases is the entering of suitable metadata. It has been suggested that systems for constructing three-dimensional models from two-dimensional images be used to automatically annotate large collections of images with metadata based upon the images' visual similarity to already-labelled images. For example, the Photo Tourism system will take annotations applied to one section of a three-dimensional model, and apply them to the same section on all images which also show that section.[163]

6.5.8. Automated incorporation of digital images into databases (1.6.4) ↔ The semantic web (2.8.3)

Semantic web technologies could potentially remove the need for the time-consuming task of converting metadata constructed using different standards and vocabularies into a single format when adding images to databases. However, this would depend upon the various metadata systems being mapped to a common ontology.

6.5.9. Automated incorporation of digital images into databases (1.6.4) ↔ Content-Based Image Retrieval (2.9.1)

It has also been suggested that systems for content-based image retrieval could be used to automatically annotate large collections of images with metadata in the same way as has been proposed for Photo Tourism and similar technologies (6.5.7).

6.5.10. Automated incorporation of digital images into databases (1.6.4) ↔ Annotation (2.8.1)

The technologies discussed in the section on annotation might be used to enable specific communities to add metadata to images after they have been incorporated into databases, rather than capture the metadata at the moment of ingest.

6.5.11. Greater interoperability between file types (1.6.5) ↔ PathMarker (2.3.4)

PathMarker provides a means whereby geographical information and multimedia files can be made to work together, adding geographic metadata to the multimedia files and multimedia content to the geographical data.

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[163] Snavely et al. 2006, § 7.2.

6.5.12. Greater interoperability between file types (1.6.5) ↔ Synthetic environments (2.4.1)

The development of synthetic environments has necessitated solving various interoperability issues in order to enable disparate systems to communicate and work together coherently.

6.5.13. Greater interoperability between file types (1.6.5) ↔ Synthetic wrap (2.4.2)

The development of synthetic wrap technologies has necessitated solving various interoperability issues in order to enable disparate systems to communicate and work together coherently.

6.5.14. Greater interoperability between file types (1.6.5) ↔ Visually significant barcodes (2.5.2)

Visually significant barcodes effectively combine two types of data – visual and character-based – albeit in physical form.

6.5.15. Greater interoperability between file types (1.6.5) ↔ Grid computing (and e-Science) (2.7.1)

The development of e-Science relies upon the solution of a number of interoperability issues, frequently addressed using web services technologies. One project which is addressing these issues and is of particular relevance to some visual arts practitioners is the AMUC project at the Newcastle Culture Lab, investigating whether libraries of motion-capture data assembled for different purposes and using different standards can be combined in useful ways.

6.5.16. Greater interoperability between file types (1.6.5) ↔ The semantic web (2.8.3)

Semantic web technologies are being developed with the specific aim of enabling computers to work across incompatible data structures, thereby ensuring the interoperability of metadata and other information.

6.5.17. Greater interoperability between file types (1.6.5) ↔ Content-Based Image Retrieval (2.9.1)

Rather than try and render different metadata systems interoperable, content-based image retrieval may, in some circumstances, remove any requirement for it at all by allowing researchers to find images which look similar. In other words, if they already know one image which meets their needs, they can use a content-based image retrieval system to find others which look like it in some way.

6.5.18. *Greater interoperability between file types (1.6.5) ↔ e-Chase and OpenMKS (2.9.2)*

As semantically-enabled technologies, e-Chase and OpenMKS are already being used to render a set of discrete multimedia databases, organised to different standards, interoperable.

6.6. Video

6.6.1. *Tools and resources for intensive work with high-definition moving images (1.7.1)*

Technologies which might meet this need are likely to be very processor-intensive, and require access to significant processor power to run effectively. However, there are also technologies which may be able to address this aspect of the need: see 6.8 for relevant mappings.

6.6.2. *Tools and resources for intensive work with high-definition moving images (1.7.1) ↔ Grid computing (and e-Science) (2.7.1)*

Grid computing is one technology which may help researchers access the resources needed to work with high-definition video. e-Science technologies are already being used to allow astronomers to produce MPEG movies of the sun from observational data, using the UK's Astrogrid 'virtual observatory' service.[164]

6.7. Visualisation

6.7.1. *Tools for mapping relationships (1.8.1) ↔ Physics-based visualisation (2.6.1)*

Physics-based visualisation provides a means for visualising the relationships between different data. It has already been used to model relationships between people, for example criminal networks.

6.8. Processor power

6.8.1. *Processing power and exploiting existing resources (1.8.1) ↔ Grid computing (and e-Science) (2.7.1)*

Computational grids, in particular, have been established to give researchers access to substantial computing power. However, the technologies are still complex, requiring detailed technical knowledge to run, and will need significant work if they are to be made

[164] http://wiki.astrogrid.org/bin/view/Astrogrid/MovieMaker, consulted 14 June 2006.

accessible to visual arts researchers who, whilst needing the power they can offer, are not necessarily technically-minded. Use of grid technologies to meet this need is likely to place high demands on institutional networks and connections to JANET, and there will therefore also be a need to ensure that there is sufficient local infrastructure to support them.

6.8.2. *Processing power and exploiting existing resources (1.8.1) ↔ Cluster computing (2.7.2)*

Cluster computing provides a well-established technology for exploiting existing, local resources. As mentioned in appendix 2.7.2, there is substantial scope for the power of machines on individual desktops, in student computer rooms, in lecture rooms, etc. to be exploited when they would otherwise stand idle (for example, overnight).

6.9. Storage

6.9.1. *Bulk storage (1.10.1) ↔ Grid computing (and e-Science) (2.7.1)*

The data grid, in particular, has been developed to allow remote access to very large datasets, and there seems little reason why the technologies which lie behind it cannot also be exploited by the visual arts community – always assuming that they can be made more user-friendly. However, such systems are likely to place high demands on institutional networks and connections to JANET, and there will therefore also be a need to ensure that there is sufficient local infrastructure to support them.

6.10. Categorisation/ordering

6.10.1. *Archiving and indexing across multiple removable media (1.11.1) ↔ Existing products*

Datacatch Librarian is an existing, commercially available product which will automatically catalogue data held on removable media alongside data stored locally, providing a unified search interface for local and removable files.[165]

6.10.2. *Annotation of images (1.11.2) ↔ VidGrid and Mixed Media Grid (MiMeG) (2.1.4)*

The MiMeG tool enables multiple users in several remote sites to annotate the same video in real time. However, in its current from, the videos need to be circulated to the individual participants before the collaborative session begins, and then run locally.

[165] http://www.datacatch.com, consulted 10 August 2006.

Further tools for collaborative annotation of video are discussed in the recent AHRC Strategy report on audio-visual media.[166]

6.10.3. *Annotation of images (1.11.2) ↔ Automatic construction of three dimensions from two-dimensional images (2.4.3)*

It has been suggested that systems for constructing three-dimensional models from two-dimensional images (2.4.3) be used to automatically annotate large collections of images with metadata based upon the images' visual similarity to already-labelled images. For example, the Photo Tourism system will take annotations applied to one section of a three-dimensional model, and apply them to the same section on all images which also show that section.[167]

6.10.4. *Annotation of images (1.11.2) ↔ Annotation (2.8.1)*

The technologies listed in this section are clearly all relevant to this need. However, the full list of desirable features – for example,

- ability to add annotations
- ability to annotate discrete sections of images
- ability to share annotations
- browser-independence (if relevant)
- ability to add annotations to a combination of on-line and local images
- ability to access one's own or stored annotations off-line

– has not yet been implemented in a single application.

6.10.5. *Annotation of images (1.11.2) ↔ Content-Based Image Retrieval (2.9.1)*

It has also been suggested that systems for content-based image retrieval could be used to automatically annotate large collections of images with metadata in the same way as has been proposed for Photo Tourism and similar technologies (see 6.10.3).

6.10.6. *Annotation of images (1.11.2) ↔ e-Chase and OpenMKS (2.9.2)*

Imminent versions of e-Chase should include the capacity for remote users to share collections of images ('lightboxes') and annotate their contents.

6.10.7. *Indicating scale in digital images ↔ MITH Virtual Lightbox (2.1.5)*

[166] Marsden et al. 2006, § 3.3.3 on pp. 32-4.
[167] Snavely et al. 2006, § 7.2.

The MITH Virtual Lightbox allows local users to carry our basic manipulations of remotely-stored images on their own machine. Whilst these do not yet include resizing, it should be possible, given an agreed method of storing the relevant information in object metadata, to reconfigure the system so that images could be displayed at comparable scales; this would simply be a resizing operation carried out to a predefined ratio.

6.10.8. New paradigms for organising archives (1.11.2) ↔ PathMarker (2.3.4)

PathMarker enables users to combine images and other multimedia files with geographical information. In other words, it can organise data geographically; it was developed with trips – i.e. particular routes – in mind, although there is no reason why these cannot be imaginary rather than real ones. Whilst apparently aimed at the consumer market, enabling users to capture the 'essence' of trips and journeys, or at commercial users such as estate agents, the system clearly has potential for use in research and practice which focuses on movement through space and time, as well as combination with genres such as GPS drawing. There are also possibilities for historical research, when particular journeys or routes may be retraced: the re-recording of some of John Ruskin's many journeys to the continent and through Great Britain might be one example.[168]

6.10.9. New paradigms for organising archives (1.11.2) ↔ Physics-based visualisation (2.6.1)

Physics-based visualisation provides a means of displaying the relationships between data in visual form. This could be used to cluster data according to different similarity criteria. In addition, the facility offered by ClusterVis software for defining descriptive rules which characterise particular clusters, could be used to create headings or sections in data archives which reflect the characteristics of the data, rather than being imposed from outside.

6.10.10. New paradigms for organising archives (1.11.2) ↔ Visual interfaces to data (2.8.4)

These technologies might allow archives to be organised in more intuitive ways, perhaps along the lines of the classical and renaissance 'memory theatre'.

6.10.11. New paradigms for organising archives (1.11.2) ↔ Content-Based Image Retrieval (2.9.1)

[168] As is done physically with the series of tours organised under the banner 'The Ruskin Journey': http://www.ruskin.org.uk/Roots/, consulted 30 October 2006.

Rather than rely upon text-based descriptions, purely visual characteristics, such as those generated for content-based image retrieval, might be used as the organising principles for archives of visual material.

6.10.12. New forms of non-linear interface to websites (1.11.5) ↔ CITRIS Gallery Builder (2.1.3)

The CITRIS Gallery Builder presents data as a series of objects in three-dimensional spaces, rather than a series of hyperlinks. Whilst the data still has to be explored in a linear fashion (i.e. starting in one place and moving to another), routes through the data are less constrained by pre-defined links and routes.

6.10.13. New forms of non-linear interface to websites (1.11.5) ↔ PathMarker (2.3.4)

PathMarker allows data to be displayed and queried using geographical data and interfaces – e.g., maps or relief models of the earth's surface. Consequently, users can access data simply by clicking upon its geographical 'location', rather than having to enter specific search strings or follow a series of pre-defined links.

6.10.14. New forms of non-linear interface to websites (1.11.5) ↔ Physics-based visualisation (2.6.1)

Physics-based visualisation presents data as a series of interconnected points in two- or three-dimensional space. This makes it much easier to browse through related data, rather than rely upon a site's creator to have created all the necessary links between connected data. The technology can also be used to visualise website structure and traffic, enabling site owners to assess how effectively their existing structure and links provide access across the site; it might also be possible to use it as a form of navigation aid, recording and illustrating the routes taken through websites.

6.10.15. New forms of non-linear interface to websites (1.11.5) ↔ The semantic web (2.8.3)

Semantic web technologies are intended to make it easier for users to navigate through data in ways that were not necessarily foreseen by the data's original creators. mSpace, in particular, is one semantic technology which allows users to reconfigure the arrangement of data elements on their screen, continuously re-arranging routes into a particular dataset to meet their own requirements.

6.10.16. New forms of non-linear interface to websites (1.11.5) ↔ Visual interfaces to data (2.8.4)

All these interfaces are based upon the notion that it is easier to browse through data visually, rather than textually; and that doing this will open up routes through datasets which may not have been envisioned when the data was originally entered and characterised.

6.11. Finding images

6.11.1. Finding images across multiple collections (1.12.1)

The *CLIC* report notes that 76% of image collection creators would support a national service holding metadata from image collections, and that this would go a long way to meeting the concerns of museums, in particular, about loss of control over their data.[169] However, the systems for sharing such metadata are not currently in place in the majority of image collections.[170] The report also discusses a variety of potential solutions to the provision of a national network of shared image collections, including metadata harvesting.[171] Federated access to image collections also emerged as the preferred solution to this need amongst respondents to the *Digital Picture* consultation.[172] It cannot be emphasised too strongly that a mature technology already exists for exposing and harvesting metadata in OAI-PMH – see 6.11.3 below.

6.11.2. Finding images across multiple collections (1.12.1) ↔ Grid Computing (2.7.1)

The data grid, in particular, should be able to incorporate visual arts data, and render different data archives interoperable. In the words of the summary of the recent e-Science scoping seminar for visual arts, 'The data grid and the computational grid provide access to large data and the means to analyse it. That doesn't necessarily just mean access to high-resolution images, but opportunities to use multiple images.'[173] However, this is likely to take some development. In addition, such systems are likely to place high demands on institutional networks and connections to JANET, and there will therefore also be a need to ensure that there is sufficient local infrastructure to support them.

6.11.3. Finding images across multiple collections (1.12.1) ↔ Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH) (2.8.2)

The Open Archives Initiative Protocol for Metadata Harvesting is an established, widely-used and comparatively easily-implemented standard which enables data owners to expose their metadata to OAI-enabled search engines. These, in turn, can 'harvest' the metadata from many sites at the same time, returning data from multiple, remote collections in a seamless, unified interface. The Getty has recently published an extension

[169] Miller et al. 2006, § 3.1 on p. 20, § 5.1.1 on p. 32, § 9.3 on pp. 52-3, & App. 11.9.8 on pp. 133-7.
[170] Miller et al. 2006, § 3.1 on p. 20.
[171] Miller et al. 2006, § 4.1.2 on pp. 27-9, § 10.6.3 on pp. 60-61, & §10.6.5. on pp. 61-2.
[172] AHDS Visual Arts 2005, § 4.3.2 on pp. 35 & 36-7.
[173] Gollifer 2006.

to the core OAI-PMH metadata standard which is explicitly intended to allow collections to share information about objects and images of objects – in other words, they have tailored the OAI-PMH standard to the needs of visual arts researchers. It should be emphasised that this is an existing, mature technology which, although under-used in visual arts areas, is comparatively easy to implement and could quickly produce extensive benefits for researchers.

6.11.4. *Finding images across multiple collections (1.12.1) ↔ The semantic web (2.8.3)*

Semantic web technologies have been developed with the specific goal of producing meaningful results from queries of multiple datasets organised according to different standards.

6.11.5. *Finding images across multiple collections (1.12.1) ↔ e-Chase and OpenMKS (2.9.2)*

As semantically-enabled technologies, e-Chase and OpenMKS are already being used to search across a set of discrete multimedia databases, organised to different standards.

6.11.6. *More sophisticated content-based image retrieval (1.12.2) ↔ Automatic construction of three dimensions from two-dimensional images (2.4.3)*

Microsoft propose that the point clouds generated by Photosynth could be used for content-based image retrieval, effectively retrieving images which showed the same object, regardless of orientation. Similar uses could presumably be made of the related Photo Tourism system.

6.11.7. *More sophisticated content-based image retrieval (1.12.2) ↔ Physics-based visualisation (2.6.1)*

Physics-based visualisation would facilitate browsing through groups of images which have been characterised using content-based characteristics: similar objects would be clustered together in a virtual three-dimensional space (see also 6.11.10).

6.11.8. *More sophisticated content-based image retrieval (1.12.2) ↔ Grid computing (and e-Science) (2.7.1)*

Current content-based retrieval techniques require intensive pre-processing of images in order to produce statistical models of their visual characteristics, before these characteristics can be searched for. The computational grid has the potential to provide substantial computing power to speed up this process; or even, as noted in the summary of the recent e-Science scoping seminar for the visual arts, allowing 'people to explore images from all over the globe in much more efficient ways, without the need for the pre-processing or re-rendering of the images.'[174] The potential for grid computing to help meet these needs has also been identified in the recent AHRC Strategy report on audio-visual media.[175]

6.11.9. More sophisticated content-based image retrieval (1.12.2) ↔ Cluster computing (2.7.2)

Current content-based retrieval techniques require intensive pre-processing of images in order to produce statistical models of their visual characteristics, before these characteristics can be searched for. Cluster computing techniques could be exploited to make the necessary processor power available locally, greatly speeding up the characterisation process and, perhaps, enabling it to be carried out on-the-fly in the not-too-distant future. The potential for cluster computing to help meet these needs has also been identified in the recent AHRC Strategy report on audio-visual media.[176] (See also 6.8.2.)

6.11.10. More sophisticated content-based image retrieval (1.12.2) ↔ Visual interfaces to data (2.8.4)

Visual interfaces to data – notably the form proposed by See-Fish Technology – would facilitate browsing through groups of images which have been characterised using content-based characteristics: similar objects can be clustered together in a virtual three-dimensional space (see also 6.11.7).

6.11.11. More sophisticated content-based image retrieval (1.12.2) ↔ Content-Based Image Retrieval (2.9.1)

Whilst content-based image retrieval is a well-established technology, it has not necessarily been optimised for the requirements of visual arts researchers. Ways in which this might be done are outlined in appendix 2.9.1; and see also 6.11.6, above.

6.11.12. More sophisticated content-based image retrieval (1.12.2) ↔ e-Chase and OpenMKS (2.9.2)

e-Chase and OpenMKS combine semantic and content-based search technologies with the aim of increasing the effectiveness of both.

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[174] Gollifer 2006.
[175] Marsden et al. 2006, § 2.5 on p. 18.
[176] Marsden et al. 2006, § 2.5 on p. 18.

6.12. Display

6.12.1. High-quality presentation of digital images (1.13.1) ↔ High-resolution imaging (2.3.7)

High-quality presentation is impossible without high-quality originals; consequently, widespread use of high-resolution image capture is necessary if very high quality images are to become the norm when research is presented.

6.12.2. High-quality presentation of digital images (1.13.1) ↔ Visualisation, particularly three-dimensional modelling (2.4.4)

Many of the display techniques used in established visualisation technologies are of much higher quality than those habitually used by visual arts researchers.

6.12.3. High-quality presentation of digital images (1.13.1) ↔ IIPImage (2.5.1)

IIPImage enables large, high-resolution files to be disseminated easily over low-bandwidth internet connections, making the remote display of high-quality images much easier.

6.12.4. High-quality presentation of digital images (1.13.1) ↔ Paper-like displays (2.10.1)

Paper-like displays, being reflective, do not require darkened rooms to increase their visibility, as data projectors do. The variable quality of blackouts is often a significant factor in the low quality of displays using projectors. Consequently, as the technology develops, large-scale paper-like displays may offer certain advantages in the display of high-quality images.

6.12.5. High-quality presentation of digital images (1.13.1) ↔ Rapid prototyping (2.10.2)

Three-dimensional images can also be presented as solid objects; rapid prototyping technologies can produce these to fairly fine resolutions. The significance of these technologies in rendering digital objects perceivable by the visually impaired should not be under-estimated, given current demands for equality of access.

6.12.6. High-quality presentation of digital images (1.13.1) ↔ High dynamic range displays (2.10.4)

High dynamic range displays address the shortcomings in the dynamic range of existing display technologies. However, the technology is comparatively new, and may need to mature before it becomes stable and widely available.

6.12.7. High-quality presentation of digital images (1.13.1) ↔ High resolution projectors (2.10.5)

Current technologies are quite capable of projecting data to very high resolutions and quality; however, such high-end systems are comparatively expensive. Consequently, their comparative rarity in visual arts situations is more a question of access and sustainability, than of technology.

6.12.8. High-quality presentation of digital images (1.13.1) ↔ Projector calibration (2.10.6)

With the recent commercial availability of projector calibration systems, there are fewer and fewer reasons why visual arts institutions should not take steps to ensure that their digital projectors are performing to as a high a standard as possible. (Similarly, with the recent release of the GretagMacbeth Huey[177] as a mass-market screen calibration device, basic monitor calibration should be within the reach of most visual arts researchers, even if their institutions are unwilling to take steps to ensure that the monitors they provide are fit for the purposes for which researchers use them.)

6.12.9. High-quality presentation of digital images (1.13.1) ↔ Volumetric displays (2.10.8)

Current three-dimensional displays require users to wear some kind of device – either flimsy glasses with red and green or polarised lenses for fairly crude displays, or heavier glasses which flicker at high speed. Because of the disparity between the single point at which the eyes must remain focussed to see the display, and the points at which they must converge to perceive the stereoscopic effect, these often cause discomfort in viewers. Apart from holography, the only exception is a technology based on the old lenticular prints, which used a ridged plastic film to present different views of a subject according to the angle from which they were viewed, but these tend to have very limited viewing angles, low resolutions, and again cause discomfort in viewers. The various volumetric display technologies discussed in appendix 2.10.8 are intended to address these shortcomings by actually displaying images in three dimensional space, rather than producing the illusion of the third dimension. Whilst these technologies are very immature, they have the potential to significantly improve the viewer's experience of three- dimensional images in the future.

6.12.10. Projection onto evanescent surfaces (1.13.2) ↔ Evanescent displays (2.10.7)

Evanescent displays have been developed with precisely this need in mind.

[177] http://www.gretagmacbeth.com/index/products/products_color-mgmt-spec/products_monitor-calibration/products_huey.htm, consulted 20 December 2006.

6.12.11. More sophisticated presentation software (1.13.3) ↔ Virtual Vellum (2.1.6)

As well as providing facilities for live collaborative work on digital images, the Virtual Vellum viewer can also be used as presentation software which enables comparison between and zooming into very high resolution files. However, like other presentation software (e.g. the presentation aspects of the Madison Digital Image Database (MDID)[178] or the ARTstor image viewer[179]), it does not contain all the functions which would be desirable, for example the ability to easily incorporate text slides within the presentation system, or facilities for the insertion of multimedia files.

6.12.12. More sophisticated presentation software (1.13.3) ↔ Projector calibration (2.10.6)

Whilst it lacks many of the functions which visual arts researchers need, Microsoft PowerPoint continues to be widely used as a presentation tool. Although it does not incorporate the standard colour management tools which are used by much of the printing and imaging industries, GretagMacbeth have released Eye-One ColorPoint software, a plugin that enables PowerPoint to support colour management.

6.12.13. Flexible interactive displays (1.1.7) ↔ Paper-like displays (2.10.1)

The more flexible forms of paper-like display will certainly fulfil the 'flexible' part of this need. Some paper-like displays – particularly the Gyricon rotating ball display – can also be written on as if they were paper. If combined with touch sensitive technologies, then they have the potential to become more interactive, whilst continuing to exploit the advantages paper-like displays have over conventional CRT, LCD and LED technologies.

6.12.14. Flexible interactive displays (1.1.7) ↔ Evanescent displays (2.10.7)

Evanescent display technologies are inherently flexible, in that they have dispensed with a fixed projection screen. In addition, both technologies discussed in appendix 2.10.7 allow viewers to interact with the projected images.

6.12.15. Three-dimensional moving typography (1.1.9) ↔ Haptic interfaces (2.2.1)

Haptic interfaces allow for three-dimensional digital objects to be experienced through the sense of touch; they might, therefore, be used to provide an additional form of interface to three-dimensional moving typography.

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[178] http://mdid.org/overview.htm, consulted 20 December 2006.
[179] http://www.artstor.org/info/tools/tools_public_oiv.jsp, consulted 20 December 2006.

6.12.16. Three-dimensional moving typography (1.1.9) ↔ Visualisation, particularly three-dimensional modelling (2.4.4)

There are established technologies for presenting digital images in three dimensions, whilst various modelling technologies might be used to construct the three-dimensional characters.

6.12.17. Three-dimensional moving typography (1.1.9) ↔ Volumetric displays (2.10.8)

Volumetric displays offer another possibility for displaying three-dimensional digital images; they are capable of doing this at video frame rates, and so could display three-dimensional moving characters.

6.13. Image collections

The recent JISC-funded report on *Community-Led Image Collections (CLIC)* has made extensive recommendations aimed at improving the provision of digital image collections for UK higher education institutions.[180] Adoption of its recommendations would make a major contribution to meeting the needs discussed below. Considered in broad terms, these recommendations are very similar to those of the *Gathering Evidence* report, that

> The AHRC may want to consider looking into creating national resources for individual subjects, along the lines of the Archaeology Data Service [i.e. AHDS Archaeology], and to somehow find a way to offer support in their use and in the use of analysis and other tools at a very local level. This could be a central repository or resource at a national level which is drawn down by individual institutions, or a support network of experienced researchers themselves.[181]

For the visual arts, the obvious subject-centre, directly analogous to AHDS Archaeology, is AHDS Visual Arts.

6.13.1. Greater and easier access to high-resolution images (1.14.1) ↔ HP Remote Access Software (2.1.2)

HP Remote Access software enable users with restricted bandwidth to access very large visualisations. Although it is not being marketed as a solution to the dissemination of high-resolution images, the fact that software does not need to be modified to run within the system suggests that it could equally be used as a means of transmitting high-resolution images over narrow bandwidth connections.

6.13.2. Greater and easier access to high-resolution images (1.14.1) ↔ High-resolution imaging (2.3.7)

[180] Miller et al. 2006.
[181] Huxley et al. 2006, p. 17.

First, capture your high-resolution image: access to high-resolution images is impossible until they have been captured. As high-resolution capture becomes easier and more affordable, so greater numbers of images will potentially be available for dissemination to researchers.

6.13.3. *Greater and easier access to high-resolution images (1.14.1) ↔ IIPImage (2.5.1)*

Likewise, IIPImage facilitates the serving of large, high-resolution images over the web: it is currently being used to serve a 10.7 GB image with no discernible difficulty. By using tiled images, it prevents users from downloading entire high-resolution images, thereby helping ease image owners' concerns about potential piracy (see 6.13.4)

6.13.4. *Greater and easier access to high-resolution images (1.14.1): additional recommendations*

Many institutions have already captured images of the objects in their collections at high resolution, but do not automatically make these available to researchers over the web. Concerns over bandwidth may have been an issue in the early days of the web, but are less relevant nowadays, particularly when there are technologies such as IIPImage (6.13.3) which help serve large files over comparatively narrow connections. The main issue seems to lie in a fear that high-resolution images will be pirated, leading to a loss of commercial revenue. The obstacles are, therefore, more to do with cultural and political concerns than they are technological. However, the V&A's recent announcement that it will make high-resolution images available to researchers without charge suggests that these considerations may not be as strong as they once where.[182] The next stage to meeting this need is therefore likely to involve putting pressure on image owners to make existing high-resolution images available to visual arts researchers, and then for these images to disseminated via the internet. Image owners may justifiable wish to restrict access to bona fide researchers; however, the JISC's commitment to a new access management infrastructure for UK higher education should facilitate the implementation of the necessary authentication and authorisation framework.[183] As suggested in the *CLIC* report, metadata harvesting (e.g. use of OAI-PMH, appendix 2.8.2) may be another means of securing institutions' collaboration.[184]

6.13.5. *Access to digital reproductions of a broader range of subjects (1.14.2) ↔ Visualisation, particularly three-dimensional modelling (2.4.4)*

Established visualisation and three-dimensional modelling techniques can be used to make a broader range of image types available – for example, three-dimensional models of buildings or artefacts.

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[182] Bailey 2006.
[183] http://www.jisc.ac.uk/whatwedo/themes/access_management/federation.aspx, consulted 31 January 2007.
[184] Miller et al. 2006, § 5.1.1 on p. 32.

6.13.6. *Access to digital reproductions of a broader range of subjects (1.14.2) ↔ Open Archives Initiative Protocol for Metadata Harvesting (2.8.2)*

It seems clear from the questionnaire that, when asking for a 'broader range' of subjects, visual arts researchers actually mean 'objects that are relevant to my personal research interests, and that I have been unable to find.' Every researcher will have their own interests, met by specific objects which may be of little interest to other researchers. It is only by digitising entire collections of objects that researchers' needs for access to a 'broader range' of subjects are likely to be met. In many case the images are 'unavailable' because they are hidden in the deep web, invisible to the search engine spiders which are still the main route by which researchers find their images.[185] If these images could be exposed for metadata harvesting using a system such as OAI-PMH, then researchers may find rather more images available than they first thought.[186]

6.13.7. *Access to digital reproductions of a broader range of subjects (1.14.2) ↔ e-Chase and OpenMKS (2.9.2)*

The issue here is, in part, that images of a broad range of subjects cannot be found easily from a few sources. OpenMKS provides a framework which can be used to provide a unified interface to multiple, remote collections.

6.13.8. *Access to digital reproductions of a broader range of subjects (1.14.2): additional recommendations*

Here, too, the issues are as much political as technological: digitisation is expensive, and its costs often cannot be met from institutions' core funding. However, there are certain steps which might result in a much broader range of data being made available

- make it a condition of government (rather than AHRC) funding which leads to the creation of a digital resource, that the resource is either deposited with a national data service, or is exposed for metadata harvesting using systems such as OAI-PMH (6.13.6)
- put pressure put on institutions which have received public funding to digitise their objects under programmes such as NOF-Digitise, to expose their collections for metadata harvesting
- make it a condition of research analogue status that institutions expose all their digital collections for metadata harvesting

6.13.9. *More sophisticated metadata for collections of digital objects (1.14.3)*

See also the section on finding images, 6.11.

[185] This is the 'discovery gap' identified by the *CLIC* report: Miller et al. 2006, §2.2 on pp. 12-13.
[186] As proposed in the *CLIC* report: Miller et al. 2006, § 5.1.1 on p. 32.

6.13.10. More sophisticated metadata for collections of digital objects (1.14.3) ↔ CITRIS Gallery Builder (2.1.3)

CITRIS Gallery Builder, by providing a less structured interface to image collections and greater potential for serendipity, may in fact enhance researchers' abilities to search collections of digital objects more effectively.

6.13.11. More sophisticated metadata for collections of digital objects (1.14.3) ↔ PathMarker (2.3.4)

PathMarker can add a level of geographical information to a collection of digital objects, providing another way in which it can be searched.

6.13.12. More sophisticated metadata for collections of digital objects (1.14.3) ↔ Annotation (2.8.1)

By adding annotations to images, researchers effectively increase the detail and extent of the metadata available for searching. In addition, if one knows that a particular researcher has interests similar to one's own, one might search for all objects which they have annotated as a means of finding objects relevant to one's own research.

6.13.13. More sophisticated metadata for collections of digital objects (1.14.3) ↔ Open Archives Initiative Protocol for Metadata Harvesting (2.8.2)

OAI-PMH allows for the unified searching of structured metadata provided by multiple, remote collections, greatly reducing the work involved in searching for objects.

6.13.14. More sophisticated metadata for collections of digital objects (1.14.3) ↔ The semantic web (2.8.3)

The semantic web has great potential for improving researchers' abilities to answer complex, structured questions of digital collections and receive sensible, focussed answers.

6.13.15. The ability to create, use and disseminate personal image collections more easily (1.14.4) ↔ MITH Virtual Lightbox (2.1.5)

The MITH Virtual Lightbox provides ready-built, open source tools for developers to enhance image collections with basic lightbox and manipulation facilities. However, it still requires a fair degree of technical knowledge to install the system.

6.13.16. The ability to create, use and disseminate personal image collections more easily (1.14.4) ↔ PathMarker (2.3.4)

PathMarker is designed to be used in conjunction with a GPS device and a digital camera. If both devices are used simultaneously, PathMarker can automatically combine the data from both into a single file which effectively creates a personal image collection complete with a geographical interface to the collection.

6.13.17. The ability to create, use and disseminate personal image collections more easily (1.14.4) ↔ Existing products

A summary of some existing image management repository software is included in the *CLIC* report, although these tend to be aimed at the large-scale use looking to create a web-based repository.[187] TASI also publish information about a variety of image management systems which may help to meet these needs.[188]

6.14. Access

6.14.1. Access to technical experts and facilities, and an environment for art/science collaboration (1.15.2) ↔ Access Grid (2.1.1)

As a large-scale communication tool, the Access Grid may make it easier for visual arts researchers to access technical knowledge and expertise elsewhere; although this does assume that they already have access to the Access Grid.

[187] Miller et al. 2006, appendix 11.5 on pp. 99-111.
[188] See relevant links on http://www.tasi.ac.uk/advice/delivering/delivering.html, consulted 30 January 2007.

7. Needs which are not yet being addressed

7.1. The relationship between needs and technologies

Figure 40 shows the number of technologies in each of the project's categories, compared to the number of individual needs in each category, this being the figure that gave the best indication of the relative demand for particular needs. This indicates the degree to which there is a mis-match between technologies and needs. Consequently, the mappings produced in section 6, above, do not address all the needs expressed by researchers in the visual arts. The categories with the greatest discrepancies are storage, interfaces, display, collaboration, video and processor power, and it is recommended that further research be directed to technologies that might meet needs in these areas. (Needs related to access and sustainability were always unlikely to be met by technologies, as they relate more to institutional problems.) Whilst collections would seem to be well-served by technologies, the majority of mappings discussed in section 6.13 above offer at best partial solutions, and the position is unlikely to be improved unless political and institutional issues are also addressed (see 6.13.4 and 6.13.8 above).

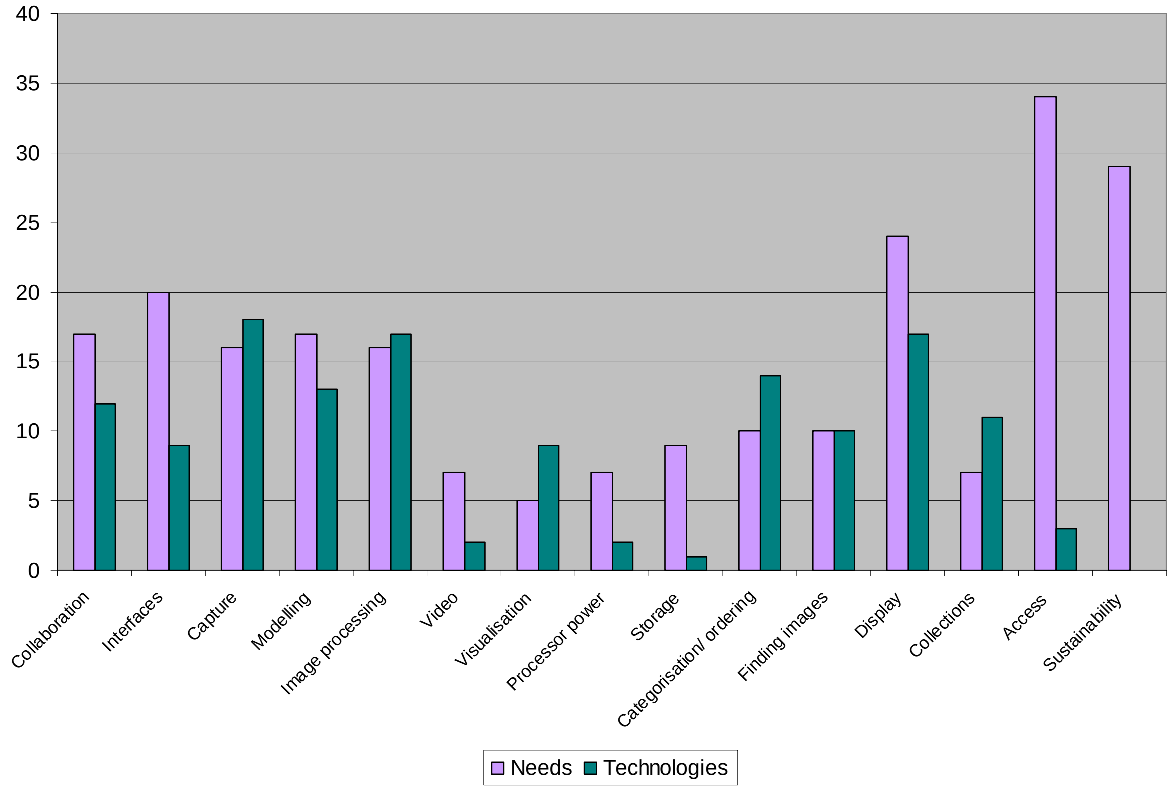

Figure 40. Individual needs and technologies compared, both divided into categories.

7.2. Un-addressed needs

In addition, no truly satisfactory mappings were established for the following technologies.

7.2.1. Collaboration

- An easy-to-use facility for creating image-rich online resources (1.2.2)

7.2.2. Capture

- Frame capture (1.4.3)
- Viewing images on-screen prior to capture (1.1.2)
- Generative media (1.1.5)

7.2.3. Image processing

- Automated optimisation of images (1.6.2)
- Online manipulation and capture of moving images (1.1.6)

7.2.4. Video

- Tools and resources for intensive work with high-definition moving images (1.7.1)

7.2.5. Display

- Output to multiple types of printer (1.13.4)
- Nano-projection onto living tissue (1.1.8)

7.2.6. Access

- Access to facilities for large-scale digital printing (1.13.4)
- Access to technical experts and facilities, and an environment for art/science collaboration (1.15.2)
- Personal access to resources (1.15.3)
- Pervasive network access (1.15.4)

7.2.7. Sustainability

- Training in use of digital images and other digital techniques (1.16.1)
- Assistance in processing and presenting digital images (1.16.2)
- Keeping the infrastructure up-to-date (1.16.3)
- Open content formats (1.16.4)
- Preservation of obsolete technologies (1.16.5)

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Appendices

1. Visual arts researchers' needs

1.1. Specific needs

1.1.1. Interactive interfaces

One practitioner expressed a need for research assistance to support work in custom interactive interfaces. This suggests that work in the field is complex and labour-intensive, and that collaborative work (see 1.2.1) may be the preferred way to address these problems.

49: interfaces, access, sustainability

1.1.2. Viewing images on-screen prior to capture

One researcher identified a need to view images from a digital camera on-screen (i.e. in reasonably high resolution) prior to capture and subsequent processing. This can be translated into a need for new interfaces to digital cameras, but solutions are likely to vary from manufacturer to manufacturer (indeed, higher-end models such as large-format digital backs already offer this facility).

68: interfaces, capture

1.1.3. Gigapixel photography

One researcher expressed a wish to work with 'gigapixel' – i.e. ultra-high resolution photography. (To provide a sense of what this entails: consumer digital cameras are pushing towards 10 Mpixel sensors at the time of writing, with professional large and medium format digital sensors capable of about 40 Mpixels, and the highest resolution commercially available scanning backs capable of about 140 Mpixels). But, as the researcher said, 'Digital technologies provide the boundaries my work aims to push.'

127: capture

1.1.4. Controlling camera movement digitally

One researcher wished to use digital means to control camera movement, presumably using specialist software and hardware not available on the mass market.

79: capture, access, sustainability

1.1.5. Generative media

One researcher expressed a need for research assistance to support work in generative media. This suggests that work in the field is complex and labour-intensive, and that collaborative work (see 1.2.1) may be the preferred way to address these problems.

49: capture, image processing, access

1.1.6. Online manipulation and capture of moving images

One researcher expressed a complex series of needs: 'generate real time, moving, manipulatable images in a web-based environment that can be captured as instances and downloaded at high resolution'. These can be divided into two separate (but inter-related) needs:

1. generating high resolution images in real time in a web-based environment
2. capturing these images as single frames *at high resolution* and downloading them

See also 1.4.3.

86: capture, image processing

1.1.7. Flexible interactive displays

One researcher wishes to make furniture which interacts with its audience. Part of this would entail incorporating displays into the furniture and, given the physical nature of furniture, these displays will need to be flexible in order to accommodate themselves to the furniture's forms. Flexibility will also permit their incorporation into upholstery as well as more rigid components. These displays will also need to be interactive – able to respond to external stimuli.

9: display

1.1.8. Nano-projection onto living tissue

An artist with interests in biological processes and cellular imaging wishes to project forms onto living tissues at microscopic scales.

14: display

1.1.9. Three-dimensional moving typography

This need was received via the survey, with little further explanation.

54: modelling, display

1.2. Collaboration

1.2.1. Space to share and comment upon ideas and work, including large files

The provision of mechanisms to aid collaboration amongst humanities researchers is one of the recommendations of the *Gathering Evidence* report.[189] In the visual arts, several researchers wish to work collaboratively, perhaps sharing ideas and work in progress for others to comment upon, contribute to or reuse, or perhaps in actual performances. Whilst work might be circulated by post or by e-mail, the speed and ease offered by accessing them online have obvious advantages. And in one case, this would be impossible: one researcher wished to engage in interactive video compositing. However, the RePAH report notes that digital technologies have not yet had a substantial impact on the means of scholarly communication within the arts and humanities, and that arrangements for collaborative research and for disseminating research results amongst arts and humanities researchers are personalised, localised and decentralised.[190] Yet the possibilities opened up by extensive collaboration are exciting, and have been described, for example, by Sue Gollifer:

> There are a lot of academics/artists who would like to engage with other people, to find out what's going on, and set up network opportunities. For example we could set up access grids not just as a conferencing facility, but also as an informal open artists' studio/café bar - where people dropped in and saw what artists were creating, and were able to view and find out about ongoing artistic processes as they evolve. There would be opportunities for people to critique the work, to discuss the process of how it was made, how the artists collaborated on it, and how things had developed creatively. For example imagine a three-dimensional object that one could explore, and that other people had access to and could view from multiple vantage points and multiple locations.[191]

In addition, online virtual research environments (VREs) might incorporate various technologies (content management systems, blogs, chat-rooms, e-mail lists, RSS feeds, etc.) which can facilitate the process of communication, collaboration and dissemination.

There is some frustration with the limitations which restricted bandwidth places on the size or resolution of images which can be delivered online, or the time taken to upload and download larger files. High-resolution image files can be very large (hundreds of megabytes), and moving media files, particularly high-definition video, even larger (running well into the tens or even hundreds of gigabytes).[192] Clearly, these cannot easily be disseminated by conventional online means, i.e. the world-wide web and standard network connections. In addition to the needs for straightforward visual-arts related VREs, there is therefore also a need to create and maintain VREs which are able to

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[189] Huxley et al. 2006, pp. 2 & 17.

[190] Brown et al. 2006, §§ 2.3.1 on p. 7 & § 4.2 on p. 24.

[191] Gollifer 2006. And so, too, the RePAH report notes that arts and humanities researchers responded favourably to the possibilities of a personally-managed research environment, particularly favouring workflow management tools and resource discovery tools: Brown et al. 2006, § 2.3.4 on p. 11.

[192] The difficulties of retrieving and downloading very large files were noted as a problem for music and performing arts researchers in the RePAH report (Brown et al. 2006, § 5.3 on p. 33). However, it must be remembered that one by-product of late-20th-century artistic developments and the growing use of ICT by visual artists is that there is often a substantial cross-over between the fields of performing arts and visual arts (and, to a lesser extent, between music and the visual arts).

accommodate very large moving media files, along with ensuring that local institutions have the hardware, bandwidth and expertise to support them.

Such a resource would also help meet the needs of large-scale projects employing research assistants, who need no longer be accommodated close to the principal investigators. It would also be one way of helping extend the use of digital technologies in the publication of visual arts research. Although the RePAH report notes that such technologies have not yet affected the ways in which arts and humanities publication is conceived,[193] it is fair to say that many practice-led researchers maintain web-sites as a means of disseminating their research and practice.

Any such mechanism should also be able to accommodate researchers working with more tactile media, such as textiles (see 1.5.1). This is likely to place rather different demands on the VREs and on possible interfaces to the data, which might incorporate haptic elements.

In all cases, care should be taken to ensure that the system is as easy to use as possible, with users able simply to sign on to the system and begin using it to upload material and begin collaborating. There must be no need for users to download, install and configure software, do any scripting, or use command lines to interact with the system.

2, 10, 26, 34, 49, 66, 67, 70, 71, 73, 74, 76, 129: collaboration, interfaces, modelling, image processing, video, storage, access, sustainability

1.2.2. Ways of collaborating online with limited infrastructures

Researchers also collaborate internationally with their peers, often in countries where the ICT infrastructure – particularly internet bandwidth – is much more limited than in the UK. Whilst the large-scale collaboration mentioned in 1.2.1 is clearly attractive, there is also a need for tools to enable similar collaborations to take place with individuals who have much more restricted resources available to them, with as little loss of functionality as possible. These might take the form of significantly-improved compression algorithms, or novel approaches to how data is actually served.

Such technologies might also, in the short term, help meet the need for spaces to share large files in cases where the local infrastructure lacks sufficient bandwidth to support the full implementations.

26, 66, 76, 89: collaboration, image processing, display, access, sustainability

1.2.3. An easy-to-use facility for creating image-rich online resources

[193] Brown et al. 2006, § 2.3.1 on p. 7.

There are already straightforward systems which enable complex websites to be constructed easily using content management systems. However, they are geared towards the delivery of text pages rather than resources containing high numbers (many thousands) of images. There is a need for a system which combines the ease of use of a content management system with the functionality of an online image database. Such a need might be met within a VRE (see 1.2.1), although there is also a need for such a system to be able to operate outside the restricted environment of a VRE.[194] This need is also related to the need for easy ways to create personal databases of visual material (1.14.4). This need might be addressed as another instance of a need for a task-specific tool (1.3.1).

34: collaboration, interfaces, storage, sustainability

1.3. Interfaces

1.3.1. Task-specific tools

It has become clear that most commercially-produced software has become increasingly complex, demanding and expensive as developers try and incorporate more features into each new release. Such software 'bloat' leads to a need for small, discrete pieces of software focussed on specific tasks. To take just one example: if one wishes to create a stencil for a silkscreen print, one needs simply to convert a tonal image to one or more monochrome images, either in blocks of tone or by screening, and then print them out onto the relevant material. It would be pointless spending several hundred pounds on the latest version of PhotoShop to do just this, and time-consuming and frustrating to find out where the relevant functions are, and how they work, in other large-scale image-manipulation programs (e.g. Corel Paint Shop, the GIMP). However, if a cheap, free or open-source package was available which *only* processed images to create silkscreen stencils, it would be affordable and much easier to master.[195] In part, these concerns are being addressed within the shareware, freeware and open-source communities, although the results are not always as user-friendly as one might wish.[196]

Specific applications for which needs have been expressed are:

- Creating stencils for silkscreen prints
- Automatic preparation of slide shows for prize juries and other assessors – a tool to automatically standardise digital images submitted as portfolios, prize entries etc., recording metadata, anonymising them, and presenting them as a slide show

[194] This need was also suggested by one of the respondents to the AHDS Performing Arts scoping survey, who stated that 'It's not so much collections or materials but the tools to enable integration without having to spend hours. A VLE on speed which assumes multimedia integration from the start would be useful. Also tools which integrate with published DVDs.' Abbott & Beer 2006, appendix 6b, question 10 on p. 88.

[195] Cf. Gollifer 2006: 'We need to develop the opportunity for experimental software to develop artistic outputs created by the use of generic bespoke tools and applications tools. At present the problem with the tools is they are not very intuitive or manageable.'

[196] This need finds an interesting echo in the user feedback on RePAH's mockup research environment, suggesting that these issues affect the arts and humanities community more generally: users 'wanted simple tools that required little or no input of time or personal engagement'. Brown et al. 2006, § 5.4 on p. 35.

- Web authoring
- Creating personal catalogues/databases of images and related material (perhaps in ways comparable to the various research-focussed bibliographic tools currently in use; see 1.2.3 and 1.14.4)
- Image annotation; and reading from, writing to and displaying embedded metadata (1.11.2)
- Creating image-rich online resources (1.2.3) – perhaps based upon a personal catalogue/database, as mentioned above?
- Creating image maps for Virtual Learning Environments (VLEs) and VREs
- Comparing images (see also the need to indicate scale in digital images, 1.11.3)
- Creating games and digital stories
- Facilitating high-quality scanning (see 1.4.7)

One researcher also expressed frustration at the user interfaces currently on offer, complaining that labels, buttons and menus were often tiny and impossible to read (and that instruction manuals were not much better).

Related to all this is the loss of user control associated with bloated software, which tends to automate more and more processes (Microsoft Word's tendency to try and anticipate what the user is doing, and format their text accordingly, is an obvious example of this). For many practitioners, such loss of control is anathema. By producing small-scale, task-specific tools, there is an opportunity to regain control by allowing users greater control over the very restricted set of processes carried out by that tool.

In addition, such task-specific tools would be likely to save money currently spent on expensive software which is only used to a fraction of its full potential.

As well as the obvious benefits of increased creative control and savings in time and money which the wider availability of such task-specific tools would bring, several researchers noted that they would have obvious pedagogic benefits. One potential application which was discussed is the creation of a digital camera with no automatic controls: all variables – 'speed' (sensor sensitivity), exposure time, aperture and focus – would have to be set manually by the user. This would have significant advantages in teaching students how to get the best quality from digital cameras by ensuring that they knew how to use the optimum settings to secure the effects they wished in each exposure. More generally, as the curriculum becomes increasingly technology-based, students tend to focus on acquiring skills in particular software packages, at the expense of an understanding of the processes underlying the actions they are taking, how they work, and what their effects might be. Use of generic tools will shift the emphasis from learning how to use a specific product to reflecting upon the processes that are being used.

1, 21, 22, 38, 41, 42, 51, 95, 109, 115, 124, 134, 139, 140: interfaces, image processing, sustainability

1.3.2. Mixed-reality environments

Although expressed by one researcher in the context of a particular project, this need is clearly transferable to other works. The project involves the development of an interactive work, using a graphics tablet and pen as the interface between viewer and work. As the work involves manipulation of a digitised body and relies for its effect upon the viewer's and body's reactions to this manipulation, the researcher wishes to produce a more immersive and reactive interface to increase the viewer's feeling of involvement with the digitised body. This would probably be based on the viewer's movements, and incorporate sensors to track this; it might also be developed to include some kind of haptic device to further increase the feeling of interaction with an actual body.

More generally, this can be expressed as a need for immersive and haptic interfaces to digital models and environments.

27: interfaces, display

1.3.3. An intuitive haptic interface

Current haptic interfaces are task-focussed, and therefore prescribed by the engineers' perceptions of how they will be used. If work produced using such interfaces is to retain the qualities which result from the application of the manual intelligence which such devices ostensibly exploit, there is a need for more intuitive interfaces that are not prescribed or limited by their designers' preconceptions. In the words of one researcher, 'This would help enable the sensitivity of the jewellery to retain the qualities my "hands", as well as my "eyes" can help me judge.' (See also 1.5.1.)

74, 75: interfaces

1.4. Capture

1.4.1. Seeing below the surface of objects

One of the questions central to historical visual arts research is, 'why does this object look the way it does?' One way of answering this is to investigate the way the object was made – both the materials used, and the ways and sequence in which it was assembled. To do this, it is often a great help to see beneath the object's visible surface. There are many techniques which can aid in this process – x-radiography, for example, has been used in the examination of paintings and other objects for decades. But, save for a couple of well-known examples, such techniques are usually only well-known in the small communities which work on the conservation and scientific examination of art works. In addition, such techniques evolve rapidly (notably in the medical imaging sector), so, unless one spends much time investigating the relevant literature, it is difficult to keep up with new developments. Consequently, many of these techniques are not well known in the broader visual arts community.

161: capture

1.4.2. Capturing quantitative data about objects

Similarly, researchers may also wish to ask precise, quantifiable questions about objects: perhaps their dimensions (external and internal), or the precise substances of which they are made up. As with seeing below objects' surfaces (1.4.1), techniques for answering these questions are usually only well-known in the conservation and scientific examination communities; and they, too, evolve rapidly, making it difficult to keep up with new developments. Consequently, many of these techniques are not well known in the broader visual arts community.

162: capture

1.4.3. Frame capture

Because of the ways in which digitally-distributed video is encoded and compressed – particularly for online, streamed delivery – it is not always easy to capture an individual 'frame' easily or accurately: in fact, there may be no such thing as a single 'frame' which contains a complete, frozen still image. Practice-led or historical researchers may wish to capture complete 'frames' for a number of reasons. See also 1.1.6.

86, 87: capture

1.4.4. Capturing process

Although not mentioned in any interviews or questionnaire responses, the definition of practice-led research adopted by the AHRC (see the discussion in 3.3.3 above) raises the question of how a practice-led research process might be captured. In part, the documentation of work-in-progress might be related to the issue of commenting upon ideas and work, discussed in 1.2.1; but the problem is broader. In the current funding system, research is characterised by the processes with which it is carried out, and means of capturing as many aspects of these processes as possible can only help in the assessment and dissemination of the research. Yet such 'manual' or 'visual' research is seldom easily expressed in words, let alone captured verbally as it occurs. Thus, the summary of the recent e-Science scoping seminar for the visual arts expressed a desire for

> the setting up of archival curatorial places, where there is an engagement with the artist, the research practitioner, and the technologist, allowing the artistic creation to be captured and archived and presented as part of ongoing process of research.[197]

Solutions developed for this need may well have applications elsewhere: the recent AHDS Performing Arts scoping study noted that

[197] Gollifer 2006.

> Respondents working mainly in theatre and in multiple subject areas seem to consider digital evidence of the process of performance creation to be at least as important as the finished product itself. This conclusion was also substantiated during many of the interviews.[198]

and

> Practice-led research is 'not just about outcomes. Knowledge is in the process – this informs the way it should be documented.' … It is the creative process that is central to Performing Arts investigations, and documenting this creative process is critical to a full understanding of the work being carried out in both practice and academia. [199]

160: capture

1.4.5. Capturing images in low light

Many works of art are displayed in areas with very low light – either for conservation reasons, or because they are housed in buildings which were not constructed with researchers' desires to examine objects in bright, even light in mind: churches are an obvious example. Similarly, the institutions which own such objects often prohibit the use of tripods and other supports when taking photographs. Whilst the ideal image will always be taken by a skilled photographer who has negotiated the use of lights, tripods, etc., in many cases researchers need to take informal images as aides-memoires for their research. To do this in these conditions, they need access to cameras which can capture images at fast shutter speeds (usually 1/60 of a second or higher with a standard lens) in very low light; in many circumstances, this would equate to an ISO film rating of 1600/33°, 3200/36°, or even higher. Conventional films of this speed were excessively grainy and contrasty; digital sensors working at these kinds of sensitivity are currently prone to unacceptable levels of noise.

120: capture

1.4.6. Mapping time

Although a rather vague questionnaire response – simply reading 'mapping time' and 'tracking timeframes?' – this need may relate to researchers' interests in the nature of time and ways in which it can be investigated and characterised visually.

64: capture

1.4.7. Tools for high-quality scanning of digital images

This need can be expressed in two parts. First is a basic infrastructural problem: as scanning technology improves at much the same rate as other IC technologies, so equipment rapidly becomes obsolete, with significantly better results (in terms of resolution, bit-depth, accuracy of rendition, speed of capture, etc.) obtainable from newer

[198] Abbott & Beer 2006, § 4.1 on p. 32.
[199] Abbott & Beer 2006, § 4.3 on p. 34.

equipment. Many institutions have trouble keeping their equipment in pace with these developments, and practitioners are frustrated at having to make do with what they perceive as second-best. (Similarly, much as institutional purchases of projectors tend to concentrate on basic office presentation machines – see 1.13.1 – so scanners, unless purchased directly by practitioners or technicians, may simply be basic office machines, rather than professional-quality image scanners.)

Second, and related, is a need for the development of professional-quality scanners which can be manufactured at lower prices; this will help meet the first part of this need. Whilst there are techniques such as colour management which help to minimise the loss of quality as analogue original are scanned, these remain complex and expensive to implement; task specific interfaces (1.3.1) which ease their implementation would help improve high-quality capture. Alternatively, steps need to be taken to ensure that suitable scanners – and the expertise necessary to run them to at the highest quality – are easily and affordably available to researchers as required.

32, 59, 105, 117, 137: capture, access, sustainability

1.4.8. New microscopic techniques, including micro-cinematography and animated cell imaging

The perennial interest among certain sectors of artistic practice (particularly those involved in art-science crossovers) in new forms of scientific imaging suggests that this need may be of widespread interest. As microscopy has developed – from straightforward optical to confocal and multi-photon techniques – so possible magnifications and the forms of processes that can be imaged have increased. There is a need for practitioners to be kept informed of these developments, and to have access to the relevant equipment if desired (see 1.15.2).

Focussing on biological applications of microscopy, confocal and multi-photon techniques have developed to such an extent that they can now be used to produce real-time images of some of the many fundamental biological processes that take place at the sub-cellular level, and there is a desire to exploit new microscopic techniques to record images of these processes as they happen. Although expressed by a single researcher, this need is clearly applicable to any practitioner with interests in the body and biological systems.

12, 13, 23: capture

1.4.9. Faster three-dimensional capture

Current techniques for capturing three-dimensional data about objects (see 2.3.5) are highly effective, but expensive, and the post-processing of the point cloud data which they capture can be time-consuming and place heavy demands on processor power. There is therefore a demand for technologies which can speed up this process.

130: capture

1.5. Modelling

1.5.1. Three-dimensional modelling

There is a general need to create manipulable three-dimensional models for a variety of purposes, including initial research through their manipulation, incorporation into research outputs and other works, and presentation and discussion of research and outputs. Depending upon individual researchers' needs, the models may need to be programmable and interactive. There will also be a need for tools with which to create these models, either by drawing on screen or from existing images.

These needs have been expressed with regard to three projects:

1. The development of a work based upon a series of video clips of a body, rendered interactive using the signal-processing software Max/MSP, extended with Jitter to handle video. However, the reliance on video clips renders the resulting image comparatively low-resolution, and its movements jerky; it also restricts the enhancement of the work with technologies such as three-dimensional display and/or projection or haptic interfaces. If, instead of being videoed, the body was rendered as a moveable three-dimensional model, it could still be programmed to react to viewers' stimuli, but with the potential for a higher-resolution, smoother image and the option to extend the work by supplying additional data with the model (e.g. depth or consistency information).
2. A research project on wearable light features, which would use digital models to simulate the fall of light on the human body in relation to various miniature and small-scale light sources positioned in relationship to the body. This would facilitate the modelling and experimentation stage of the project.
3. The development of ceramic pieces through the investigation of the relationship between the interior and exterior forms of vessels; and the manipulation of three-dimensional models as an aid to the generation of new forms, similar to the use of a sketchbook. The researcher in question would also be interested in using three-dimensional models of her work when presenting and discussing it, and as a teaching aid.

29, 52, 62, 73, 74, 80, 83: capture, modelling

1.5.2. Modelling unconventional forms of vision

An additional form of modelling required is the ability to mimic unconventional forms of vision. In such cases, the act of specifying the relevant model is likely to form part of the research process.

This need has been expressed with respect to two specific projects:

1. Simulating the act of looking through old (i.e. 18th-20th-century) optical microscopes, with their various aberrations and limitations, as part of a project related to microscopy and its history.
2. Mimicking an animal's perception, once the components and form of the relevant animal's vision had been characterised.

24, 82: modelling, visualisation

1.5.3. Modelling non-visual and complex visual properties

Whilst non-tactile objects such as paintings or drawings can be digitised without an excessive loss of detail, it is incredibly difficult to produce an adequate digital reproduction of tactile objects such as textiles: as all but the basic visual information is discarded, too much information is lost, for example aspects such as feel, texture, weight, drape, movement, reflectance and transmissiveness, and surface and non-surface. In order to allow artists working in non-visual media to collaborate, and to facilitate the discussion and study of such works without having direct access to the originals, there is a need for modelling techniques which can capture non-visual or complex visual properties.

Similarly, researchers working with virtual environments and models which incorporate haptic interfaces face the problem of the lack of accepted conceptual models with which to characterise the haptic aspects of their models (see also 1.3.3.). In order to develop effective models, one must know how to characterise them. This is an area where practice-led researchers will also be able to help scientists: they are equipped with the conceptual frameworks and vocabularies to differentiate and characterise the properties which will need to be modelled. Significantly, modelling of textiles is also an area of great importance to games developers, and one of the significant challenges facing the development of games engines.

25, 44, 45: interfaces, modelling

1.5.4. Scalable or animated methods of recording work

Current methods of recording and disseminating research outputs which take the form of installation work rely upon still images or video. The former have the disadvantage of only being able to capture single views of the work, which relies for its impact upon qualities of space and movement. The latter is highly demanding of processor power, storage and bandwidth, and can often only be disseminated at low quality.

This need was explained by an artist whose work takes the form of 'small (even tiny) scale drawings and sculptures, installed quirkily in large architectural spaces'. Using photography is unsatisfactory: 'installation views typically show a blank wall with a few specks on it, detail views show a "pretty" image with no sense that this isn't simply a luxury object'. Likewise, when using video or animation, 'I find the quality limitations of making a file portable enough outweigh the advantages'.

There is therefore a need for high resolution three-dimensional digital capture and modelling of installations, ideally combined with techniques for generating compact forms of output (see 1.2.2).

77: capture, modelling, display

1.6. Image processing

1.6.1. Direct output to industrial tools

Practice-led researchers have expressed wishes to:

- automate the cutting of MDF forms directly from digital files, saving the time and effort required to produce intermediate templates and, if using water-cutting tools, also leading to fewer health and safety problems caused by dust, etc.
- use laser cutting and other, similar industrial techniques

These can be expanded into a more general need for direct output from digital files, of the types usually used by artists and practitioners, to industrial equipment: a specific subset of the larger need for greater interoperability between file types (1.6.5).

53, 148: capture, modelling, image processing, display

1.6.2. Automated optimisation of images

Many researchers wish to digitise personal collections of images, or wish to see their institution's collections digitised. But this can be extremely time-consuming (see 1.16.2), particularly if the images require any form of optimisation, e.g. as a result of problems with either capture, or the originals themselves (such as faded or dirty slides). There is therefore a need for automating the process of regaining the original quality of problematic digitised images without having to spend time optimising each individual image.

56: image processing

1.6.3. Automated image analysis

There are many ways in which researchers' work could be made much easier by the automated analysis of images. Those working on renaissance and baroque art, for example, might wish to check the coherence of an image's perspective construction, or identify the optimum viewing point for an illusionistic ceiling painting; whilst students of architecture might wish to produce real-world measurements from scale drawings and compare them to the building as built, or produce three-dimensional models from drawings. Others might wish to isolate certain features – areas of one particular colour; or particular motifs. The list could be extended more or less ad infinitum, but in all cases, they translate into the need for automated analysis of images, so that the computer carries out the donkey work.

163: image processing, categorisation/ordering

1.6.4. Automated incorporation of digital images into databases

Just as acquiring, optimising and re-purposing digital images can be time-consuming (see 1.16.2 and 1.6.2), so too is the process of loading images and their accompanying metadata into databases such as library OPACs. There is a need for assistance in developing automatic solutions for uploading images and metadata into different cataloguing, storage and delivery systems.

57: image processing, categorisation/ordering, finding images

1.6.5. Greater interoperability between file types

A perennial problem of work using ICT in any field is the proliferation of incompatible (or, even worse, semi-compatible) file types. This is especially true of visual arts research, particularly when it extends into three-dimensional and time-based media. Particular issues which have emerged in the course of the project are:

- direct output to industrial tools (1.6.1)
- preparing files for a range of digital printing devices (this would include mappings between different colour spaces, both the perennial RGB → CMYK issue, but also more esoteric colour spaces)
- colour management more generally
- converting straightforward images to image maps
- combining multimedia files and geographic data (i.e. GPS data, GIS files)
- using images, and – a particular problem – multimedia files in Microsoft PowerPoint
- maintaining image resolution between programs and devices

53, 88, 96, 97, 108, 112, 137, 147, 156: image processing

1.7. Video

Issues relating to audio-visual material were the focus of a recent AHRC Strategy report, focussing on ICT tools for the searching, annotation and analysis of audio-visual media.[200]

[200] Marsden et al. 2006.

1.7.1. Tools and resources for intensive work with high-definition moving images

Researchers are increasingly attracted by the possibilities offered by high-definition digital video formats. As standards evolve, so do the tools with which to work with the relevant files. Researchers wish access to the tools required to work with full-colour, uncompressed, high-definition video – i.e. to capture, edit, share, disseminate and archive it – and the necessary re-training to ensure that researchers are not continuously running to keep up with new technologies.[201] The demands placed by audio-visual material more generally upon institutional infrastructures are highlighted in the AHRC Strategy report on audio-visual media.[202]

2, 61, 69, 71, 78: capture, video, processor power, storage

1.8. Visualisation

1.8.1. Tools for mapping relationships

As with many humanities subjects, much visual arts research lies in investigating the relationships between different entities: objects, people, places, events, concepts, etc. When investigating more than a small number of entities, it rapidly becomes difficult to identify patterns in the relationships and maintain a coherent overview. Better tools for the mapping and visualisation of relationships would help meet the need for assistance in this area.

132: visualisation

1.9. Processor power

1.9.1. Processing power and exploiting existing resources

The digital processing of images makes intensive demands on processor power and memory; these demands are significantly increased when dealing with large quantities of time-based media, or the modelling and rendering processes required in the fields of modelling, visualisation and animation. Whilst such power can be purchased from commercial rendering farms, or the new commercial Sun Grid service,[203] these are not necessarily cheap for intensive jobs. There is therefore a need for access to intensive computing power to run specific jobs.

This might be facilitated locally by exploiting existing resources (e.g. the computers in IT resource centres or libraries, or even individual office desktops) to run as individual units

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[201] The RePAH report also noted that performing arts and music researchers had difficulty in obtaining the software needed to manipulate and consult very large files (Brown et al. 2006, § 5.3 on p. 33). As noted above, however, there is often a cross-over between the fields of performing arts, music and the visual arts.

[202] Marsden et al. 2006, §§ 1.3.1-2 on pp. 9-10.

[203] http://www.sun.com/service/sungrid/overview.jsp, consulted 27 July 2007.

in a clustered or distributed computing network when not being used for their primary tasks (e.g. overnight or in vacations).

5, 36, 61, 66, 71: collaboration, processor power, storage, sustainability

1.10. Storage

1.10.1. Bulk storage

As noted in 1.2.1, image and multimedia files are becoming increasingly large, whilst significant digitisation projects can lead to tens or hundreds of thousands of digital images being created. Individual requirements for terabytes of storage are no longer unusual; it will not be long until petabytes are required. Whilst there are a growing number of hardware solutions for storage on this scale, they need to be properly set up and managed if they are to provide ease of use, high speed reading and writing, and reliability. Anything beyond the most basic solution remains complex and expensive. Consequently, there is a need for large-scale, easy to use, high speed, reliable storage, perhaps requiring access to intensive processing to speed up access. The authors of the *Gathering Evidence* report also note that 'space for [images'] storage appear[s] problematic in responses to several sections of the survey', and they recommend that methods for addressing this need be investigated, focussing on 'national or regional consortia or services'.[204]

This need might be addressed in combination with that for visual arts VREs equipped to deal with large files (see 1.2.1).

7, 66, 71, 138: collaboration, processor power, storage, access

1.11. Categorisation/ordering

1.11.1. Archiving and indexing across multiple removable media

As storage technologies have developed piecemeal, and computers have been provided with a changing range of external storage devices, so researchers' digital images are often found randomly scattered across a series of CDs, DVDs or external hard drives. The quality of the labelling varies. Whilst such ad hoc storage may meet the immediate goal of preserving images in the short term, it is very difficult to find particular images quickly or easily. There is therefore a need for a simple system which can produce a unified index to images stored on a series of removable media; it would be more useful if such a system could extract the image files and accompanying metadata and unify them onto a single (backed-up) device, effectively combining hardware and indexing. Such a system is likely to call upon the technologies developed for bulk storage (see 1.10.1), including online storage and perhaps VREs.

[204] Huxley et al. 2006, pp. 8 & 17.

35: storage, categorisation/ordering, finding images

1.11.2. Annotation of images

Visual arts researchers' source material are very often images; but it is very difficult to add notes to a digital image in the same way that one could add notes to a printed or digital text. Many researchers wish to be able to attach textual notes to images, and to specific parts of images. The notes may take the form of extended metadata; or they may be more discursive and interpretative. Whilst this may seem comparatively simple, researchers would also like to be able to do this with images that are stored remotely (e.g. available on the web); and to be able to share their annotations with other researchers.

Whilst there are facilities for inserting metadata tags into the header area of many image file formats, these often restrict the information that can be added. However, when it is present (and in the field of visual arts images, this is the case much less often than is desirable), it is often useful to have such embedded metadata displayed alongside the image, and to be able to run searches on the embedded metadata of a range of images at once. Whilst there are systems that can do this, they tend to be expensive, or to restrict the data elements that can be exploited. This need is another specific aspect of the broader need for task-specific tools (1.3.1)

95, 131: collaboration, categorisation/ordering

1.11.3. Indicating scale in digital images

One of the great problems of carrying out visual arts research from reproductions is the loss of any sense of the relative scale of the original objects. Although an original's dimensions could be stored as part of the image's metadata, there is no way, short of manual calculation and re-scaling of the image, to use this information to compare images at their relative sizes. This makes tasks as simple as the preparation of PowerPoint slides for the presentation of research incredibly time-consuming.

It is worth noting that there are one or two ad hoc solutions to this problem, notably Prof. Tim Benton's tool for the re-scaling of digitised architectural drawings;[205] but as he would be the first to point out, the system, developed in VBA v. 4, has been overtaken by developments in programming languages which are rendering it increasingly difficult to install and use.

103, 157: categorisation/ordering

[205] Benton 2000.

1.11.4. New paradigms for organising archives

As researchers store more and more visual material in electronic form, the shortcomings of current digital archiving systems will become more and more apparent. These are organised using text-based paradigms; yet it is in the nature of many practice-led researchers that they think visually, rather than verbally, and would find archiving systems organised using visual paradigms easier to navigate. Similarly, much practice-led research produces outputs that are resistant to presentation in conventional written forms, but are much more suited to techniques such as video or multimedia presentation. There is therefore a need for archiving systems or interfaces to be organised using visual, rather than verbal, paradigms – perhaps in a manner similar to the classical 'art of memory', based upon an architectural metaphor; and for such archives to focus more upon visual, time-based and multimedia resources than upon textual ones.

43, 85: interfaces, visualisation, storage, categorisation/ordering, finding images

1.11.5. New forms of non-linear interface to websites

The principles of 'good' website design emphasise a clear structure to the site and largely linear navigation paths based on a 'drilling-down' metaphor. This conflicts with the non-linear ways of working and conceptual models espoused by many practice-led researchers, which are also characteristic of the richness and complexity of data based upon real life, whether current or historical. However, the hypertext model on which websites are based is inherently non-linear, and this aspect could be exploited to meet the need for non-linear navigational systems through websites.

48: interfaces, categorisation/ordering, finding images

1.12. Finding images

As noted by the *Digital Picture* report, finding suitable images is a major issue for those working in the visual arts, with 91% of respondents to their consultation agreeing that finding images should be straightforward.[206] The *Gathering Evidence* report also notes that humanities researchers generally expressed a need for more sophisticated search tools.[207] More specifically, the problems experienced by arts and humanities researchers when seeking relevant audio-visual material amongst the burgeoning quantity of available data is highlighted in the recent AHRC Strategy report on audio-visual media.[208]

1.12.1. Finding images across multiple collections

[206] AHDS Visual Arts 2005, § 4.2.4 on p. 18 & § 4.2.6 on p. 22.
[207] Huxley et al. 2006, pp. 14-15, including table P.
[208] Marsden et al. 2006, p. ii & §1.2.2 on pp. 4-5.

Researchers frequently need access to images as source material, but continue to be frustrated with the process of finding digital images suitable for re-use. Whilst Google is the central means of finding digital information amongst visual arts researchers,[209] it does not always drill down into the databases which serve many image collections dynamically, effectively rendering them invisible to Google users. This has been termed the 'discovery gap' in the recent *CLIC* report.[210] The alternative, searching across each individual collection in turn, is time-consuming and already relies on prior knowledge of where an image may be found; once an image has been found, rights restrictions may prevent its re-use.[211] Thus, the *Gathering Evidence* report notes that images, in particular, are subject to complex and expensive copyright problems.[212] In fact, 38% of all humanities researchers pointed out that licensing and rights issues caused them problems.[213] The problem was expressed with particular strength by two of the visual arts researchers in their case studies, both assembling research databases which include images. According to the report:

> Regulations are described as 'prohibitive' and decision-makers as being far removed from the research. Just one image of a painting by Dalí important to the research has a re-use cost of £500 (Visual arts and Media). Another case study respondent adds: 'Images are becoming very expensive. Everyone wants to make money. It can be £60-£100 for one image where we would have paid nothing at all [in the past]. So some important collections may not be in the final database' (History of Art).[214]

The *Digital Picture* survey, too, noted strong concerns in the visual arts community regarding copyright.[215]

The fragmented nature of current visual arts image provision, and the need for users to find images across multiple collections, was also expressed strongly by participants in the *Digital Picture* consultation.[216] The ability to enable federated searching across collections was one of the main requirements which creators of community image collections had of image cataloguing software, according to the *CLIC* report.[217]

More intelligent ways of searching for images across multiple collections are a significant need, which might be met by combinations of content-based image retrieval (see 1.12.2) and semantic web (2.8.3) or data-mining technologies, perhaps exploiting the processing power of grid- or cluster-based systems (see 1.8.1) for the intensive processing required to carry out such work on-the-fly. As noted by the RePAH report, arts and humanities researchers generally prefer to deal with particulars, qualities and complication.[218] Such sophisticated searching techniques may help to break down the difficulties caused for these researchers by categorised, pre-structured information.

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209 Brown et al. 2006, § 5.3 on pp. 32-3.
210 Miller et al. 2006, §2.2 on pp. 12-13.
211 These problems of lack of sophistication in internet search engines, and of difficulties in accessing digital image collections and enabling them to interoperate, were also noted as a problem specific to visual arts researchers in the RePAH report: Brown et al. 2006, § 2.3.2 on p. 9 & § 5.3 on pp. 32-3.
212 Huxley et al. 2006, p. 2.
213 Huxley et al. 2006, p. 8 & table D.
214 Huxley et al. 2006, p. 8, referring to the case studies on pp. E: 1 & E: 5; see also that on p. E: 7.
215 AHDS Visual Arts 2005, § 4.2.7 on p. 24.
216 AHDS Visual Arts 2005, § 2.1.2 on p. 5, § 4.2.4 on pp. 18-19, § 4.2.6 on pp. 22-3, § 4.2.9 on pp. 29-30 & § 5.1 on p. 40.
217 Miller et al. 2006, § 7.3 on pp. 39-40.
218 Brown et al. 2006, § 4.2 on p. 25.

50, 65, 100, 112: categorisation/ordering, finding images, sustainability

1.12.2. More sophisticated content-based image retrieval

It is becoming increasingly apparent that searching for images using text-based methods is problematic, calling as it does for the categorisation of non-verbal objects in verbal terms. In addition, search criteria may be vague: one researcher expressed a need to find 'cutting-edge images' on the web, and it seems highly unlikely that existing verbal metadata strategies could adequately label images in this way. There is therefore a need for more extensive use of content-based image retrieval (i.e. image-matching) to retrieve, for example, images of work that has been produced by unknown artists, where the verbal descriptions are inadequate (e.g. 'abstract'), and using more subtle factors beyond the common and relatively simple ones of colour and shape. This need has been expressed as a way of enhancing access to a collection of around 100,000 digitized slides; as a need to search on criteria such as colour and format; and to search simply on non-verbal content. Clearly, meeting this need has broad potential, particularly when combined with technologies for searching across multiple collections (see 1.12.1).

55, 98, 118: image processing, categorisation/ordering, finding images

1.13. Display

1.13.1. High-quality presentation of digital images

The great majority of data projectors installed in art education establishments are standard office machines, intended for projecting PowerPoint displays and other basic presentations. They are the digital equipment of overhead projectors, and still do not offer the resolution, contrast, and colour fidelity of a well-made 35mm slide. Those working in the visual arts are concerned with the subtleties of visual appearance, and the ability to reproduce this accurately when evaluating or disseminating works of art is highly important to them, yet the institutions in which they work seem to have ignored these requirements in the rush to digitise their teaching spaces as cheaply as possible.

There are, of course, technological reasons for this. Current displays suffer from three main drawbacks, preventing the most accurate possible reproduction of images:

1. dynamic range: the dynamic range available from monitors and, particularly, projectors is much lower than either the recording capabilities of more sophisticated scanners and cameras, or the dynamic range encountered in everyday scenes as they are observed by the naked eye.
2. resolution: whilst the resolution of monitors and projectors grows continuously, the majority of projectors, in particular, are still of comparatively low resolution, resulting in pixellated images which are poor representations of the original subject or of the digital image: they are unable to display an entire image whilst retaining the detail which can be captured at everyday resolutions. For example, 8 Mpixel cameras are not

uncommon; the highest-resolution projectors in everyday use are of XGA (1024 x 768 = 0.79 Mpixels) resolution.
3. lack of calibration: devices and software have existed for some time which can profile the colour and contrast characteristics of individual monitors, and calibrate them so that images can be displayed as accurately as possible. Despite this, outside the fields of photography and print, few researchers seem to calibrate their monitors in this way, and fewer institutions make it their policy to ensure that their staff's monitors are correctly calibrated. For projectors, the state of affairs is even worse: they are often used in rooms where ambient lighting significantly reduces the image contrast, and until recently devices to calibrate digital projectors have been hard to come by.

There is consequently a strong need for high-resolution data projectors to be installed – carefully – in arts establishments, and for them to be calibrated so that they can reproduce image files as accurately as possible. Related to this is the need to ensure that all practitioners working in arts research establishments have access to calibrated monitors.

18, 46, 49, 70, 92, 105, 135, 156: video, display, access, sustainability

1.13.2. Projection onto evanescent surfaces

Again expressed by a single researcher but clearly extendable to other works, this need is for a less obviously computer-mediated form of large-scale display than a standard front- or rear-projection screen. It was suggested that projecting onto smoke or water would remove the obvious physical surface of the screen, and therefore increase the suspension of awareness that one was viewing a digitally-mediated image.

28, 70: display

1.13.3. More sophisticated presentation software

The vast majority of arts education institutions rely upon the Microsoft Office suite of software for their day-to-day needs, including PowerPoint for digital presentations. However, this has notable restrictions on the multimedia file formats which can easily be incorporated into presentations (for example, support for the widely-used QuickTime file format is very limited). There is a definite need for a more versatile piece of software which would allow the incorporation of common (and ideally more esoteric) multimedia formats into presentations.

47, 70, 116, 135, 136: interfaces, display

1.13.4. Output to multiple types of printer

Different printing devices, particularly higher-quality and more esoteric devices which produce particular effects, require image files to be optimised in different ways. Such optimisation is a highly skilled task. Consequently, there is a need for much easier conversion between the relevant file formats forms of optimisation. (See also the more general need for interoperability, 1.6.5.)

88: image processing, display

1.14. Image collections

Image collections are a significant need for visual arts researchers, for whom images are the source material with which they work. The *Digital Picture* report notes that 53% of respondents felt that 'existing online image resources are not sufficient for my research', whilst only 17% disagreed.[219] It should be noted that issues surrounding the provision of image collections for use in UK higher education institutions are discussed at length in the JISC-funded report on *Community-Led Image Collections* (*CLIC*).[220]

1.14.1. Greater and easier access to high-resolution images

Visual arts researchers concentrate upon the subtleties of the images they work on. The average web-delivered digital image is of comparatively low resolution – usually a maximum of 600 pixels wide – and is useless for any kind of detailed, nuanced analysis.[221] The *Digital Picture* report notes that useful image resolution varies according to the use that will be made of the particular image – but also notes that low resolution is a problem with many of the image currently provided to visual arts researchers.[222] When institutions make high-resolution images available, they are often too expensive for researchers to be able to afford access to more than one or two at a time: prices are usually at least four or five times more expensive than the old charge for a good 10x8" photographic print. Consequently, many researchers expressed a need for much more widespread access to high resolution images – and, for those who use time-based resources, to high definition video files. Whilst this need is simply expressed, its importance cannot be under-emphasised.

92, 105, 110, 114, 150, 159: image collections, access

1.14.2. Access to digital reproductions of a broader range of subjects

Although 55% of the digital image collections surveyed in the *CLIC* report covered visual arts, music and cinema, and 37% covered architecture, building and planning,[223] this need

[219] AHDS Visual Arts 2005, § 4.2.9 on p. 29.
[220] Miller et al. 2006.
[221] For a discussion of the resolution at which museums usually deliver their images, see Miller et al. 2006, appendix 11.9 on pp. 128-9.
[222] AHDS Visual Arts 2005, § 4.2.2 on pp. 14-15.
[223] Miller et al. 2006, § 3.1.2 on pp. 22-3.

was still expressed by several researchers in their responses to the current project's survey. This may be because visual arts researchers are like all researchers, in that their interests are often focussed on very recondite areas. The institutions that make digital images available, on the other hand, are under pressure to maximise access to and use of their resources as efficiently as possible, and so tend to focus on only the most popular images in their collections. Consequently, the great majority of digitisation projects are comparatively selective and superficial, whilst the only way to seriously attempt to meet researchers' needs would be for comprehensive programmes aiming to digitise *all* works in particular collections. Many of the respondents to the project questionnaire expressed frustration at the range (and standard – see 1.14.1) of images provided by the institutions that own them. It should be noted that there are very few projects in the visual arts which aim to make comprehensive corpora available in the way that Early English Books Online (EEBO) and Eighteenth-Century Collections Online (ECCO) have done. As the recent LAIRAH report noted of humanities resources generally, 'projects which collect together large collections of information resources for reference, whether generic or subject based are likely to be well used.'[224]

It is clear from the *Gathering Evidence* report that visual arts researchers are not alone in needing digital access to the subjects of their research: the report continually stresses humanities researchers' desire for more extensive digitisation of primary sources.[225] More than two-thirds of researchers expressed a preference for investment to be directed towards the digitisation of primary resources, rather than on the development of tools for search, retrieval and access.[226] Similarly, digitisation and access to more primary material was the leading area in humanities researcher's ICT 'wish-list', outnumbering the next most popular item by a factor of well over two. Allied to this (fourth on the wish-list) was a desire for easier and cheaper access to digital resources.[227] (Access to images is one of the issues that the *Gathering Evidence* authors suggest might be addressed through 'national or regional consortia or services'.[228])

Current digital image collections also tend to be limited in the ways they document three-dimensional works – perhaps including two or three static views (if one is lucky) – and in the evidence they provide of objects' physical contexts: a need has been expressed for a broader range of ways of illustrating objects within digital collections (perhaps videos or three-dimensional images), and for broader views of the objects in their settings. [229]

As an illustration, specific needs mentioned during the course of this project were for broader representations of images focussing on:

- Type
  - Architecture
  - Topographical material (maps, photographs)
  - Mediaeval manuscripts

[224] Warwick et al. 2006, § 6.3 on p. 33.
[225] Huxley et al. 2006, p. 2.
[226] Huxley et al. 2006, p. 13.
[227] Huxley et al. 2006, pp. 2 & 14-15, including table P.
[228] Huxley et al. 2006, p. 17.
[229] The need for, and issues surrounding, digitisation of audio-visual material are discussed in Marsden et al. 2006, § 2.1 on pp. 12-13 & § 2.3 on pp. 14-17.

    - Art and design
    - Current exhibitions
- Geography
    - Oceania
- Period
    - Pre-history
    - Contemporary
- Film and video clips (and stills)
    - Historic television
    - Public rituals
- Different views
    - Videos of static / immobile objects
    - Three-dimensional
    - CAD/VR flythroughs

But these are only a tiny fragment of all the interests of the visual arts research community, included here as an indication of the breadth of the problem, rather than a set of recommendations for content creation.

There is also a need for more extensive provision of images cleared for research (and educational) re-use, whilst clearer labelling of rights information would also be helpful.

94, 99, 104, 106, 107, 110, 111, 113, 123, 126, 134, 136, 144, 149, 152, 155, 158: image collections, access

1.14.3. More sophisticated metadata for collections of digital objects

Researchers' frustrations at restricted ways of finding images (see 1.12 above) also apply to the ways in which collections make their images available. Concerns have been expressed about the limitations of current metadata standards, which, for example, seldom include objects' cultural contexts. Thus, whilst more sophisticated searching of digital images is one need which focuses on the user's capabilities, more sophisticated metadata is another, which is more the responsibility of collection creators.

98, 152: finding images, collections

1.14.4. The ability to create, use and disseminate personal image collections more easily

Barriers to creating image collections are discussed in the *CLIC* report, which describes lack of time and funding as major problems, closely followed by lack of technical knowledge.[230] Very few systems make it easy for researchers to construct personal research databases of digital images. The majority of packages are aimed at photographers who wish to create digital albums and websites of their images, and so place little

[230] Miller et al. 2006, § 3.1 on pp. 19-20.

emphasis on the kinds of information (media and dimensions of original object, for example) which are vital to visual arts researchers. Such a need is part of the more general need for task-specific tools (1.3.1). Similar needs, regarding audio-visual materials, were identified by the recent AHRC Strategy report on audio-visual media.[231]

Researchers would also like to share their databases with other researchers (see 1.2.3) – although this is likely to prove problematic due to copyright restrictions.

95, 109, 115, 124, 133: collaboration, interfaces, categorisation/ordering, collections

1.15. Access

1.15.1. Access to facilities for large-scale digital printing

Fine art digital printing technologies (e.g. giclée, gouttelette) have several benefits over analogue ones, notably in the ease with which they may incorporate digitally-processed imagery and their ability to ensure highly-consistent output in terms of colour rendition, contrast etc. However, such systems can be expensive, particularly when considering large-scale output (e.g., A0 and above), and require skilled operators to ensure the best results. Consequently, there is a need for easier and more affordable access to large-scale fine art digital printing equipment and expertise. Practitioners are still concerned about the long-term stability of the materials used in fine art digital printing.

37, 58, 63, 70, 90, 153, 154: display, access, sustainability

1.15.2. Access to technical experts and facilities, and an environment for art/science collaboration

This need was first expressed by a researcher with a specific interest in discussing ageing, decay, eye disease, liver and pancreatic function with clinicians. In the course of this project, however, it has become clear from other interviews that this need is more general – existing facilities for collaboration (main report, 3.3.5) notwithstanding. Researchers have expressed frustration at not having easy access to scientists and other technical experts when they wish to find out about specific issues as part of the initial research into theoretical, critical and technical issues when developing projects; or when they are seeking collaborators for trans-disciplinary projects: they need a forum which can help them develop their research in areas which may be unfamiliar to them, and which can help them develop the contacts which lead to future collaborations. In the words of the summary of the recent scoping seminar for e-Science in the visual arts,

> We need to look at setting up multi-disciplinary research centres and working with people inside and outside academia, who can pull things together and give people new opportunities for using high end technologies.[232]

[231] Marsden et al. 2006, § 1.3.8 on p. 11.
[232] Gollifer 2006.

In fact, within the humanities generally, very few people work with technologists, computing scientists or industry.[233]

Intute's recent report on the research community's requirements has also pinpointed a desire for a national database of researchers and research, noting that

> Although there are localised directories of research or researchers working in particular fields or in particular institutions, there is no nationwide service. Such a service would make it easier for researchers to arrange collaborations …. Most academics … are much less knowledgeable about who might be able to contribute to interdisciplinary work.[234]

Like the Intute report, the *Gathering Evidence* report recommends the creation of 'a single, readily-usable source of information about the research population and mechanisms for contact'.[235] The RePAH report, however, noted a degree of unwillingness for individual researchers' CVs to be automatically harvested and aggregated, suggesting that any such database might meet some resistance.[236]

One researcher interviewed for this project combined these needs in a desire for access to an unpressured and uncompromised environment in which scientists and artists could collaborate.

There is also a need for access to technical experts, equipment and programmers in other fields, such as:

- work with high-definition moving images
- three-dimensional models
- haptic interfaces
- digital biometric identification techniques and surveillance equipment
- new developments in microscopy and animated cell imaging
- generative media
- interactive interfaces
- motion capture
- sending images to mobile phones
- gesture- and motion-based interfaces
- high-speed video

Solutions developed here may be transferable to other areas of humanities research: the AHDS Performing Arts scoping survey raised similar concerns, noting that their

> survey and interview results demonstrate that innovation and experimentation on an individual level with digital resources are high. The institutional infrastructure to facilitate this innovation and experimentation lags behind. Academics and scholars observe that IT departments are not always the first port of call when researchers seek assistance in overcoming the technological challenges inherent in creating digital resources. … Tony Dowmunt, a screen-documentary lecturer at Goldsmiths College, said: '... the AHDS could be skilling universities as institutions rather than individuals'.[237]

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[233] Huxley et al. 2006, p. 6.
[234] Wilson & Fraser 2006, § 4.3.6.
[235] Huxley et al. 2006, p. 2.
[236] Brown et al. 2006, § 5.4 on p. 36.
[237] Abbott & Beer 2006, § 6 on pp. 39-40. Similar points are made by Huxley et al. 2006, pp. 2 & 10-12.

Similarly, whilst some art schools have developed programmes for the commercialisation of research and knowledge transfer into the business community, others have not. Researchers in those institutions would welcome access to the cultures, know-how and mechanisms which would enable them to develop commercial spin-offs from their research, which would in turn bring funding back into the institutions.

There is a clear link in these needs to the need for facilities to enable more extensive online collaboration, as outlined in 1.2.1.

Allied to access to expertise is the need for access to scientific imaging facilities, which are becoming increasingly restricted and/or expensive as the need to recoup costs is emphasised more and more. For example, in the field of medical imaging, as the NHS has come under ever-increasing pressure to cut costs and run more efficiently, whilst greater attention is paid to patients' consent to the distribution and re-use of medical recordings, so access to medical imaging equipment such as CT and PET scanners and MRI machines, and the images derived from them, has become ever more restricted.

Researchers who wish to work with the following technologies have expressed a need for easier access to them:

- medical imaging
- electronic and electromechanical hardware for use in immersive and interactive environments, such as triggers, sensors, stepper motors etc. (one example of the kinds of devices in question is the Teleo range from Making Things[238])
- capturing, editing, sharing, disseminating and archiving full-colour, uncompressed, high-resolution video files
- outdoor projection
- locative technologies
- working with satellite data and imagery
- microscopic images of plants

A means of sharing access to these tools is likely to help reduce the costs of individual practice-led research projects.

4, 6, 11, 16, 17, 23, 31, 49, 61, 69, 70, 73, 74, 78, 81, 121, 122, 128, 141, 143, 145, 146: access

1.15.3. Personal access to resources

As practitioners finish their education, they leave behind the institutional support they (may) have enjoyed whilst studying, at exactly the moment when they have the greatest need to keep working and make their work widely available if they wish to continue a career in practice or research. The great majority finish their education without the knowledge, equipment or software to facilitate this: they do not necessarily know how to set up a network, how to systematically archive digital copies of their works, how to program a dynamic website which might draw upon their archived material, etc. Similarly,

[238] See http://www.makingthings.com/teleo.htm, consulted 27 July 2006.

they cannot afford the kind of equipment, software and training which will support their practice and its dissemination. Consequently, there is a need for training, financial support and access to equipment and expertise at this point in practitioners' careers; alternatively, this need might in part be addressed by greater access to specific training whilst still at college (cf. 1.16.1) and the wider availability of task-specific software tools (1.3.1).

1: interfaces, image processing, display, access

1.15.4. Pervasive network access

Although a need for access to cheap wireless broadband anywhere and at any time was expressed by only one researcher, it seems highly likely that this would make much visual arts research significantly easier.

84: access

1.16. Sustainability

1.16.1. Training in use of digital images and other digital techniques

Several researchers pointed out that they had not had the time or opportunity to acquire the knowledge they required to work confidently with digital images and other forms of digital output. There is a strong need for task-based training, directed at researchers' needs (rather than providing overviews of the capabilities of different programs), and a straightforward advice service regarding current best practice in these areas. It should be remembered that many researchers have acquired notable skills in areas such as analogue photography; they need to be shown how to translate those skills to the digital arena.

This need has been identified in several recent reports on ICT in the arts and humanities. The AHRC Strategy report on audio-visual material reached similar conclusions, whilst the *LAIRAH* report found that accessing training in more advanced technologies for the creation of digital resources was often difficult.[239] Likewise, the *Digital Picture* noted that, although 37% of respondents to their consultation felt they could obtain the training they needed, 30% still felt that they could not.[240] Access to suitable training also features amongst the needs identified by the *Gathering Evidence* report, which recommends further research into 'more precise details of specialised training and skills acquirement needs for different [humanities] disciplines'.[241] In fact, 'more support/training' was the second most popular need in the report's ICT 'wish-list', with a particular demand for local, subject-specific support.[242]

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[239] Marsden et al. 2006, § 1.3.2 on p. 10; Warwick et al. 2006, § A 4.1 on p. 57.
[240] AHDS Visual Arts 2005, § 4.2.8 on p. 27.
[241] Huxley et al. 2006, pp. 2 & 17.
[242] Huxley et al. 2006, pp. 14-15 (including table P).

Subjects for which a need for training or advice was expressed were:

- Basic understanding of digital images, e.g. the differences between file types, which resolutions are suitable for which purposes, etc. Introductory training in these matters is vital if researchers are to work efficiently with digital images in future.
- More advanced users – for example those with some knowledge of analogue photography – would also welcome advice on current techniques and best practice in digital imaging. This is particularly important given the speed with which technologies change (e.g. the recent change in image-processing software – notably Apple's Aperture and Adobe Lightroom[243] – to work by saving alterations to RAW files rather by directly altering files in more open formats, as in PhotoShop and similar programs).
- Web authoring.
- Drawing programmes which can be used with industrial manufacturing processes.
- Creation of e-books.
- Moving images, particularly new technologies.

19, 30, 39, 51, 52, 67, 69, 72, 119, 125: access, sustainability

1.16.2. Assistance in processing and presenting digital images

The RePAH report notes that digital technologies have not yet fed through to the habits and procedures for digital archiving in the arts and humanities.[244] However, this is less true of the visual arts, as researchers have increasingly tried to archive and disseminate their work digitally. But they are continually frustrated by the time it takes to do this: capturing at high resolutions is itself time-consuming, and once captured, digital images have to be optimised, derivative copies need to be created for various purposes, metadata needs to be added to or associated with the images, and the images need to be stored and backed up. This contrasts with the comparatively simple process of shooting a 35mm slide, having it processed and mounted by someone else, writing on the mount and filing it. Similar issues are encountered with moving images.

Institutional and personal collections of images have been hit particularly hard by this need: when Kodak announced in June 2004 that they were ceasing production of 35mm slide projectors, it became clear that slides were increasingly unfeasible as a means of presenting research. But this faced many institutions and researchers with the daunting task of converting collections of slides which had been built up over decades into digital format: most art history departments' slide libraries contain somewhere between 100,000 and 500,000 slides. These need to be digitised and – just as time-consuming – the metadata which identifies the images needs to be standardised and entered into digital asset management databases. Such a need was also expressed in one of the *Gathering Evidence* case studies.[245]

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[243] Apple Aperture 1.1 is available for Macintosh only: http://www.apple.com/aperture/. Adobe Lightroom currently exists as a beta version for Macintosh and Windows: http://labs.adobe.com/technologies/lightroom/. Both sites consulted 31 July 2006.
[244] Brown et al. 2006, § 2.3.1 on p. 7.
[245] Huxley et al. 2006, p. E: 2.

Thus, there are needs for:

- money to appoint staff to digitise institutional image collections
- training for researchers to enable them to digitise their own collections as efficiently as possible
- or, as one researcher suggested, 'digital assistants', people who would take on the repetitive but time-consuming tasks of preparing digital images for archiving and re-use[246]

20, 33, 61, 69, 70, 102, 125: sustainability

1.16.3. Keeping the infrastructure up-to-date

The rapid pace of change of commercial imaging technologies has been noted above (see 1.16.5). This causes significant problems for institutions, which ideally would re-equip every two years – although this in turn leads to the problems mentioned under 1.16.1, of staying abreast with current developments in technology and best practice. Of respondents to *The Digital Picture*, only 34% agreed that 'our institute is fully kitted out with the latest technology', whilst 41% disagreed.[247] Indeed, these concerns may be felt more generally: the recent AHDS Performing Arts scoping study noted that

> The differential availability of technical support, services and resources remains a challenge. As one interviewee stated …: 'We need more interaction between humanities and IT in Higher Education …'.[248]

Similarly,

> Other interviewees said that technical challenges are becoming less and less of a problem, but that the problem now is making sure that institutional infrastructures keep up with changes in technology as fast as individuals are able to.[249]

The AHRC Strategy report on audio-visual media reached similar conclusions.[250]

Likewise, the tendency in academic institutions to acquire equipment intended for office use, rather than that developed specifically for imaging purposes, has also been mentioned (see 1.13.1 and 1.4.4). One researcher explained that management and IT staff in his institution lacked an understanding of the possibilities and implications which lie within creative use of ICT, and so failed to support it in any form which enabled its thorough exploitation; having had experience of the position in similar institutions in the US, he noted that UK higher education was about 10 years behind in its attitude to new technologies in an art and design environment. In a similar vein, the *CLIC* report identified a need to incorporate existing commercially-driven image-sharing technologies into local higher education infrastructures.[251]

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[246] See the request for technical support made by creators of digital image collections in the *CLIC* report: Miller et al. 2006, § 3.1 on p. 19.
[247] AHDS Visual Arts 2005, § 4.2.5 on p. 20.
[248] Abbott & Beer 2006, § 3.4 on p. 30.)
[249] Abbott & Beer 2006, § 6 on pp. 39-40. For the final point raised in this quotation, see 1.16.3 below.
[250] Marsden et al. 2006, § 1.3.1 on p. 10.
[251] Miller et al. 2006, § 2.4 on pp. 16-17.

Similarly, respondents to the *Gathering Evidence* survey also expressed frustration at the quality or price of hardware and software available at their institution, and so 'better/updated hardware and software' was the third most popular item on the report's ICT 'wish-list'.[252]

This translates to a need for:
- sufficient funding and expertise to keep abreast of technical developments and their implications for creative practice
- ensuring that new developments are quickly made available to practitioners and their institutions *as part of the basic infrastructure*
- providing training for researchers in the use of new technologies

But the latest technology is useless if it is not properly supported by technicians and advisors. Consequently, greater support for discipline-specific ICT needs across the humanities is another of the needs identified in the *Gathering Evidence* report, pointing out the essentially reactive nature of local ICT support and the trend to centralise expertise in advanced humanities computing in a few, well-funded institutions at the expense of more widespread provision.[253] Its authors note that 'researchers really need to be more aware of and know where to go for specialised support (whether nationally or locally provided …)'.[254] Consequently, as mentioned above, 'more support/training' was the second most popular need in the report's ICT 'wish-list', with a particular demand for local, subject-specific support.[255]

39, 40, 61, 69, 72: sustainability

1.16.4. Open content formats

The RePAH report notes that, in the visual arts in particular, key research information may only be available in proprietary formats.[256] Media corporations continue to develop technical protection measures to prevent illicit circulation of audio and video content. These often become embedded in file formats and software and hardware media players, leading to severe restrictions on what users may do with the content, and leading to potential problems in the future, as formats and hardware evolve and older technologies fall by the wayside. Consequently, as the AHRC Strategy report on audio-visual media notes, digital rights management systems 'threaten to prevent research altogether'.[257] In contrast to the large corporations, it is in the interests of researchers and the visual arts community as a whole that research outputs and other work are distributed as widely as possible, whilst continuing to take advantage of up-to-date formats and technologies. There is therefore a need for widely-supported multimedia file formats which remain free of technical protection measures, allowing practitioners to retain control over how their

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[252] Huxley et al. 2006, pp. 2, 8, 12 & 14-15, including table P.
[253] Huxley et al. 2006, pp. 11-12.
[254] Huxley et al. 2006, pp. 16-17.
[255] Huxley et al. 2006, pp. 2, 14-15 (including table P) & 17.
[256] Brown et al. 2006, § 4.3 on p. 26.
[257] Marsden et al. 20006, quoting from p. ii, but see also § 1.2.2 on p. 5, § 1.3.3 on p. 10, & § 2.7 on pp. 19-21.

work is distributed. This is a major cause for concern well beyond the field of visual arts research, and was recently the subject of an inquiry by the All Party Internet Group.[258]

3, 91: sustainability

1.16.5. Preservation of obsolete technologies

Established and functioning technologies continue to become obsolete as more advanced ones are developed; the problem lies behind many of the issues addressed by organisations such as the Digital Preservation Coalition.[259] The well-known example of the triumph of VHS over the Betamax format for home videos indicates that the technically superior technology does not always win, and this is one of many reasons why researchers may wish to continue to use obsolete technologies in their work. Aesthetic reasons are another; after all, visual arts practice still includes a great many people who continue to work with purely manual technologies such as painting, engraving, carving, etc. In addition, if work created using old technologies is to be preserved as a subject for future historical research, there is a strong argument for retaining the technologies originally used to produce and display it. There is therefore a need for access to and support for obsolete technologies, both hardware and software.[260]

8: sustainability

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[258] Further information can be accessed via http://www.apig.org.uk/current-activities/apig-inquiry-into-digital-rights-management.html, consulted 27 July 2006; their report is APIG 2006.
[259] http://www.dpconline.org, consulted 27 July 2006.
[260] See too Marsden et al. 2006, § 1.3.6 on p. 11.

2. Digital imaging technologies

2.1. Collaboration

2.1.1. The Access Grid

The Access Grid is an international network of nodes equipped with high-resolution displays, high-speed network connections, tools and environments for large-scale distributed meetings and collaboration.[261] It can be seen as an extension of video-conferencing, but offering much higher data transmission standards, more flexible setups for the relevant interfaces between venues, and greater flexibility in sharing files during the meeting. The Access Grid Support Centre lists the following characteristics:[262]

- Near natural sounding audio
- Big display to enable full-size people shots and simultaneous viewing of all remote sites
- Multiple cameras to show groups and multiple viewpoints
- Collaborative software to enable remote participants to share and interact with data
- Usage of IP multicast to enable bandwidth-efficient networking

Access Grid nodes fall into three main types:[263]

Type	Equipment required	Cost to set up
Studio	Multiple (usually 4) cameras, large projected screens, multiple echo-cancelling microphones.	£25,000 basic, up to £40,000 with document viewers, presentation laptop, etc.
Office	Multiple monitor display, echo-cancelling microphones.	£8,000-£12,000
Personal[264]	Good webcam, headset with microphone.	£50-£100

Setting up and maintaining a studio or office Access Grid node is a major undertaking, in terms of expense, equipment, and technical know-how, and so the majority of large-scale Access Grid nodes are based in scientific or technological institutions.[265] However, the software required to establish a node – the Access Grid toolkit – is freely available and open source.

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[261] The Arts and Humanities e-Science Support Centre have produced a useful briefing paper on the Access Grid, available at http://www.ahessc.ac.uk/briefing_papers/AG_BP.pdf, consulted 31 August 2006. Support for the Access Grid in the UK is provided by the Access Grid Support Centre, http://www.agsc.ja.net, whilst there is a more technical website devoted to the Access Grid at http://www.accessgrid.org; see also http://agcentral.org, all consulted 26 October 2006.

[262] http://www.agsc.ja.net/support/whatisag.php, consulted 26 October 2006.

[263] http://www.agsc.ja.net/support/whatisag.php, http://www.agsc.ja.net/support/getting.php, both consulted 26 October 2006.

[264] Personal Interface to the Grid, or PIG.

[265] See the global node listings at http://agcentral.org/nodes; there is also a forum devoted to artistic use of the Access Grid on the same site, at http://agcentral.org/forums/culture/art, although this appears to be fairly inactive. A list of UK nodes is available at http://www.agsc.ja.net/QAtesting/QApasses.php. All sites consulted 26 October 2006.

Figure 41. An Access Grid meeting taking place at the North-East Regional e-Science Centre, Newcastle University.

The Arts and Humanities e-Science Support Centre (AHeSSC) have noted several potential uses of the Access Grid in visual arts research:

- as a system enabling remote collaborative performances – i.e. telematic art
- as a system for collaboration: in addition to facilitating meetings, it allows large digital objects to be shared and discussed
- as a new form of display for research outputs

There are already some organisations which promote or facilitate visual arts use of the Access Grid, for example:

- Internet2, http://arts.internet2.edu, based in the USA, which 'assists Internet2 members in enabling and advancing collaborations between high performance networking technologies and applications in the arts and humanities'[266]
- artgrid, http://artgrid.chpc.utah.edu, again USA-based, 'an informal consortium of sites on Internet2 that utilize the Access Grid as an art medium'[267]
- Marcel, http://www.mmmarcel.org, 'a permanent broadband interactive network and web site dedicated to artistic, educational and cultural experimentation'[268]

In addition, support and advice for researchers in the arts and humanities in the UK who wish to use the Access Grid can be obtained from AHeSSC at http://www.ahessc.ac.uk, and more general user support is provided by the UK's Access Grid Support Centre, http://www.agsc.ja.net.

24: collaboration, interfaces, display, access

2.1.2. HP Remote Graphics Software

Developed by Hewlett Packard, Remote Graphics Software is a system for displaying fully-rendered, high-resolution two- or three-dimensional graphics anywhere, across any

[266] http://arts.internet2.edu, consulted 27 October 2006.
[267] http://artgrid.chpc.utah.edu, consulted 27 October 2006.
[268] http://www.mmmarcel.org/marcel/index.php/About%20MARCEL, consulted 22 May 2006.

network, without any specialised graphics equipment at the display end.[269] The system assumes one graphics workstation, carrying out the actual graphics processing (the 'sender'), and one or more remote machines viewing and interacting with the graphics output (the 'receiver'). All rendering is carried out on the sender using its own hardware and software resources, including hardware graphics accelerators, and only the screen output is transmitted over the network to the receiver. This significantly reduces the system requirements on the receiver side, which need only be equipped to handle two-dimensional images. Bandwidth is further reduced by compressing the transmitted data, using the proprietary variable-compression HP2 codec. The system has been developed to provide remote access to graphics workstations, presenting an image of the sender's entire desktop, and the system allows the receiver to control the graphics output being delivered by the sender. Because only the display data is transmitted, source data remains secure on the sender, whilst all network traffic is encrypted. Existing applications need not be modified to use the Remote Graphics Software. Hewlett Packard suggest that the software can facilitate

- remote access to a graphics workstation
- demonstrations of applications running on a remote workstation
- design review and collaboration
- teaching and training

17: collaboration, image processing, display, collections

2.1.3. CITRIS Gallery Builder

According to the project's website, 'The CITRIS Collaborative Gallery Builder is a system designed to allow researchers in the humanities to interact with 3-dimensional artefacts and related digital content inside of a collaborative virtual environment.'[270] The system creates a series of three-dimensional virtual spaces, filled with digital objects (images, multimedia files, etc.); it can accept files in JPEG, BMP, PNG, MPEG, MP3 and VRML2 formats. Users are represented by avatars, which can then navigate through the virtual space and interact with other avatars and the digital objects. Users can annotate objects, modify the layout of the virtual space, add new objects, etc. The system can be run as a gallery-like system, where one or two 'curators' create a space and content for other users to explore, or it can function in a more open fashion, like a wiki.

32: collaboration, visualisation, categorisation/organisation, collections

2.1.4. VidGrid and Mixed Media Grid (MiMeG)

[269] See http://h20331.www2.hp.com/Hpsub/cache/286504-0-0-225-121.html, with further information available at http://h20331.ww2.hp.com/Hpsub/downloads/HP_remote_graphics_datasheet.pdf and http://h20331.ww2.hp.com/Hpsub/downloads/hp_remotegraphics.pdf, all consulted 25 October 2006.

[270] http://citrissrv1.eecs.berkeley.edu/hosted/projects/ith/gallery/index.html, consulted 26 October 2006.

The VidGrid project, which has evolved into the Mixed Media Grid (MiMeG), developed a system to allow social scientists to work collaboratively with digital video.[271] The system is based around 'data sessions', where a group of participants view video materials together as a means of identifying analytical issues and themes. Such sessions often include other materials as well – background information, transcripts, etc. The MiMeG tool, written in Java, works with MPEG-1 and AVI files, allowing annotation of the files in real time by multiple users distributed over several remote sites. Annotations are preserved in XML. Audio communication between participants in an online data session uses existing Voice over IP systems such as Skype. The system is structured so that one user has control over playback of the video, although this can be passed freely from one participant to another. However, the system relies upon physical distribution of the actual video under discussion, so that each user has a local copy, rather than distributing it live over the network. This avoids some technical, and many ethical and legal, problems.

33: collaboration, video, categorisation/ordering

2.1.5. MITH Virtual Lightbox

Developed at the Maryland Institute for Technology in the Humanities, the Virtual Lightbox exists in two versions, both available as open source software programmed in Java.[272] The applet version is aimed at web developers who wish to add an image comparison and manipulation tool to their websites. [273] It provides a display area in which users can:

- move, juxtapose and re-size an indefinite number of images at will
- add individual images held on the user's machine
- adjust image contrast, convert colour to greyscale and invert colour and greyscale images
- save the state of a session (as long as underlying image URLs remain constant) and re-open previous sessions

The application version retains similar functionality, but allows a group of remote users who participate in a session to view and manipulate the same image set collaboratively in real time. [274]

34: collaboration, image processing, categorisation/ordering, collections

2.1.6. Virtual Vellum

Virtual Vellum is an e-Science (2.7.1) demonstrator project based at the University of Sheffield.[275] It aims to deliver a prototype system enabling scholars in different locations

[271] VidGrid: http://www.cs.bris.ac.uk/~fraser/projects/vidgrid/; MiMeG: http://www.ncess.ac.uk/research/nodes/MiMeG/, both consulted 26 October 2006; Fraser et al. 2005.
[272] http://www.mith2.umd.edu/products/lightbox/about.html, consulted 19 September 2006.
[273] http://www.mith2.umd.edu/products/lightbox/applet.html, consulted 19 September 2006.
[274] http://www.mith2.umd.edu/products/lightbox/application.html, consulted 19 September 2006.
[275] http://www.shef.ac.uk/hri/projects/projectpages/virtualvellum.html, consulted 21 November 2006.

to collaborate on the analysis of manuscripts of texts by Jean Froissart by viewing high resolution images (typically 8000 x 6000 pixels, = 48 Mpixels, approximately 144 MB per image for an uncompressed 8-bits per channel RGB image). To this end, it has produced a VRE incorporating an image viewer which enables remote users to view the same high resolution image, zoom into it, and move it around the screen. The view of the user manipulating the image is shared by all the other users who are logged on to the system, which can run as part of an Access Grid meeting (2.1.1) or as a standalone presentation tool. The system uses the JPEG 2000 pyramid-file technology and is written in Java. Although Virtual Vellum is dedicated to research on Froissart manuscripts, the technology can work with digital images of any subject.

Figure 42. Virtual Vellum in use. © Michael Meredith, by kind permission of Besançon Public Library (all rights reserved).

Virtual Vellum's customisable multiple document interface permits simultaneous examination and comparison of folios from the same or different but related Froissart manuscripts in real-time, using high-resolution digitised images. Each of the main image view windows provides independent zoom and pan controls, plus correctly scaled ruler bars, colour scale and image preview thumbnail, all of which can be turned on or off.

60: collaboration, image processing, categorisation/ordering, display

2.2. Interfaces

2.2.1. *Haptic interfaces*

Haptic interfaces are intended to mimic the sense of touch. Current devices can mimic the sensations of position, shape, size and weight which can be gained via the sense of touch. The majority of available technologies focus on devices which provide a single point of contact with the digital model.[276] The most advanced devices offer six degrees of

[276] See the useful list of manufacturers maintained by Iman Brouwer at http://www.bracina.com/haptichardware.html, consulted 11 December 2006.

freedom (6DOF), i.e. movement in three dimensions and rotation around three axes, and fall into two main types:

- Robot arm: Robot arm devices are produced by, for example, SensAble Technologies Inc.® (the PHANTOM® range, Figure 41), Haption (Virtuose) and FCS Robotics (Haptic Master).[277]
- Delta: Force Dimension (Omega & Delta), Haption (Virtuose).[278]

There are also devices which will provide two-point and three-point contact – notably the CyberGlove and CyberForce devices[279] – but these are very expensive. Recent research has tried to combine two or three robot arm devices to provide similar contact, but the mechanical complexities involved severely restrict the space within which the devices can move.

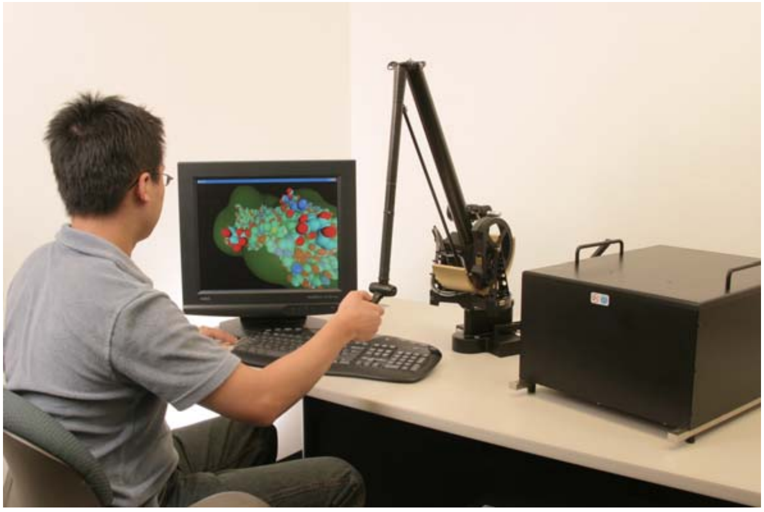

Figure 43. The SensAble™ PHANTOM® Premium 3.0/6DOF haptic device. © SensAble Technologies, Inc®. Used with permission.

'SenSitus' molecular docking software package shown above courtesy of Stefan Birmanns, Ph.D. of the Laboratory for Structural Bioinformatics, University of Texas Health Science Center at Houston. PHANTOM, SensAble, and SensAble Technologies, Inc. are trademarks or registered trademarks of SensAble Technologies, Inc.

It should be noted that both the cheaper stylus-based devices and finger-tip devices are all mediated: the user wields a device which in turn touches the 'object' under investigation – the sensation is akin to touching an object using a stylus or whilst wearing a thimble. Currently, the least mediated devices are haptic gloves.

At the moment, haptic devices do not mimic the feelings of temperature, and cannot mimic the feeling of texture. In the latter case, significant work is still to be done: it is not at all clear precisely what is being assessed when a human being feels 'texture'. Research is being done in this field, notably in the EU-funded NanoBioTact project, which seeks to build an artificial touch-sensing system – but the project is still in its infancy.[280] On a more fundamental level, we still have insufficient knowledge of the sensory system to

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277 http://www.sensable.com/products-haptic-devices.htm; http://www.haption.com/index.php?lang=eng&p=2; http://www.fcs-cs.com/robotics/products/hapticmaster; all consulted 11 December 2006.
278 http://www.forcedimension.com/fd/avs/home/products/, consulted 11 December 2006.
279 http://www.immersion.com/3d/products/, consulted 11 December 2006.
280 http://www.e4engineering.com/Articles/296892/The+sensitive+touch.htm, consulted 11 December 2006.

allow us to reduce haptic problems to a manageable size, in a way that we have been able to do with visual problems by characterising colours using only three (RGB) or four (CMYK) colours, rather than the full, continuous spectrum of visible light. Thus, although often they are often greeted with astonishment when first experienced, there is still much room for development in haptic technologies.

15: interfaces, modelling, visualisation, display

2.2.2. Virtual clay

Virtual clay is a generic term for combinations of three-dimensional modelling software and haptic (force-feedback) devices which allow users to create three-dimensional digital models by moving a sculpting 'tool', which feels as if it is interacting with real clay. The subject of several recent research projects,[281] the basic techniques now seem sufficiently established for the design of such systems to form undergraduate projects.[282] Virtual clay modelling software is now commercially available from, for example, SensAble Technologies Inc.®, whose ClayTools® system can interact with animation and visualisation software such as 3ds Max and Maya.[283]

35: interfaces, modelling, visualisation, display

2.2.3. VASARI Image Processing Software (VIPS)

VIPS was developed to facilitate the capture and manipulation of high-resolution digital images as part of the National Gallery's VASARI project (see 2.3.7), and has continued to be developed subsequently.[284] Whilst it aims to contain much of the functionality of standard imaging software, it has been optimised for the kinds of task required in the imaging of paintings in museums – e.g. working with very large image files, composing mosaics, masking of cradles or stretcher bars in x-radiographs, histogram-matching, image comparison, even virtual mounting and framing – at the expense of techniques which are largely irrelevant in this area, such as retouching. A 'workspace' (i.e. a series of manipulations applied to one file) can be stored as XML data and re-applied to other files.

[281] Two more-or-less random examples can be found at http://www.vrlab.buffalo.edu/projects_group_manufacturing/interactive_nurb/interactive_nurb.html and http://graphics.idav.ucdavis.edu/research/virtual_clay_sculpting, both sites consulted 1 September 2006.
[282] http://www.cs.manchester.ac.uk/ugrad/projects/year05/vr.html#A6, consulted 27 October 2006.
[283] http://www.sensable.com/products-claytools-system.htm, consulted 27 October 2006.
[284] Further information and copies of the software available at http://www.vips.ecs.soton.ac.uk, consulted 16 October 2006. For a discussion of x-radiograph acquisition and processing carried out using VIPS, see Padfield et al. 2002.

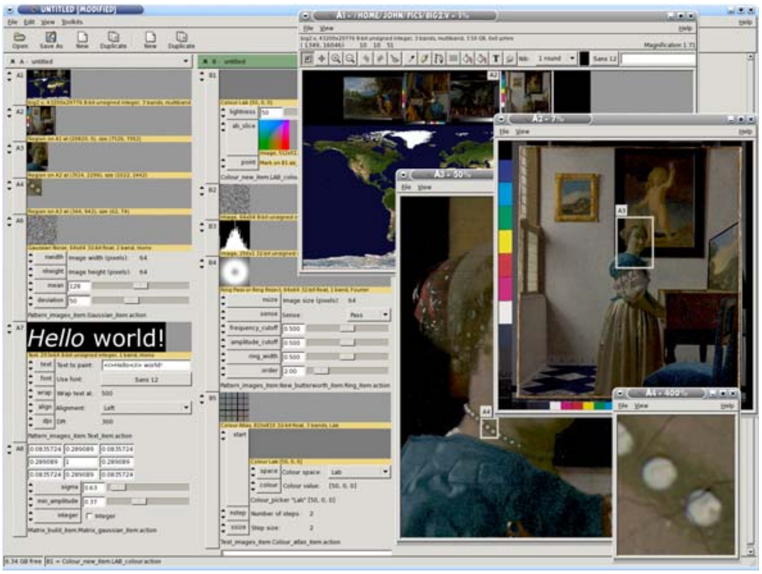

Figure 44. Editing large images with VIPS version 7.10 running under Linux, developed by John Cupitt. Screenshot by John Cupitt.

Downloaded from http://www.vips.ecs.soton.ac.uk/index.php?title=Image:Screenshot-7.10-largeimage.png, 12 January 2007.

36: interfaces, image processing

2.3. Capture

2.3.1. Electro-wetting and liquid lenses

Electro-wetting uses electric currents to change water's response to a hydrophilic or hydrophobic surface, changing the amount which it spreads out or beads up. This can be used to alter a water drop's shape on a clear surface, in other words altering its optical properties. The water drop therefore acts as a flexible lens, which can be altered incredibly quickly, and in ways impossible with solid optical systems (see Figure 45).[285] This leads to very rapid auto-focus and zooming.

[285] Electro-wetting is discussed at length in Mugele & Baret 2005; see pp. R737-8 & R742 for discussions of liquid lenses. For a journalistic overview of liquid lenses using electro-wetting, see Bains 2005; a more detailed discussion of the technology as applied to miniature auto-focus lenses is given in Hendriks & Kuiper 2004, which describes Philips' FluidFocus system. A broader summary of liquid lens development aimed at digital cameras can be found in Kabza 2006.

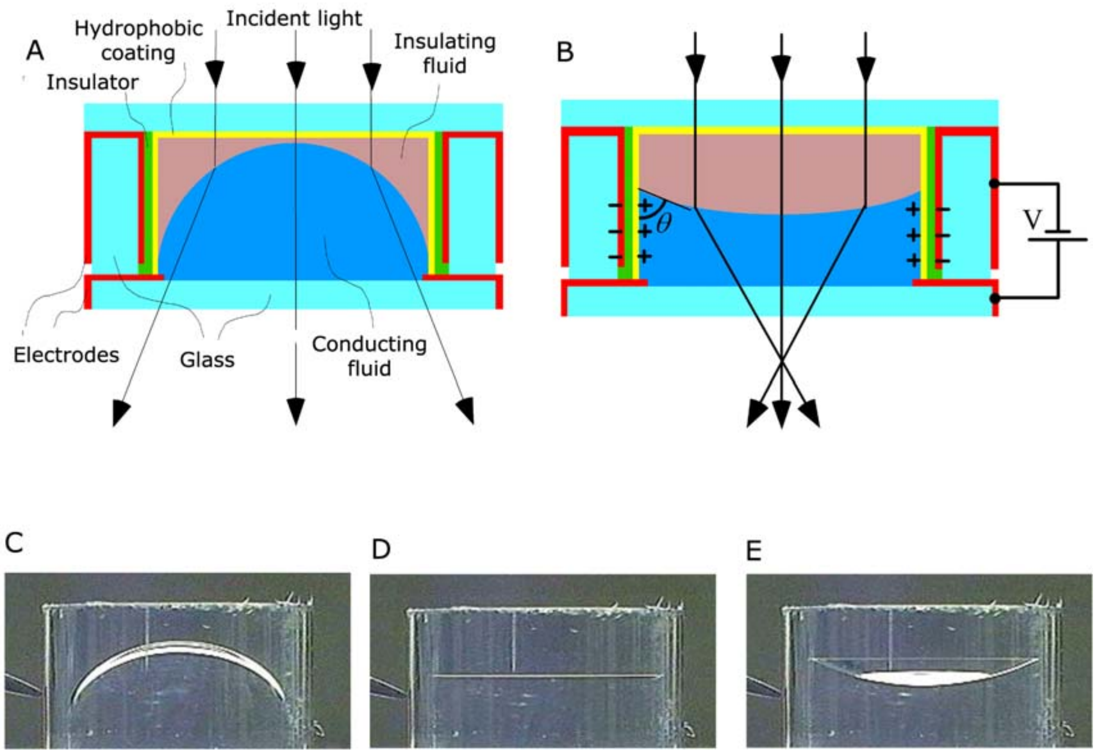

Figure 45. How the FluidFocus liquid lens system works. Photo: Philips.

A) Schematic cross section of the FluidFocus lens principle. (B) When a voltage is applied, charges accumulate in the glass wall electrode and opposite charges collect near the solid/liquid interface in the conducting liquid. The resulting electrostatic force lowers the solid/liquid interfacial tension and with that the contact angle θ, and hence the focal distance of the lens. (C) to (E) Shapes of a 6-mm diameter lens taken at different applied voltages.

The technology is being developed by:

- Philips Research (the 'FluidFocus' system; see Figure 45 and Figure 46)[286]
- Varioptic, whose auto-focus lenses using electro-wetting are now commercially available and who are developing commercial zoom lenses using the same technology[287]
- Lucent Technologies' Bell Labs[288]

There are similarities between all three technologies, to the extent that Varioptic and Philips appear to be engaged in a patent dispute over the technology.[289] Notably, the Lucent technology uses many more electrodes to add much more sophisticated control of the liquid drop, including complete control over the focal point in three dimensions,

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[286] http://www.research.philips.com/technologies/light_dev_microsys/fluidfocus/index.html; see also the March 2004 press release announcing demonstration of a working lens at http://www.research.philips.com/newscenter/archive/2004/fluidfocus.html, both consulted 11 August 2006. The technology is described in greater detail in Hendriks and Kuiper 2004.
[287] http://www.varioptic.com/en/index.php; the technology is summarised on http://www.varioptic.com/en/technology.php. Details of commercially available auto-focus lenses can be found at http://www.varioptic.com/en/Arctic_320.php, and a statement regarding zoom lenses at http://www.varioptic.com/en/products.php?cat=zooms; development kits are also available: http://www.varioptic.com/en/products.php?cat=assessment. All consulted 11 August 2006.
[288] Bains 2005; Kabza 2006.
[289] Bains 2005, Kabza 2006, and see Varioptic's original press release of 17 March 2004: http://www.varioptic.com/en/news.php?cat=news&code=14, consulted 11 August 2006.

leading to rapid pan and tilt as well as focus and zoom, a possibility also proposed by the developers of the FluidFocus system.[290]

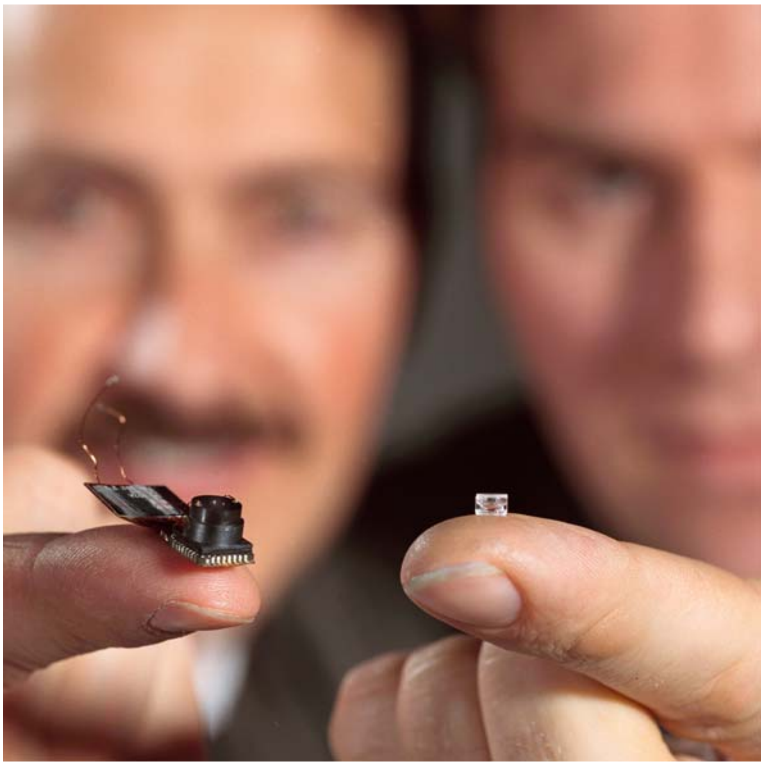

Figure 46. Philips researchers showing a FluidFocus miniature liquid lens, and the camera that contains the lens. Photo: Philips.

Electro-wetting also forms the basis of one form of paper-like display: see 2.10.1.

30: capture

2.3.2. Charge Injection Devices (CIDs)

The sensors traditionally used for digital imaging have been Charge-Coupled Devices (CCDs). However, Charge Injection Devices (CIDs) offer another form of sensor which differs from the CCD in certain useful ways.[291] The technology is not new – CIDs were developed in the early 1970s, with the first camera created in 1972. However, the technology has largely been neglected outside certain scientific imaging areas, notably astronomy.

In a CID, the charge accumulates progressively within the sensor – even during readout. This is very different from a CCD, where the act of reading the sensor removes the charge and therefore clears the image. Thus, CIDs are particularly useful in imaging in

[290] For Lucent, Bains 2005; for FluidFocus, Hendriks and Kuiper 2004.
[291] Useful summaries of the technology and its capabilities can be found at the website of the Chester F. Carlson Center for Imaging Science at Rochester Institute of Technology (NY): http://ww.cis.rit.edu/research/CID/a_cid_is.htm, consulted 11 December 2005. Backer et al. 1996 provide a technical discussion of the characteristics of a ¼ Mpixel CID sensor array.

low light levels: a series of readouts can be taken until it is determined that sufficient light has been acquired to record a suitable image. It is possible to use CIDs for very long, cumulative exposures, and they produce much sharper images in low light.[292] In addition, when exposed to high light levels, they are much less to prone to blooming and smearing. They also have a comparatively long spectral sensitivity, running from well into the near ultra-violet to well into the near infra-red. In addition, it is easy to address and read a single pixel in a CID array at a time, whilst the other pixels accumulate data.[293] These characteristics – readout without clearing the image, and single-pixel addressing – suggest that CIDs would be useful for work that records images over time, such as Susan Collins's (mentioned in the main report, 3.4.1 above). Their ability to record images from beyond the visible spectrum may also have creative uses.

CIDs are, at the moment, used in specialised scientific devices, and CID cameras for scientific apparatus are available off the shelf. For example, Thermo Electron Corporation offer the CIDTEC SpectraCAM 84, offering a 1,024 x 1,024 pixel (1 Mpixel) array and a spectral response from 165 nm (near ultra-violet) to 1,000 nm (near infra-red).[294]

31: capture

2.3.3. Functional Electrical Impedance Tomography of Evoked Responses (fEITER)

fEITER is being developed at the University of Manchester as a brain imaging technique.[295] As implemented at Manchester, it uses a series of electrodes fitted around the head, to which a small, high-frequency electric current is applied. The voltages received by a series of separate, interspersed reference electrodes are then measured, and using tomographic techniques, the voltages are converted into a series of slices which depict the electrical impedance within the brain. The technique is sufficiently fast to track the brain's processing activity in response to specific stimuli.

fEITER offers several advantages over more established brain-scanning techniques such as computed tomography (CT, see 2.3.12), magnetic resonance imaging (MRI), functional MRI (fMRI) and positron emission tomography (PET):

- it has a fast imaging speed, capturing an image in under 100 ms
- it is directly sensitive to the brain's electrical activity, in particular more sensitive to electrical activity deep within the brain than other, indirect methods
- it is portable, able to fit onto a small trolley or even a briefcase-sized casing
- it does not require a clinical specialist to operate it
- it is relatively cheap, being comparable in price to Electro-Encephalogram (EEG) equipment

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[292] This property has been exploited in astronomical imaging: see Backer et al. 1995.
[293] Kitchin 2003, p. 35.
[294] http://www.thermo.com/eThermo/CMA/PDFs/Product/productPDF_26754.pdf, consulted 21 September 2006.
[295] Anon. 2006; http://www.umip.com/images/ip_projects/pdf12.pdf; http://www.medicine.manchester.ac.uk/abouttheschool/news/brainscanner; both consulted 30 October 2006.

The technology's cheapness and ease of use may render it much more accessible to practitioners who wish to use brain imaging (and possibly other forms of anatomical tomography) within their research and practice.

The technology is currently being developed with funding from the Wellcome Institute, awarded in January 2006, enabling the construction and trialling of a prototype fEITER brain scanner. It is being offered for licensing by The University of Manchester Intellectual Property Ltd.[296]

10: capture

2.3.4. PathMarker

Developed by Hewlett-Packard, PathMarker is a system for combining continuous path data with media files to produce what HP call Path-Enhanced Media (PEM).[297] The system enables users to gather, edit, present and browse Path-Enhanced Media. PathMarker can use off-the-shelf hardware: reconciliation of path data and media files is based on correlating the capture times of media files with the times listed in the path data; once GPS receiver and camera clocks have been synchronised, the process can be performed automatically. The data generated by the system are stored as an application-independent XML file, and the system will also automatically create a directory structure for storing media, map background etc. Map data can be provided by the user or downloaded from online map servers. New media (additional files, annotations, etc.) can be added to trips, whilst the media can be separated out into different 'layers'. The system can also be used to construct entirely fictitious journeys, for example when planning new trips or querying a set of PEM data.

Sample applications have been developed to:
- edit, present and browse Path-Enhanced Media via a map overlay
- combine digital elevation maps with Path-Enhanced Media to produce trip flybys and browse the media
- generate an interactive DVD from Path-Enhanced Media

21: capture, image processing, categorisation/ordering, finding, collections

2.3.5. Laser capture of three-dimensional objects

Laser scanners are an established technology for capturing a series of distance measurements to a set of points on the surface of an object. The resulting point cloud is then processed in order to reconstruct the object's surface planes, resulting in a three-dimensional image of the object. Some devices also incorporate cameras to capture

[296] http://www.umip.com/ip_categories/ip_projects/full_project/?id=12 & http://www.umip.com/images/ip_projects/pdf12.pdf, both consulted 30 October 2006.
[297] Samadani et al., 2004; Harville et al., 2004; http://www.hpl.hp.com/research/isl/pathmarker/, consulted 30 October 2006.

colour information which is then mapped onto the three-dimensional image. The technology can be used to capture anything from small-scale objects such as museum artefacts, up to entire buildings or landscapes.

Often used as a form of surveying technique, the technology is widespread in industry and the sciences, as well as disciplines such as archaeology. In historical research, its main role has been in the heritage visualisation sector, where it has been used to create virtual images and reconstructions of objects, buildings and environments.[298] A similar technique has recently been used to examine the surface structure of paintings such as the Lansdowne Madonna, a version of Leonardo da Vinci's *Madonna of the Yarnwinder*.[299] It produces a three-dimensional model of the painting's surface, and is more quantifiable than the traditional examination of paintings under raking visible light (see 2.3.8). A trial of the technique with medieval wall paintings has proven less satisfactory, although future technical developments may render the technology more useful in this context.[300] (However, recent developments in polynomial texture mapping (2.3.10) may provide a more easily implemented substitute for raking light photography in some contexts.) It is less widely used in visual arts practice and research, although, as it is a relatively straightforward means of creating three-dimensional digital models from existing objects, it is a potentially useful tool, particularly when combined with techniques such as rapid prototyping (2.10.2).

Three-dimensional laser scanning is often offered as a service by universities or academic research centres, such as the University of Birmingham's Visualisation and Technology Centre (VISTA).[301]

27: capture, modelling

2.3.6. Volumetric cinematography

Current methods of capturing motion in three dimensions are surprisingly low-resolution, relying upon the placing of a small number of markers on a performer's body or face. Although effective for rigid or near-rigid structures such as the human frame, they are less useful for capturing deformable surfaces. Mova have recently announced a system that enables much more effective three-dimensional motion capture, the Contour Reality Capture System.[302] This uses a combination of an array of cameras, fluorescent make-up and paint, and rapidly-flickering lights to capture a much higher number of three-dimensional points, as well as matching visual images of the scene; it can be used for

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[298] For example, the model of the Vice-Chancellor's Cup created at the University of Birmingham: http://www.vista.bham.ac.uk/opening/main.htm and http://www.vista.bham.ac.uk/opening/scanning.htm; the relevant section of the Wikipedia entry for '3D scanner' at http://en.wikipedia.org/wiki/3D_scanner#Cultural_Heritage contains useful links to this kind of project. All sites consulted 30 October 2006.

[299] http://www.universalleonardo.org/sicentificAnalysis.php?tool=4902, consulted 10 October 2006.

[300] Howe 2006, pp. 44-5 & 159-74.

[301] See http://www.vista.bham.ac.uk/equipment/scanners.htm, consulted 30 October 2006.

[302] http://www.mova.com/technology.php?t=capture and http://www.mova.com/pages/whitepaper.html, both consulted 13 November 2006.

actors and related props. The system works for any dry surface that remains in one piece as it moves; it cannot, for example, capture eyeballs, loose hair or the inside of the mouth. Mova claim to be able to capture 100,000 points on a human face to 0.1 mm resolution, compared to a maximum of about 160 points on a face using conventional motion capture.

56: capture, modelling

2.3.7. High-resolution imaging

With its origins in a desire to use digital imaging to provide accurate measurements of subtle changes in colour,[303] the National Gallery has been involved in a series of developments in highly accurate digital imaging using visible light. The VASARI (Visual Arts System for Archiving and Retrieval of Images) system was developed in the early 1990s. A combination of masking of the individual CCD cells and careful micro-positioning of the entire CCD sensor increased the effective resolution of the 0.145 Mpixel sensor to 6.96 Mpixels, whilst a series of 7 colour filters (applied to the light source rather than the imaging sensor) ensured the highest possible accuracy in colour recording. Images were intended to be used to measure colour change in the paintings which were its subjects, and to allow their surface texture to be analysed.[304]

After the VASARI project, the emphasis on imaging research extended to pioneering the use of high-resolution digital imaging throughout the publication workflow, from image capture to press, beginning with the MARC (Methodology for Art Reproduction in Colour) project. To this end, the National Gallery were using a camera with an effective resolution of nearly 400 Mpixels as early as the mid-1990s. Using red, green and blue lacquers applied to the CCD sensor cells and careful micro-positioning of the sensor so that exactly the same area of the image was exposed to a sensor cell sensitive to each of the three colours, it was possible to obtain images of very high colour accuracy. Micro-positioning was used to give the 1.34 Mpixel sensor an effective resolution of 5.36 Mpixels, and large-scale positioning ('macro-positioning) was used to acquire images up to 394 Mpixels in size. It should be noted that a painstaking calibration process was used for each exposure. (Intriguingly, focussing the camera whilst the operator was distant from the computer monitor was aided by converting a measure of sharpness to a sound, the frequency of which increased as sharpness increased.) The system produced resolution comparable to 8x10" sheet film, and considerably better colour fidelity.[305]

From 1999, the very high resolution MARC images were incorporated into the VERMEER (Virtual Environment for Education, Exploration and Research) data-management system, which necessitated a greater throughput than the 100 paintings per year which could be imaged using the original MARC camera. The newly-developed MARC II camera was used, which combines micro- and macro-scanning and very careful

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[303] Saunders 1988; interestingly, the solid-state sensor discussed here was not the more common Charge-Coupled Device (CCD), but a Charge Injection Device (CID) – a technology discussed in 2.3.2.
[304] Saunders & Cupitt 1993.
[305] Cupitt et al. 1996, pp. 3-12 & 16-17.

and repeated calibration to produce very high-fidelity colour images up to a total image size of approximately 100 Mpixels, as well as producing much less image noise and being significantly more sensitive.[306]

Commercial capture technologies also continue to develop apace, under pressure to produce higher resolutions, quicker capture rates and more faithful colour rendition. Consequently, very high quality images can be obtained now with existing commercially-available technology, such as the recent PhaseOne and Hasselblad high-resolution single-shot digital backs for large- and medium-format cameras which produce 39 Mpixel images,[307] or BetterLight scanning backs for large-format cameras which produce images of up to 140 Mpixels.[308]

In addition, there are a growing number of sources of advice on best practice in high-quality digital photography of artworks – for example, the Digital Archive of Medieval Music (DIAMM) have outlined the principles under which they capture digital images of medieval manuscripts to the highest possible quality.[309] But advances in equipment and up-to-date advice notwithstanding, the fundamental prerequisite for high-quality digital capture remains, as always, a well-trained and highly-skilled photographer.

37: capture, display, collections

2.3.8. Multi-spectral imaging

Neil Grindley has already noted the importance of multi-spectral imaging for the analysis of works of art (notably paintings, drawings and sculpture), focussing on questions of condition, construction and development (e.g. changes in composition).[310] To summarise existing uses of different parts of the electromagnetic spectrum, from short to long wavelength:[311]

β-radiography	used to reveal watermarks in paper as an aid to attribution, dating, studies of the trade in materials.
X-radiography	used to penetrate paint layers and supports in paintings, and to penetrate other solid or dense objects.
Ultra-violet light	for paintings, used to assess the date of the surface layers of

306 Saunders et al. 2002.
307 The PhaseOne P 45, with a native resolution of 7216 x 5412 pixels (39 Mpixels): see http://www.phaseone.com/upload/p_45_us.pdf. The Hasselblad CF-39 and CFH-39 also have a native resolution of 39 Mpixels: see http://www.hasselblad.se/Archive/documents/Downloads_files/Productsheets/Hasselblad_CF-39_English.pdf and http://www.hasselblad.se/Archive/documents/Downloads_files/Productsheets/Hasselblad_CFH-39_English.pdf. All consulted 22 September 2006.
308 The BetterLight Super 10K-HS™, with a native resolution of 10,200 x 13,800 pixels (140 Mpixels), listed (albeit as 'availability delayed') at http://www.betterlight.com/products4X5.asp and http://www.betterlight.com/superModels.asp. Both consulted on 28 July 2006.
309 http://www.diamm.ac.uk/content/description/capture.html and http://www.diamm.ac.uk/content/description/quality.html, both consulted on 18 September 2006.
310 Grindley 2006, pp. [9]-[10].
311 For a breakdown for the electromagnetic spectrum, giving relevant wavelengths, see appendix 4.2.

	paintings: aged resinous varnishes fluoresce greenish-yellow, more recent varnishes lavender or purple, and new surface features tend not to fluoresce at all. For manuscripts, used to reveal the text of erasures: parchment fluoresces, but this is quenched by quite small residues of ink, rendering erased or abraded text more visible.[312]
Visible light (raking)	used to reveal minor irregularities in surface texture (see also Polynomial Texture Mapping, 2.3.10).
Visible light (transmissive)	used to reveal alterations in density.
Infra-red photography	used to penetrate some paint layers: infra-red light is absorbed by carbon, and so is often used to reveal carbon-rich underdrawing in paintings, normally hidden by the paint layers in visible light (although not all pigments are translucent to infra-red light). Initial work with infra-red used photographic film sensitive in the near infra-red; the development of the infra-red vidicon, and then of solid-state infra-red sensors, have extended the use further into the infra-red spectrum (see 2.3.9).

Several of these spectra are combined in the Video Spectral Comparator, a device which has been used for some time in forensic document analysis and in the technical study of works on paper and parchment (drawings and manuscripts).[313] The instrument combines a series of spectrally-limited light sources with a broad-spectrum video camera, linked directly to a computer. This allows the user to change the spectrum with which the object under investigation is illuminated, rapidly assessing which wavelength of radiation gives the best contrast between mark and support. By comparing the spectral response of two different samples, dissimilarities can quickly be identified. In addition, the device can be used for more established work under ultra-violet and infra-red illumination, and can also distinguish, at a broad level, between different types of ink and pigment, which are visible only under certain wavelengths.

A similar technique, although using quite broad spectra (red, green, blue and infra-red), has recently been used on the Lansdowne Madonna, a version of Leonardo da Vinci's *Madonna of the Yarnwinder*, which was examined using the re-configured INOA InGaAs scanner (2.3.9).[314] A more developed technique uses a series of images taken at regular intervals in a broad spectral range (near ultra-violet or visible to near infra-red). By analysing how the reflectance of different pigments in the object change under the different wavelengths, it is possible to identify areas of the object marked with the same pigment or combination of pigments. The National Gallery has described the use of a purpose-built multi-spectral camera with a spectral range of 400 to 1000 nm at 40 nm intervals, and a 1300 x 1030 pixel (i.e. 1.3 Mpixel) sensor, capable of a resolution of 3900 x 3090 (i.e. 12 Mpixels) with micro-positioning. At its closest focus, this gives a resolution

[312] An ultra-violet photograph of Leonardo's 'Lansdowne Madonna', which can be compared directly with the visible surface of the painting, is available online at http://www.universalleonardo.org/scientificAnalysis.php?tool=548, consulted 10 October 2006.
[313] Clarke 2002 provides a useful summary of the machine's capabilities when applied to the investigation of manuscripts.
[314] http://www.universalleonardo.org/scientificAnalysis.php?tool=544, consulted 10 October 2006.

of 20 pixels/mm.[315] Equipment for multi-spectral imaging is also commercially available. For example, Howe used a MuSIS camera, loaned by Forth Photonics,[316] to investigate medieval wall paintings in situ in Westminster Abbey. The MuSIS camera has been developed specifically for art and art history applications, and covers the spectrum from 370 to 1000 nm at 20 nm intervals using a 1280 x 960 pixel (i.e. 1.2 Mpixel) sensor.[317] However, the technique is comparatively recent, and, although a database has been compiled for the characteristic spectra of single pigments, the identification of pigments within any admixtures which might be encountered continues to be difficult unless the possible pigments are already known. In addition, the technology is not yet able to take into account the presence of different painting media. It also cannot provide the stratigraphic information available from traditional sampling and optical microscopy or newer techniques such as optical coherence tomography (2.3.15). In addition, standard file formats for the resulting 'spectral cubes' have not been established, and the very broad spectral range can lead to registration problems as the system's optical properties will vary with wavelength.[318]

A well-publicised application of multi-spectral imaging to enhance the visibility of faint marks is the examination of the 'Archimedes Palimpsest', currently on deposit in the Walters Art Museum, Baltimore. This contains the sole surviving Greek texts of Archimedes's *The Method*, *Stomachion* and *On Floating Bodies*, as well as at least four other of his texts and a previously unknown fragment by Hyperides.[319] Unfortunately, the tenth-century Byzantine manuscript of Archimedes had been scraped down and incorporated into a prayer book in Constantinople by 1229. Initial experiments with multi-spectral imaging proved promising, but were incapable of providing the clarity of image required to interpret the missing text.[320] Using a more refined technique, the manuscript was imaged under two visible light spectra, one red and illuminated by visible light, and one blue and illuminated by ultra-violet light – so that it recorded the fluorescence given off by the parchment.[321] When combined, these two spectra allowed viewers to distinguish between:

- The underlying parchment, reflecting both blue and red light, and appearing more-or-less white in the combined image
- The later text, absorbing both blue and red and appearing black
- The original text, absorbing blue but reflecting red light, and so appearing red

Whilst highly satisfactory for much of the missing text, there were still areas that remained unreadable. The multi-spectral technique was refined once more, abandoning filters between the manuscript and the sensor to narrow the spectrum in favour of illumination by narrow-band light-emitting diodes (LEDs), further increasing the legibility of the damaged text.[322]

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315 Liang et al. 2005b.
316 http://musis.forth-photonics.gr, consulted 24 November 2006.
317 Howe 2004, pp. 45 & 175-8, describing research funded by English Heritage.
318 Attas et al. 2003; Howe 2004, pp. 45-6 & 175-197.
319 http://www.archimedespalimpsest.org/palimpsest_making1.html, consulted 15 September 2006.
320 http://www.archimedespalimpsest.org/imaging_initialtrials1.html, consulted 15 September 2006.
321 http://www.archimedespalimpsest.org/imaging_production1.html, consulted 15 September 2006.
322 http://www.archimedespalimpsest.org/imaging_experimental1.html and http://www.archimedespalimpsest.org/imaging_experimental2.html, both consulted 15 September 2006.

Multi-spectral imaging, including the video spectral comparator and the Archimedes Palimpsest project, will be one of the subjects of a Methods Network workshop on 'Approaches to the forensic investigation of primary textual materials', to be held in 2007.[323]

38: capture

2.3.9. New infra-red sensors

Some pigments which are opaque to visible light are more translucent in the infra-red portion of the spectrum.[324] This can be used to penetrate certain pigments, revealing what lies beneath them.[325] Infra-red investigation is particularly effective in revealing pigments containing carbon black and other infra-red absorbers. Because of these characteristics, it is usually used to study underdrawings, the preparatory drawings made by artists on the support of a painting prior to applying the painted layers. In this context, it can be used to examine:[326]

- The evolution of the finished painting:
  - how the underdrawing developed, and how it relates to other drawings for the composition
  - what changes took place between the underdrawing and the final painted composition
  - which parts have been underdrawn, and which not
- The style of the underdrawing:
  - its authorship
  - its characteristics
  - the use of any copying processes to transfer the design from another drawing
- The materials and technique of the underdrawing:
  - the materials used to create the underdrawing
  - how the underdrawing has been applied (pen, brush, etc.)

First carried out in the 1930s, infra-red examination of paintings traditionally used infra-red sensitive photographic films. Whilst they could produce very sharp images, their sensitivity was restricted to the very near infra-red, up to approximately 800-900 nm, which made it difficult to penetrate some pigments, particularly copper-based blues and greens.[327] The late 1960s saw the development by J.R.J van Asperen de Boer of infra-red reflectography.[328] This technique uses a video tube (usually referred to as a 'vidicon'), conventionally using a target coated with lead oxide-lead sulphide (PbO-PbS). The

[323] http://www.methodsnetwork.ac.uk/activities/ws11.html, consulted 18 September 2006.
[324] See Appendix 4.2 for a breakdown of the spectrum.
[325] A useful introduction to infra-red imaging and the examination of underdrawings is given in Bomford 2002, pp. 10-25 & 181; see also the bibliography on p. 187. A series of plates demonstrating the different opacities of a range of pigments in a selection of media at visible and infra-red wavelengths can be found in Faillant-Dumas 1968.
[326] Bomford 2002, p. 20.
[327] Bomford 2002, pp. 14-15.
[328] Bomford 2002, pp. 15-16 & 181. An infra-red reflectograph of Leonardo's 'Lansdowne Madonna', which can be compared directly with the visible surface of the painting, is available online at http://www.universalleonardo.org/scientificAnalysis.php?tool=544, consulted 10 October 2006.

vidicon has a vastly greater spectral range than infra-red film, running from 400 nm (near the violet end of visible light) to 1900 nm or even 2200 nm.[329] As it is most sensitive in the visible light spectrum (400-800 nm), filters with a cut-off of 900 nm are used to remove the visible spectrum. The use of video tubes and monitors gives the advantage of 'live' capture, but the vidicon also has many drawbacks: low resolution (hence small fields of view), general lack of sharpness, geometric distortions, and variations and fluctuations in intensity. Notwithstanding, apparently due to the popularity of the vidicon, infra-red films are increasingly difficult to obtain.

Consequently, solid-state sensors are increasingly being used due to the drawbacks in vidicon technology. These fall into two types:

- Platinum silicide (PtSi): sensitive from 1200 to 5000 nm, peaking at 2000-3000 nm. However, little is gained in studying underdrawing beyond 2500 nm (though wavelengths beyond 2500 nm can provide other information), and most PtSi cameras are configured to work in the range 1200-2500 nm. Extending this far into the infra-red can actually cause problems: iron-gall inks are clearly visible in the very near infra-red spectrum used by infra-red photography, but are transparent in the spectrum used by PtSi sensors.[330]
- Indium gallium arsenide (InGaAs): sensitive from 900 to 1700 nm. In other words, the InGaAs sensor has no greater spectral range than the vidicon, but it does offer much greater resolution and significantly fewer aberrations and irregularities.[331] The latest developments involve the use of a very high-resolution scanning InGaAs back, which can be used at a range of scales from whole object down to very close detail. One system has been developed at the Istituto Nazionale di Ottica Applicata (INOA), and a portable version has been developed by the National Gallery. The latter, known as SIRIS (Scanning Infra-Red Imaging System) creates images approximately 5000 pixels square (25 Mpixels) using a 320 x 256 pixel sensor and macro-positioning; its resolution ranges from around 2.5 pixels/mm on large works (up to 2 m square) to 10 pixels/mm on an area measuring 50 cm square. Whilst penetration of paint-layers is broadly similar to that achieved with the vidicon, the images produced are much sharper, and of course obtained much more easily and quickly.[332] The INOA scanner, in contrast, uses a single photodiode which is moved rapidly across the image together with its accompanying light sources, removing the problem of non-uniform lighting. It works at a resolution of 4 pixels/mm on areas up to 1 m^2. It has recently been adapted to image in the visible spectrum as well as the infra-red, where the single-photodiode design has the additional advantage of negating any lens aberration caused by the broad spectrum to which it is sensitive. It is now capable of the capture of images of identical spatial resolution in the different spectra, turning it into a form of multi-spectral imaging device (2.3.8).[333] The results of an examination using an InGaAs sensor reached the national press recently when they revealed a hitherto unknown composition by Leonardo da Vinci beneath the London version of the

[329] See Bomford 2002, figs 14-16 on p. 17 for an illustration of how the greater spectral range of IR vidicon reflectography enables greater penetration of green and blue pigments.
[330] Bomford 2002, p. 181.
[331] Bomford 2002, p. 181.
[332] Saunders et al. 2005.
[333] Marras et al. 2003.

Virgin of the Rocks; the examination was carried out using the INOA scanner under the aegis of EU-Artech's MOLAB.[334]

39: capture

2.3.10. Polynomial Texture Mapping (PTM)

Polynomial texture mapping 'allows the viewer to simulate on the computer screen the effect on the appearance of the painting of moving a point source of light to any position between the viewer and the object.'[335] Significantly, the illumination visible in a PTM image is independent of the position of the light sources used during image acquisition, but is interpolated by the software from a series of images made under a set of precisely-defined lighting conditions.[336] Originally developed by HP Labs for three-dimensional graphics rendering applications, it has also been used to render the surface detail on three-dimensional digital images of museum objects.[337]

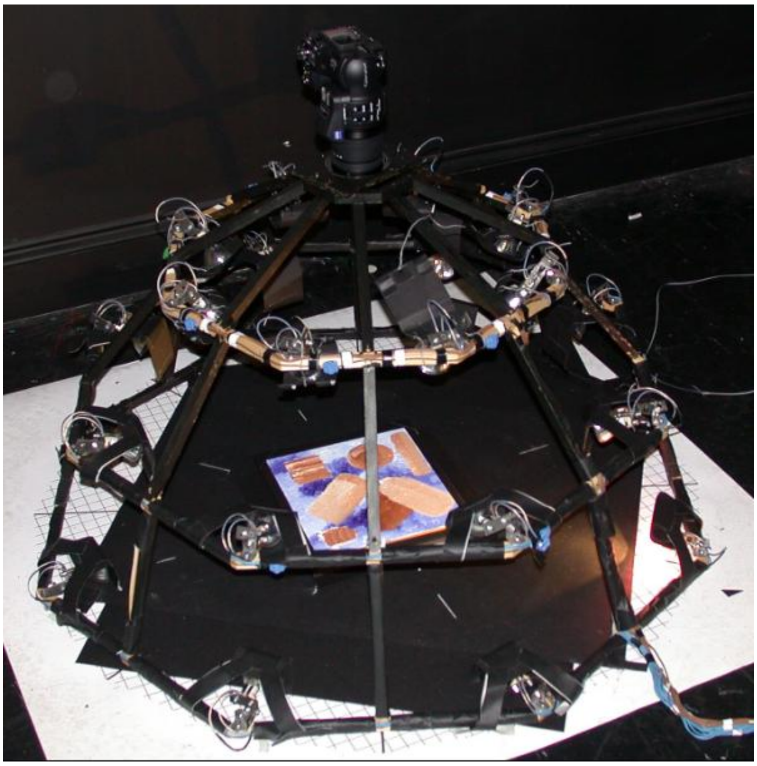

Figure 47. The National Gallery's experimental PTM lighting/camera rig, built by Joseph Padfield. Image by Joseph Padfield.

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[334] Syson & Billinge 2005; see also Syson 2005.
[335] Padfield et al. 2005, p. 504.
[336] Padfield et al. 2005, p. 505.
[337] Malzbender et al. 2001, which includes in § 4.1 discussion of two ways in which manipulation of a PTM can enhance the legibility of three-dimensional artefacts; Padfield et al. 2005, p. 504. The technique is also outlined at http://www.hpl.hp.com/research/ptm/; see also http://www.hpl.hp.com/research/ptm/ri.html and http://www.hpl.hp.com/research/ptm/se.html for the legibility-enhancing techniques. Sample PTM images of two museum objects can be accessed online via http://www.hpl.hp.com/research/ptm/downloads/agreement.html; additional objects are available on the Cultural Heritage Imaging website at http://c-h-i.org/examples/ptm/ptm.html. All sites consulted 16 October 2006.

Downloaded from http://cima.ng-london.org.uk/ptm/dome.html, 12 January 2007.

The technique has been developed at the National Gallery, London, as a digital version of raking-light photography under visible light (for which see 2.3.8). The use of digital technology has two significant advantages over conventional photography:

- The virtual light-source can easily be moved at will, including to positions not used when the image was captured.[338]
- The position of the virtual light-source can be matched exactly in two images of the same object taken at different times, whereas repositioning the light source for conventional photographs in exactly the same position is extremely difficult. As a result, images taken of the same object at different times may be digitally subtracted from each other to isolate changes, practically impossible with images acquired conventionally.[339]

In addition, PTM is significantly cheaper and produces much smaller data files than other three-dimensional image capture techniques such as laser scanning (see 2.3.5) or scanning under structured light.[340]

As developed by the National Gallery, the technique captures a series of still images of a painting, each image illuminated by one of a set of 24 lights permanently fixed to a dome above the painting.[341] PTM images have been evaluated as a way of investigating the surface structure of paintings (including evidence of pentimenti), and of evaluating changes to surface structure as a result of various interventions.[342] Whilst the current setup only allows for capture of objects up to about 40 cm x 40 cm, a system which will enable imaging of images up to 2m x 2m with a higher-resolution camera is under development.[343] More portable implementations are also being investigated, including the use of flash and LEDs as light sources.

In addition, PTM allows the storage of other parameters, not just relating to texture and illumination, in the image file. Two examples are depth and position of focus, allowing a user to set the plane at which a PTM image is focussed themselves; and time, allowing the user to determine the time at which an image appeared to be taken.[344] Similarly, PTM might be used to aid the viewing of multi-spectral images (2.3.8) or the images created by neutron activation autoradiography (2.3.11).

40: capture, modelling

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[338] Malzbender et al. 2001, § 4.1; Padfield et al. 2005, p. 504.
[339] Padfield et al. 2005, pp. 504 & 509.
[340] Padfield et al. 2005, p. 504.
[341] Padfield et al. 2005, p. 505.
[342] Padfield et al. 2005, pp. 506-509. Sample files, viewable over the web using a Java viewer, are available online from http://cima.ng-london.org.uk/ptm/; a standalone viewer can also be downloaded from http://www.hpl.hp.com/research/ptm/downloads/agreement.html, both consulted 16 October 2006.
[343] Padfield et al. 2005, p. 510.
[344] Malzbender et al. 2001, § 4.2. It must be remembered that this is not simply a case of selecting one image from a stack held in a single file; each image is interpolated from the file's polynomial texture map, allowing for the selection of images which do not directly match any of those initially captured when creating the PTM.

2.3.11. Neutron activation autoradiography

A work of art is irradiated in a beam of thermal neutrons; immediately afterwards, the irradiated object is placed in contact with a series of conventional x-ray films. These films are exposed by the β-particles emitted by the decaying newly-radioactive elements in the object. Different elements have different radioactive half-lives, and so the amount of radiation which will be emitted at different times after the initial irradiation will vary for different materials. Careful comparison of films exposed at different times after the initial irradiation, in combination with a series of γ-ray energy spectra measurements, will therefore allow for the identification of certain materials, the most notable omission being organic pigments.[345] In addition, elements which are invisible to the naked eye or to conventional x-radiography are sometimes revealed. Although used in the 1970s and 1980s, the technique appears to have gone out of fashion.

As described in 1982, the technique relied upon examination of the exposed photographic films with the naked eye; however, as analysis of the films depends upon their position in a chronological sequence, digital imaging may further aid interpretation by:

- using direct digital capture of the emitted radiation, allowing for more flexible and sophisticated analysis of the changing radiation patterns over time
- combining digitised images of the x-ray films or digital capture files in animations
- using automatic processing to isolate areas which occur in specific exposures and so are characteristic of particular substances

41: capture

2.3.12. Computed Tomography ('CT scanning')

Computed tomography (also known as computerised axial tomography, CT scanning or CAT scanning) is a well-established medical technique whereby a series of x-rays taken around a patient are digitally assembled into a 'slice' through the patient's body. A series of such slices can in turn be assembled into a three-dimensional image of the body. More recent developments include multi-slice and helical scanning. In the former, many slices are captured at once, reducing the potential for artefacts caused by breathing or heartbeat, common when a series of slices are captured in sequence, as well as producing a higher resolution image. In the latter, the sensors move in a single helix around the body, resulting in a single helical slice which is then integrated into the three-dimensional model. The two can be combined.

The technique can also be applied to other objects, including works of art. For example, Sarrió and Blay describe the application of multi-slice computed tomography to the eighteenth-century wooden sculpture known as *Cristo de la Peña* in Guadassuar, revealing the internal structure and construction of the object.[346] The Lansdowne Madonna, one of

[345] Ainsworth et al. 1982, pp. 9-12, 96 & 101-110.
[346] Sarrió & Blay 2006; see also the image in Abbott 2006.

two known versions of Leonardo da Vinci's *Madonna of the Yarnwinder*, has recently been examined using computed tomography, revealing the basic structure of the painting and its support.[347] However, the system as currently configured is not yet sensitive enough to discriminate between individual paint layers (unlike conventional examination under the microscope of samples removed from a painting, or optical coherence tomography (2.3.15)), although this remains a possibility if the technique is optimised for the examination of works of art.

Recent developments include a microscopic implementation of the technique (2.3.13).

42: capture

2.3.13. X-ray micro and nano computed tomography

The techniques of medical computed tomography (2.3.12) have been extended, with the use of more intensive radiation and/or longer exposure times and a rotating sample holder rather than a rotating x-ray head and sensor, to work on a microscopic level. This effectively produces microscopic three-dimensional models and cross-sections of the sample.[348] The main limitation is the small maximum size of sample which can be imaged. The technique permits the examination of internal structures in three dimensions, without the deformation which would be caused by sample preparation such as coating or slicing: it is inherently non-invasive. Whilst the technique images x-ray opacity within the sample, the data collected can be used to map other variables such as different moisture levels. The resulting models can also be subjected to various kinds of quantitative analysis.

The technique can be used on soft samples such as food materials and other domestic substances such as washing powder, as well as more obvious applications such as the imaging of engineering components and materials. Textiles may be one suitable subject for examination, as the technology should enable the analysis of the inner structures of individual fibres, for example.

The technology is young, but evolving fast, and the equipment can now be found in many university departments, provided by manufacturers such as Skyscan.[349] Future developments are likely to lead to nano-scale imaging, able to show clusters of molecules: resolutions of approx. 150-250 nm are already achievable.[350]

29: capture, modelling

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[347] http://www.universalleonardo.org/scientificAnalysis.php?tool=545, consulted 10 October 2006.
[348] For a series of images and animations captured using micro computed tomography, see the Australian National University's X-Ray CT Facility Image Repository at http://xct.anu.edu.au/ct_movies/, consulted 12 January 2007.
[349] For example, the University of Birmingham Department of Chemical Engineering uses a Skyscan 1172: http://www.skyscan.be/next/spec_1172.htm, consulted 17 July 2006.
[350] E.g. the Skyscan 2011: http://www.skyscan.be/next/spec_2011.htm, consulted 17 July 2006.

2.3.14. Raman microscopy

Raman microscopy uses monochromatic laser light to excite the molecules contained in a sample.[351] As they de-excite, the sample's molecules emit a small quantity of light at different wavelengths. The spectrum of light emitted by the sample molecules is different for different molecules and so, by examining the spectrum of light emitted by the sample after stimulation, its composition can be determined. The technique is non-destructive, non-invasive, requires no preparation of the sample, and will indicate precisely where in the sample different substances may be found, down to a resolution of 1 μm. If individual spectral measurements are taken across a sample and assembled into an image, the technique has the potential to combine spectroscopic analysis with imaging.

The technique has been made much more practical with the refinement of laser designs in recent years, whilst the development of fibre-optic probes means that the sample need no longer be placed on a microscope stage. Modern equipment is also portable, and can be taken to the object if necessary. The wavelength of laser used to excite the sample can lie anywhere from the near ultra-violet to the near infra-red. Some care is needed when examining fluorescing materials, as the Raman radiation may be drowned out by any fluorescence stimulated by the probe laser, although this may be reduced by using Fourier Transform Raman spectroscopy, which uses a Neodymium:Yttrium Aluminium Garnet (Nd:YAG) laser and so works further into the infra-red at 1064 nm, albeit with reduced spatial resolution.[352]

The technique has been used recently by the British Library, in conjunction with University College London, to determine the materials used in the text and decoration of illuminated manuscripts and incunabula in their own collections and other institutions.[353] Raman microscopy has also been used to investigate the pigments in samples taken from oil paintings, in ceramics, icons, polychrome sculptures and wall-paintings.[354] This informs research into both the production of objects, reasons for their degradation over time, and possible techniques for their conservation.[355] One aim is to build up profiles of the materials used in particular regions as an aid to the identification of the origin of manuscripts of unknown origin. Location of materials in particular places at particular times will also help develop our understanding of the movements of materials, expertise and people.[356] Another proposal is that the precise knowledge of materials given by Raman microscopy might facilitate the virtual 'restoration' of degraded objects. The technique also has implications for the authentication of works of art.[357]

43: capture

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351 See http://www.bl.uk/about/collectioncare/pdf/raman.pdf, consulted 10 October 2006.
352 Howe 2004, p. 42; Clark 2005, p. 167.
353 Chaplin et al. 2005; Clark 2005, pp. 169-74.
354 Clark 2005, pp. 174-80.
355 For degradation, see Clark 2005, pp. 181-3.
356 These are subjects of increasing interest: see for, example, the recent conference on *The European Trade in Painters' Materials to 1700*, held at the Courtauld Institute, 11-12 February 2005: http://www.courtauld.ac.uk/researchforum/conferences/archive04-05.html, consulted 20 October 2006.
357 Clark 2005, pp. 163, 175, 177, 179-80 & 183.

2.3.15. Optical Coherence Tomography (OCT)

Optical coherence tomography uses low-coherence light (i.e. light with a broad range of frequencies, rather than the single frequency of coherent light).[358] This is split into two beams, one travelling to a reference mirror before being reflected back to a sensor, the other travelling to the object of interest before being reflected back to the same sensor. If the path travelled by the light to the mirror and the sample are of the same length, then any irregularities on the sample cause the light travelling back from it to the sensor to be slightly out of phase with the light from the reference mirror. (The principle is that of the Michelson Interferometer, developed for astronomical observations.) The irregularities therefore manifest themselves as a series of interference patterns.

The technique was originally developed for *in vivo* imaging of biological tissues, notably the eye. It has the advantages of being non-contact, non-invasive and low-power, and not requiring dyeing or staining of the object of interest. It can provide images at cellular and sub-cellular resolutions. It has also recently been applied to works of art, as it is possible to penetrate to a limited depth into the sample, giving both images of paint layers below the surface of the object, and information which indicates how far below the surface the region of interest lies.[359] This is a major advantage over infra-red reflectography (2.3.9), which cannot indicate the depth of the image it produces. The system also works in real time.

By using mirrors to scan the sample beam along the x- and y-axes, a two-dimensional image can be acquired; if a penetrating wavelength of light (e.g. infra-red) is used, a three-dimensional scan can be produced by also moving the reference mirror. The slices through the sample produced by this technique are assembled into a three-dimensional image. Systems have been developed which work in the near infra-red spectrum (850 and 1300 nm), with transverse resolution of as little as 15 µm and depth resolution of 18-20 µm; on paintings, they can penetrate up to approximately 1 mm below the surface, depending upon the materials under examination. Whilst the technique is able to penetrate substances such as silver foil, highly-scattering materials (for example, yellow ochre) remain problematic. The system can produce images of varnish layers, as well as infra-red images which appear sharper and with greater contrast than those taken with the InGaAs camera (see 2.3.9). The technique therefore has the potential to aid investigations into:

- The evolution of the finished painting
- The style of the underdrawing
- The materials and technique of the underdrawing
- The subsequent conservation treatment of the painting

Recent developments in OCT include the use of wide-bandwidth short-pulse solid-state lasers, enabling capture at video frame rates and higher resolutions (as low as 1.5 µm), as

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358 The technique is described in Boppart 2006; a more theoretical discussion can be found in Sheppard & Roy 2006.
359 Liang et al. 2005a; see also the multimedia file at http://www.opticsexpress.org/viewmedia.cfm?id=85276&seq=1, consulted 24 November 2006.

well as combinations of OCT with other techniques such as multi-photon microscopy, polarisation or spectroscopy.[360]

44: capture

2.3.16. X-Ray Fluorescence (XRF)

The object to be investigated is illuminated with x-rays. However, x-ray fluorescence does not image the shadows caused by x-ray-opaque parts of the object, as happens in conventional x-radiography (see 2.3.8). Instead, secondary x-rays are detected, which have been created by the excitation of certain substances within the object by the x-rays to which it has been exposed. As different elements generate fluorescence x-rays at different wavelengths, the technique can be used to image the presence of different elements at different locations within the sample. If very long capture times are to be avoided, a source of high-energy x-rays, such as a synchrotron, is required.

The technique has been applied to the Archimedes Palimpsest, producing the clearest images to date of original text concealed beneath the ink of the secondary text.[361] The project used the Stanford Synchrotron Radiation Laboratory. The imminent and much-published opening of the U.K.'s new research synchrotron, the Diamond Light Source, will potentially facilitate access to the high-energy x-rays necessary to render this technique a useful analytical and imaging tool.[362]

45: capture

2.4. Modelling

2.4.1. Synthetic environments

The terminology comes from modelling and visualisation in military contexts, and refers to the connection of a series of discrete digital components so that they inter-operate in a real-time environment.[363] The components may be any of a range of objects such as digital models of hardware, ordnance, terrain or supply lines; physical simulators; graphics systems; or software used in real-life operations. Synthetic environments are created when the scenario being examined is entirely virtual; if real-world data are included, the technology is known as 'synthetic wrap' (2.4.2). Whilst one might assume that the

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[360] Bopart 2003, pp. 314-22.
[361] http://www.archimedespalimpsest.org/imaging_experimental4.html, consulted 15 September 2006.
[362] Information about the Diamond Light Source is available at http://www.diamond.ac.uk, consulted 15 September 2006.
[363] E.g. the British Aerospace Intelligence, Surveillance, Target Acquisition and Reconnaissance (ISTAR) Synthetic Environment, run in October 1999, http://www.dcmt.cranfield.ac.uk/esd/ssel/baeistar/view; and the student exercises run in the Simulation and Synthetic Environments Laboratory (http://www.dcmt.cranfield.ac.uk/esd/ssel) of Cranfield University's Defence College of Management and Technology, http://www.dcmt.cranfield.ac.uk/esd/ssel/longhaul/view. All sites consulted 1 November 2006.

technology is intended to produce photo-realistic visualisations, this need not be the case: it is the combination of discrete digital components that is the defining factor.

4: interfaces, modelling, image processing, visualisation

2.4.2. Synthetic wrap

Like synthetic environments (2.4.1), synthetic wrap refers to a combination of virtual components so that they inter-operate, but extends the inter-operability to include activities in the real world. For example, an armoured battalion would carry out a real-life exercise on Salisbury Plain, but the digital systems they rely upon might be fed information relating to an entirely virtual conflict taking place across the entire British Isles. As with synthetic environments, photo-realistically rendered interfaces are not necessarily the aim of synthetic wrap; rather, it aims to combine digital ('synthetic') and real-world data so that the two can interact.

5: interfaces, modelling, image processing, visualisation

2.4.3. Automatic construction of three dimensions from two-dimensional images

Hewlett Packard's HP Labs have been working on 'image-based graphics', in which new two-dimensional views are produced from other two-dimensional images or videos.[364] Polynomial Texture Mapping, 2.3.10, is one aspect of this research.

A more finished product has been announced by Microsoft who, in collaboration with the University of Washington, have developed Photosynth, which combines the Washington 'Photo Tourism' system with image zooming and streaming technology developed by Seadragon.[365] Photosynth 'takes a large number of photographs of a place or object, analyzes them for similarities, and displays them in a reconstructed 3-Dimensional space'. The images may come from a mixture of sources, be taken under different conditions, and be of variable sizes. The system isolates many distinctive features in each image, and connects images that share matching features. Multiple images displaying the same feature are then used to calculate the feature's position in three dimensional space. The system is also able to calculate camera positions and directions for each image. The end result is a point cloud of distinctive features, over which the original photographs are laid. The image viewing component displays the images as three-dimensional models; the image-zooming technology developed by

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[364] Slabaugh et al. 2001 provides a technical survey of methods for reconstructing volumetric information from photographs; Slabaugh et al. 2004 discuss further technical developments; a brief summary of activity is available at http://www.hpl.hp.com/research/mmsl/projects/vision.html, consulted 1 November 2006.
[365] Photosynth: http://labs.live.com/photosynth/ and particularly http://labs.live.com/photosynth/whatis/ and linked pages, and http://labs.live.com/photosynth/blogs/SIGGRAPH+2006+And+A+Quick+Update+On+Photosynth.aspx (all consulted 15 September 2006); Photo Tourism: Snavely 2006, http://phototour.cs.washington.edu/, and see the online demo at http://phototour.cs.washington.edu/applet/index.html (consulted 31 October 2006); Seadragon: http://labs.live.com/Seadragon.aspx (consulted 31 October 2006).

Seadragon renders the process of moving around and zooming into the model as smooth as possible, depending upon screen size and bandwidth: the size of the original image or of the digital model is not a limiting factor.

Microsoft are also proposing that the point clouds generated by Photosynth could be used for content-based image retrieval (see also 2.9.1), effectively retrieving images which showed the same object, regardless of orientation. They also suggest extending this capacity to deliver automatic tagging of images (see 2.8.1), something already carried out in the earlier Photo Tourism system. Photo Tourism was also used, in conjunction with digital elevation maps, to reconstruct the point from which Ansel Adams's famous photograph *Moon and Half Dome, Yosemite*, was taken; this suggests a potential application for historians of photography and, possibly, for historians of landscape painting – although the potential 'inaccuracies' in depiction introduced by artists may prove too much for the system.

However, in its current form the system is processor-hungry, and the image matching can take hours or even days for large datasets when run on a desktop machine (although Grid technologies, 2.7.1, might enable more powerful computing clusters to be used for the process). Consequently, the focus is currently on developing an ActiveX browser control to allow users to explore pre-processed collections.

The Photosynth/Photo Tourism technology relies upon multiple views of the same scene in order to produce a three-dimensional model. Work has also been carried out at the University of Oxford on the construction of three-dimensional models from a single two-dimensional image.[366] The need for only one image is a significant advantage in cases where, for example, a building has been destroyed and only a single image (or several images with very poor overlap) record its existence.[367] The techniques, which produce precise measurements of objects placed at different distances from the camera using only a single two-dimensional image, are based upon perspective geometry, and 'can be seen as reversing the rules for drawing perspective images given by Leon Battista Alberti in his treatise on perspective (1435)'.[368] Consequently, they need an image which follows the geometric rules of perspective, and with clear, straight-edged structures.[369] Applications have been proposed in forensic science and surveillance (obtaining measurements from single images), and in general virtual modelling.

However, as the reference to Alberti suggests, the technique has also been developed as a tool for the investigation and presentation of paintings.[370] This is based upon the fact that any painting which obeys the laws of linear perspective can be treated mathematically in

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366 http://www.robots.ox.ac.uk/~vgg/projects/SingleView/, consulted 7 November 2006. Leibowitz et al. 1999 outline the basic technique for creating architectural models from single images; Criminisi et al. 1999 give a more detailed account of the metrological aspects.
367 Leibowitz et al. 1999, § 1.
368 Criminisi et al. 1999, § 1.
369 Leibowitz et al. 1999, § 2.2; however, future investigations may include methods for reconstructing less obviously geometrical objects such as human figures: Criminisi et al. 2003, p. 20.
370 Criminisi et al. 2003; an abbreviated version of the same appear was published at Criminisi et al. 2005

the same way as a photograph of a similar subject; in fact, the geometry of paintings is often simpler than that of photographs of complex scenes.[371]

As published by Criminisi, Kemp and Zisserman, the technology comprises a series of techniques which

1. identify edges in a painting
2. use these to establish whether the painting's perspective is consistent
3. establish the painting's underlying geometry and perspective construction
4. produce a three-dimensional model of the painted space
5. fill in any background areas occluded by foreground objects

The technology can also be used to determine the position of the artists' viewpoint (the 'camera position') with respect to the scene depicted.[372] Whilst such investigations could be carried out manually, or using three-dimensional models constructed using CAD software, this method has several advantages:[373]

- it uses information directly available from the image itself, and no re-drawing is involved; this means that any internal inconsistencies within the painting or the reconstruction are immediately apparent
- a series of assumptions about how the space in a painting is constructed can be systematically described and easily explored
- it retains the textures and colours of the original image
- inaccuracies in the original perspective construction and in the reconstruction can be quantified and, in the case of the latter, corrected
- background areas occluded by foreground objects can be reconstructed systematically

Individual components of the technique are of some interest in themselves. For example, the developers have published three basic methods for assessing the accuracy of the perspective construction in a painting, all of which can be automated to some extent:[374]

- examining the consistency of the vanishing points, applied to Hendrick van Steenwijk's *St Jerome in his Study* (Amsterdam , coll. Joseph R. Ritman) and Jan van Eyck's *Arnolfini Portrait* (London, National Gallery)
- examining the rate of recession of regular patterns, applied to Saenredam's *Interior of the Church of St Bavo, Haarlem* (Edinburgh, National Galleries of Scotland)
- comparing the heights of human figures (which has the added advantage of identifying any figures whose size is altered as an indication of their status), applied to Piero della Francesca's *Flagellation* (Urbino, Galleria Nazionale delle Marche; Figure 48) and Raphael's *Marriage of the Virgin* (Milan, Brera)

[371] Criminisi et al. 2003, pp. 1 & 5.
[372] Criminisi et al. 1999, fig. 12.
[373] Criminisi et al. 2003, p. 3.
[374] Criminisi et al. 2003, pp. 4-10.

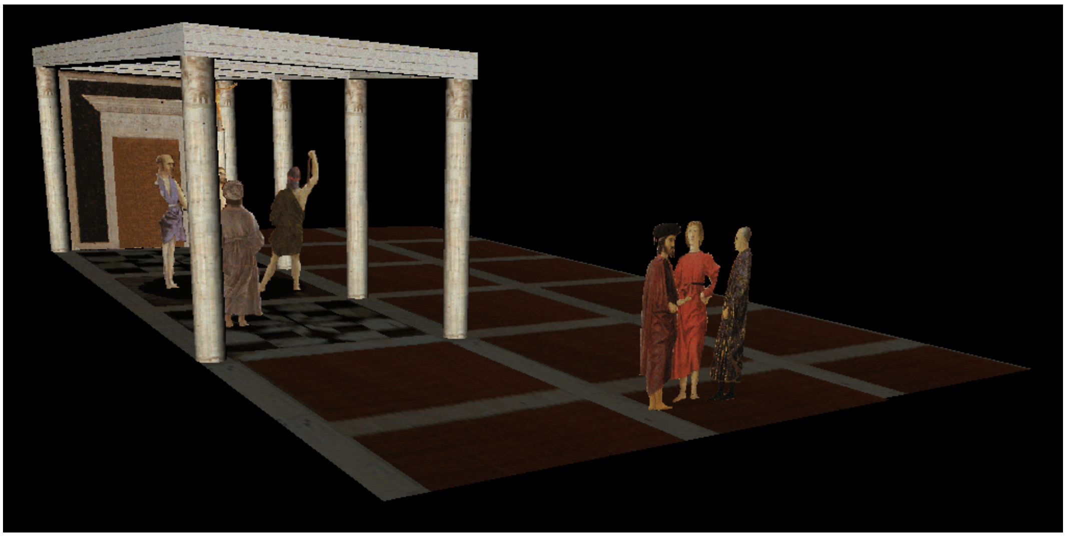

Figure 48. A three-dimensional model of Piero della Francesca's *Flagellation* generated directly and automatically from an image of the painting. Courtesy of Dr A. Criminisi, Microsoft Research Ltd, Cambridge, UK.

In establishing the painting's underlying geometry, the system can be used, for example, to examine the complex patterns often depicted on floors or carpets in extreme foreshortening, as has been carried out on the tiled floors of Piero's *Baptism* (Figure 48) and Domenico Veneziano's *St Lucy Altarpiece* (Florence, Uffizi).[375] Similarly, it can help identify adjustments made by the artist to the space they depict in order to emphasise or de-emphasise parts of the composition – for example, determining that the central dome in Raphael's *School of Athens* (Vatican Palace, Stanza della Segnatura) is elliptical rather than circular in plan.[376] The act of constructing a full three-dimensional model of the structures depicted in a painting can also be used to clarify its precise arrangement and identify inconsistencies.[377] For example, in modelling Masaccio's *Trinity* (Florence, Santa Maria Novella), it was clear that there were two possible, mutually-exclusive, assumptions which might be made about the depicted space: either the ground plan was square, and the coffers in the vault above rectangular; or the plan was rectangular and the coffers square. Two different models were constructed, one for each assumption.[378] The different views offered by the three-dimensional model can make inconsistencies in the artist's rendering much more apparent – for example the irregular thickness of the arch of the large window on the left of van Steenwijk's *St Jerome* – and the system allows the areas where such inconsistencies are more likely to occur to be predicted mathematically.[379]

The models constructed using this technology can, of course, be displayed on their own on a standard computer monitor using the appropriate virtual reality software. They have

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375 Criminisi et al. 2003, pp. 11-12.
376 Criminisi et al. 2003, pp. 12-15.
377 The examples discussed below can be accessed at http://www.robots.ox.ac.uk/~vgg/projects/SingleView/examples.html, consulted 7 November 2006.
378 Criminisi et al. 2003, pp. 18-21.
379 Criminisi et al. 2003, pp. 21-24. Three-dimensional models have also been constructed of Vermeer's *The Music Lesson* (Royal Collection), Criminisi et al. 2003 pp. 25-6; and of Piero's *Flagellation*, Criminisi et al. 2003 p. 21, as well as Leibowitz et al. 1999, § 3.1 and Criminisi et al. 1999, § 5.3.

also been installed in an immersive Cave Automatic Virtual Environment (CAVE).[380] In addition, a small 'virtual gallery' has been constructed, containing two-dimensional images of the paintings, at the appropriate scales, hung on its walls; as visitors pass through the viewing point defined by the perspective construction, they transform into the three-dimensional models, into which visitors can pass.[381]

To summarise, a number of algorithms have been developed which will:[382]

- assess the internal consistency of the geometry in a painting and its conformity to the rules of linear perspective
- generate new views of patterns of interest
- reconstruct occluded areas of the painting
- measure and compare object sizes within the painting
- construct complete three-dimensional models from paintings
- systematically explore possible ambiguities in reconstruction
- assess the accuracy of the reconstructed three-dimensional geometry

Whilst these may seem comparatively abstract capabilities, the techniques outlined above have already been used to answer several very specific questions relating to the geometry of Italian renaissance art:[383]

- 'is the geometry of Masaccio's *Trinity* correct?
- 'how deep is the *Trinity*'s chapel?
- 'what is the shape of the architectonic structure in Piero della Francesca's *Flagellation*?
- 'what is the shape of the dome in Raphael's *School of Athens*?'

Potential uses suggested by the techniques' developers include:[384]

- development of tools which clarify the relationship between perspective constructions and finished paintings
- assessing the levels of individual artists' concerns with perspectival accuracy
- identifying departures from strict perspective constructions and analysing possible reasons for them
- exploring the relationships between the viewpoints defined by perspective constructions and those which are available to spectators in the paintings' original locations
- setting paintings within virtual reconstructions of their original locations

The system can also make objects shown in extreme foreshortening much clearer, possibly enabling the more detailed examination of details within the image.

19: capture, modelling, image processing, visualisation, categorisation/ordering, finding

2.4.4. Visualisation, particularly three-dimensional modelling

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[380] Criminisi et al. 2003, p. 22.
[381] Criminisi et al. 2003, pp. 26-7.
[382] Largely quoting directly from Criminisi et al. 2003, p. 31.
[383] Quoting from Criminisi et al. 2003, p. 1.
[384] Criminisi et al. 2003, p. 31.

Visualisation techniques and accompanying large-scale three-dimensional display technologies are already widespread in the archaeology and cultural heritage sectors, forming a significant part of large-scale projects such as EPOCH (European Research Network on Excellence in Processing Open Cultural Heritage),[385] and the focus of organisations such as the Virtual Archaeology Special Interest Group (VASIG) and the Cultural Virtual Reality Organisation (CVRO). Support for the visual arts is provided by the 3D Visualisation in the Arts Network (3DVisA), which lists its aims as being

> … to enhance and extend 3D visualisation-related knowledge, understanding and opportunities in Arts and Humanities domains, where an increasing number of researchers, educators, and learners are creating and/or using 3D visualisation technologies.
>
> 3DVisA aims to bridge the gap in the sharing of knowledge and skills among projects within Arts and Humanities disciplines, and between these and other domains.
>
> 3DVisA will coordinate research on methods and standards, and provide information and advice regarding opportunities for funding or collaboration, intellectual property issues, and commercial exploitation of resources.[386]

Significantly, 3DVisA's theme for 2006-7 is 'Posing Research Questions in the Visual Domain: Training, conceptual model overview & interdisciplinary translation', and to this end they will be running an entry-level conference with the same title in the first week of February 2007.[387] More general support for the academic community is provided by the UK Visualisation Support Network (VizNET).[388] Many academic institutions maintain centres which work with visualisation technologies, for example those at the University of Birmingham, King's College London, Birmingham Institute of Art and Design and Glasgow School of Art.[389]

49: interfaces, modelling, image processing, visualisation, display, collections

2.5. Image processing

2.5.1. IIPImage

IIPImage is a development of the Internet Imaging Protocol (IIP), begun by the National Gallery, London and the University of Southampton to address the problems involved in disseminating very large, high-quality, two- and three-dimensional image files over the

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[385] http://www.epoch-net.org, consulted 8 September 2006.
[386] http://3dvisa.cch.kcl.ac.uk, consulted 8 September 2006.
[387] http://3dvisa.cch.kcl.ac.uk/PRQconference.html, consulted 8 September 2006.
[388] https://www.viznet.ac.uk; note the list of visualisation centres at http://www.viznet.ac.uk/viznetcentres.html, and that further information is available on the VizNET wiki at https://wiki.viznet.ac.uk/bin/view/VizNET/WebHome; all sites consulted 13 November 2006.
[389] The University of Birmingham Visual and Spatial technology Centre, http://www.vista.bham.ac.uk, consulted 30 October 2006; the King's Visualisation Lab, http://www.kvl.cch.kcl.ac.uk, consulted 8 November 2006; the Visualisation Research Unit at Birmingham Institute of Art and Design, http://www.biad.uce.ac.uk/vru/index.php, consulted 30 November 2006; the Digital Design Studio at Glasgow School of Art, http://www.gsa.ac.uk/gsa.cfm?pid=12, consulted 11 December 2006.

internet.[390] The system uses 64-pixel tiles derived from the original file at several resolutions, which are compressed using the JPEG system and stored in a TIFF file. Like other tiling technologies, the system only delivers the tiles which are required by the user, thereby greatly reducing bandwidth requirements. It can easily deliver images which, uncompressed, measure hundreds of MB; it is currently serving a 10.7 GB image of the complete surface of the earth with no obvious difficulty.[391] The system is based upon the CGI technology, and so is highly compatible with a variety of web servers. This also means that it can use a variety of client-side technologies; versions have been developed using Java, JavaScript, and combinations of the two.

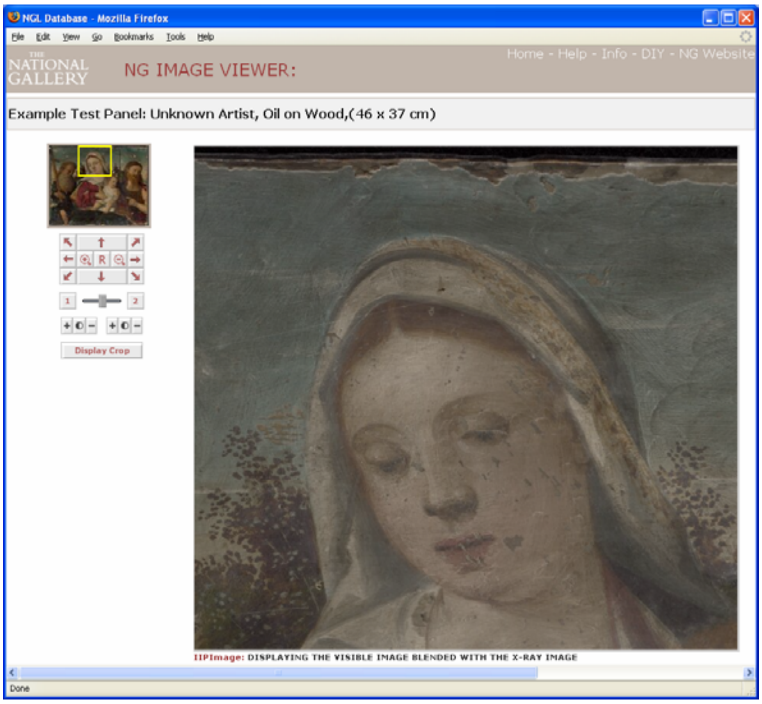

Figure 49. Screenshot of a demonstration JavaScript IIPImage client showing delivery of high-resolution images and the ability to cross-fade between two images (a painting and its x-ray). Website and client developed by Joseph Padfield, image server developed by Ruven Pillay and Denis Pitzalis.

Image downloaded from http://cima.ng-london.org.uk/~joe/ngv_example/viewer.html?painting=1, 15 January 2007.

The current version, or imminent releases,[392] have several features which make them particularly attractive to users who wish to deliver the highest possible image quality:

- it can store image files which use the CIE colour-space, read the client's display's ICC colour profile, and generate a custom colour-matched image on the fly
- it can work directly with 16 bits-per-channel images
- it can compare two different images by superimposing them and allowing the viewer to select their relative transparency

[390] http://iipimage.sourceforge.net/, consulted 11 December 2006; see also Martinez et al. 2000.
[391] See http://iipimage.sourceforge.net/demo.shtml, consulted 11 December2006, for this and other demonstrations of very large files being served by IIPImage.
[392] For a demonstration of the latest server running in conjunction with a javascript client, see http://cima.ng-london.org.uk/~joe/ngv_example/, consulted 15 November 2006.

- the system can record commonly-fetched tiles and use these to pre-fetch the most popular tiles whilst the client is otherwise unoccupied, optimising download time for the majority of users
- the image displayed can resize itself dynamically if the size of the browser window is changed
- the client can generate 'snapshot' images of particular views for downloading and incorporation into other systems (e.g. PowerPoint)

The system is available as open source software.

57: collaboration, image processing, display, collections

2.5.2. Visually significant barcodes

The barcodes with which we are most familiar from product packaging are one-dimensional – the series of stripes they contain can be read only along one line, in one dimension. Two-dimensional barcodes have also been created, such as the PDF417 standard, where the data is arranged horizontally and vertically in a grid of elements (i.e., in two dimensions). However, the pattern of marks in such a barcode has no obvious visual significance: it does not resemble anything. Hewlett Packard's HP Labs have developed 'visually significant barcodes', in which the barcode pattern creates an image as well as carrying non-visual data.[393] These barcodes are capable of displaying both graphical images (logos etc.), and barcodes which embody a coarse greyscale image.[394] Graphical barcodes are also capable of containing digital signatures, allowing their integrity and authenticity to be confirmed.

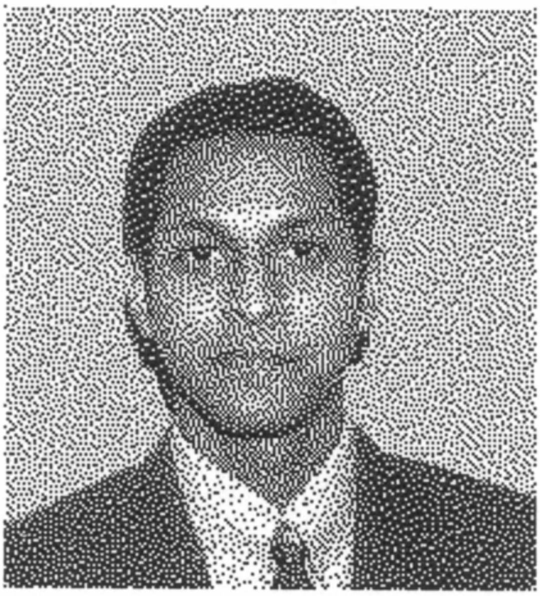

Figure 50. A visually-significant barcode, developed by HP Labs. Copyright (2007) Hewlett-Packard Development Company, L.P. Reproduced with permission.

[393] http://www.hpl.hp.com/research/isl/vsb/, consulted 8 November 2006.
[394] For the former, see Shaked et al. 2003; for the latter Damera-Venkata & Yen 2003.

20: modelling, image processing, categorisation/ordering, display

2.6. Visualisation

Visualisation tools for use on digital audio-visual data are discussed in the recent AHRC Strategy report on audio-visual media.[395]

2.6.1. Physics-based visualisation

This technique takes data with multiple aspects to each item, and produces a three-dimensional representation of the relationships between the data. At its root lie techniques for projecting multiple dimensions down into two or three dimensions, coupled with a model for visualising the relationships between the data which uses simulated physics. Each data element is considered as a point, joined to all the other elements by springs. The tension in each spring relates to the degree of similarity between the data elements which it connects. Once the system has found its equilibrium, the three-dimensional relationship between data elements reflects their similarity, with similar elements being clustered together.

The technique has been implemented at the University of Birmingham as ClusterVis, and a demonstration application and dataset (based on the chemical properties of olive oils from different regions in Italy) is available as a download; this makes the basis of the visualisation rather clearer.[396] ClusterVis can handle up to 3,000 records if used live on a desktop computer, and more if information is processed offline or on a high-performance machine or cluster. It can also automatically generate descriptive rules which define the attributes of a particular cluster. The system has already been applied to the visualisation of networks (notably mobile phones, and criminals). It has also been used as a means of analysing website log files, providing visualisations of routes taken through complex sites, weighting the number of times individual pages have been visited and particular links have been followed. In this form, the system can also run beyond a single website and out into the wider web. It can also be updated dynamically to produce a snapshot of the current state of a site.

14: modelling, visualisation, categorisation/ordering, finding images

2.7. Processor power

2.7.1. Grid computing (and e-Science)

Grid computing describes a series of technologies developed to provide access to distributed high-powered computing resources.[397] Whilst the shaping vision of the grid is

[395] Marsden et al. 200, § 3.6.3 on pp. 45-6.
[396] http://www.cs.bham.ac.uk/~cmf/cluster/, consulted 30 November 2006.
[397] See http://www.ahessc.ac.uk/briefing_papers/Grid_BP.pdf, consulted 31 August 2006.

an internet-like global application providing transparent access to these resources, it seems fair to say that this is still some way off for the arts and humanities: significant technical knowledge is still required to create and run grid applications.

Conceptually, grid computing can be divided into:

- Computational grids, providing access to high-performance processor clusters, super-computers, and distributed computing networks, in order to provide substantial computing power.
- Data grids, providing combined access to distributed data resources.
- Service grids, providing specific computing functions (for example, a tool to compare two datasets), which can be combined with other services to perform particular tasks.

Many scientific grid applications exploit two or three of these different facets of grid computing, creating 'virtual organisations' or 'virtual research environments' (VREs).[398]

It should be noted that the Access Grid (2.1.1), enabling distributed collaboration over high-performance networks, is another grid-related technology.

At the time of writing, there are few grid applications for the visual arts. Some work is being done in the field of manuscript studies, notably the Virtual Vellum project (2.1.6), which is producing a VRE for the investigation of late-medieval manuscripts of texts by Froissart, including their illuminations. However, the grid does offer possibilities for the virtual combination of distributed datasets (e.g. image banks, multimedia databases), and for processor-hungry tasks such as automatically creating or rendering large three-dimensional models or animations (2.4.3, 2.4.4),[399] or processing images and videos on the fly for content-based image retrieval (2.9.1). For example, the Resource-Aware Visualisation Environment (RAVE) project at the Welsh e-Science Centre at Cardiff University uses grid technologies to distribute high-end visualisations of data in ways that take account of the potential or limitations of the client systems – to take one example, distinguishing between the extensive data required for a full immersive environment and the minimal data which can be displayed on a PDA.[400] The project also provides access to substantial computing power for rendering complex datasets beyond the capability of local clients.

Grid computing is usually considered to be one facet of e-Science,[401] and so support and advice for researchers in the arts and humanities in the U.K. who wish to investigate grid technologies can be obtained from the Arts and Humanities e-Science Support centre (AHeSSC) at http://www.ahessc.ac.uk. e-Science developments are showcased at the annual 'All Hands' meetings (http://www.allhands.org.uk/), which are increasingly incorporating arts and humanities implementations into their proceedings. The UK also has a national grid service providing coordination and support (http://www.grid-support.ac.uk/).

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398 For the latter, see http://www.ahessc.ac.uk/briefing_papers/VRE-BP.pdf, consulted 31 August 2006.
399 Examples can be found in Blaxill 2006, § 5.
400 http://www.wesc.ac.ukprojectsite/rave/, consulted 8 May 2006.
401 http://www.ahessc.ac.uk/wiki/bin/view/WorkShops/EscienceIntroduction, consulted 21 November 2006.

Several projects are currently underway to develop the use of e-Science in the arts and humanities. A scoping study is being conducted by the AHDS, which should be reporting imminently.[402] The conclusions of the survey's seminar on the visual arts are already available via the project website.[403] In addition to Virtual Vellum, mentioned above, two other projects are of particular relevance to visual arts researchers:

- AMUC: Associated Motion Capture User Categories, investigating whether libraries of motion-capture data assembled for different purposes and using different standards can be combined in useful ways[404]
- Building the Wireframe: E-Science for the Arts Infrastructure has presented a series of workshops aimed at introducing visual arts researchers to e-Science technologies[405]

23: collaboration, image processing, video, processor power, storage, finding images, access

2.7.2. Cluster computing

Although neither new nor an imaging technology, cluster computing – where a group of small computers works together in a way that resembles one large computer – is an established technology for providing substantial computing power relatively cheaply. The small computers it uses are usually commercially available servers or desktop machines. Cluster computing is already used extensively in industry for rendering animations, CGI, and other processor-intensive tasks relating to images. There are numerous software systems available for managing clusters, and some of these – such as Hewlett Packard's Scalable Visualization Array – are directed specifically at tasks such as rendering.[406]

Many clusters use dedicated computers, but there must be potential in many institutions to exploit the capacity of the many computers attached to the network and not in use at any given time (overnight, for example) for tasks such as rendering animations, extracting three-dimensional models from two-dimensional images (2.4.3), or characterising images for content-based retrieval (2.9.1). This would work in a way similar to the best-known distributed computing project, SETI@home, which exploits idle time on internet-connected computers across the world to process radio telescope data in the Search for Extra-Terrestrial Intelligence (SETI).[407] The software used by SETI@home, Berkeley Open Infrastructure for Network Computing (BOINC) is open source, and is already being used by a significant number of distributed projects.[408]

16: collaboration, visualisation, processor power, finding images, access

[402] http://ahds.ac.uk/e-science/e-science-scoping-study.htm, consulted 21 November 2006; see also Blaxill 2006.
[403] Gollifer 2006.
[404] http://www.ncl.ac.uk/culturelab/research/amuc.htm, consulted 22 November 2006.
[405] http://www.biad.uce.ac.uk/vru/escienceworkshops/, consulted 22 November 2006.
[406] http://h20311.www2.hp.com/HPC/cache/281455-0-0-0-121.html, consulted 22 November 2006.
[407] http://setiathome.berkeley.edu, consulted 23 November 2006.
[408] http://boinc.berkeley.edu; a partial list of current projects using BOINC is provided at http://boinc.berkeley.edu/projects.php, both consulted 23 November 2006.

2.8. Categorisation/ordering

2.8.1. Annotation

Various projects have been addressing the related issues of

- how to attach annotations to specific sections of images (comparatively straightforward)
- how to allow users to attach their own annotations and share them with other users (more complex)

Neil Grindley, in his discussion of 'What's in the art historian's toolkit?', notes a couple of projects which have successfully met some of these challenges.[409]

Pliny is a tool 'for supporting certain kinds of scholarly research' which is centred around the creation and organisation of notes.[410] Programmed in Java and running in the Eclipse environment, it can work with non-digital and digital resources, effectively embedding annotations in digital resources such as images, texts (PDF files at the time of writing) and websites. Pliny is still a prototype, being developed by John Bradley at the Centre for Computing in the Humanities, King's College, London. Although it focuses upon the creation and organisation of annotations rather than their sharing, it does so in ways that are specifically intended to meet the needs of humanities researchers, including art historians and practice-led researchers. As Grindley notes, it has the potential to become 'a computing tool that can support the scholarly act of interpretation across formats at a truly useful level of detail'.[411] Currently, annotations are created, stored and used locally, but if it can be developed to allow users to share their annotations, then Pliny has the potential to become a significant aid to collaboration.

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[409] Grindley 2006, pp. [2]-[4].
[410] http://pliny.cch.kcl.ac.uk, consulted 18 September 2006.
[411] Grindley 2006, p. [4].

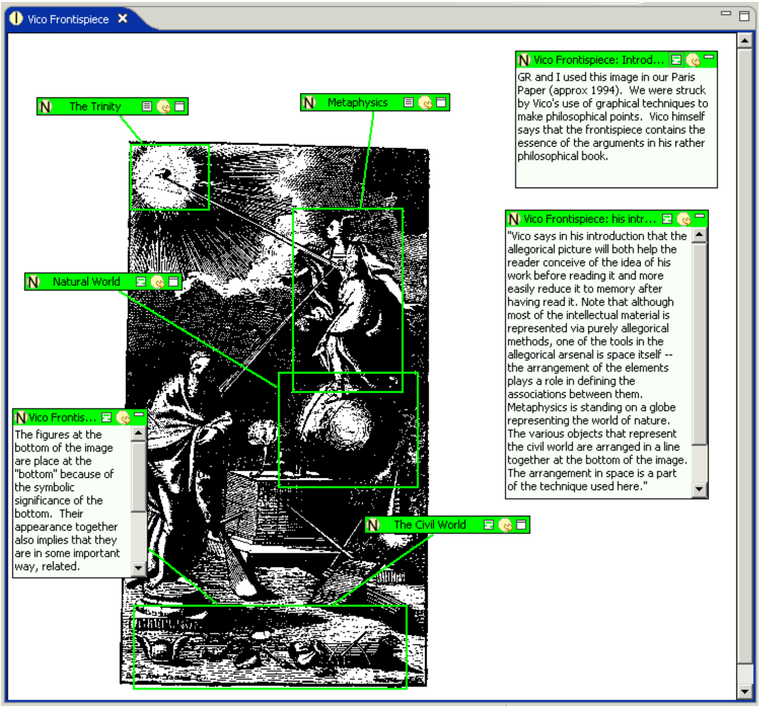

Figure 51. Frontispiece of Vico's *New Science* with overlaid annotations created within the *Pliny* software. Image courtesy of John Bradley.

The Online Chopin Variorum Edition (OCVE) presents images of source material for Chopin's compositions online, together with annotations added to sections of the images by the project's staff and a set of tools for comparing and superimposing the images of individual bars within the web browser.[412] Although the ability to add comments is currently restricted to project staff, the intention is that any registered user will be able to add their own annotations to the site at a future date.[413] However, as the project is web-based, annotations will presumably be stored on the server, and only available to their creator if they are online.

The Digital Archive of Medieval Music (DIAMM) presents registered users with a series of large-format, high-resolution images of manuscript pages, which they can annotate.[414] Although once again comments are presumably stored on the server, and comments can only be added to images as a whole, the project is significant in applying the technology to large image files, which can be magnified on screen using the 'Zoomifyer' tool.[415]

412 http://www.ocve.org.uk, in particular http://www.ocve.org.uk/content/description.html (consulted 18 September 2006).
413 http://puffin.cch.kcl.ac.uk:8080/ocve/docs/index.html (consulted 18 September 2006).
414 http://www.diamm.ac.uk (consulted 18 September 2006).
415 http://www.zoomify.com (consulted 21 September 2006).

Figure 52. Annotating an image of medieval manuscript using the DIAMM annotation tool. Reproduced by permission of the Digital Image Archive of Medieval Music (DIAMM) http://www.diamm.ac.uk; image shown detail of Bodleian Library, MS. Douce 139, fol. 5 © Bodleian Library.

Grindley also notes the presence of annotation functions on other online image resources, such as ARTstor and the Courtauld Institute's *Art and Architecture* site.[416] Flickr also allows users to annotate specific parts of images, and share these annotations with other users.[417] As all these examples show, much work is being done on the process of annotating images and sharing those annotations, but the full list of desirable features – for example,

- ability to add annotations
- ability to annotate discrete sections of images
- ability to share annotations
- browser-independence (if relevant)
- ability to add annotations to a combination of on-line and local images
- ability to access one's own or stored annotations off-line

– have not yet been implemented in a single application.

It has also been suggested that systems for content-based image retrieval (2.9.1) and constructing three-dimensional models from two-dimensional images (2.4.3) be used to automatically annotate large collections of images with metadata based upon the images' visual similarity to already-labelled images. For example, the Photo Tourism system will take annotations applied to one section of a three-dimensional model, and apply them to the same section on all images which also show that section.[418]

Annotation tools for time-based media are discussed in the AHRC strategy report on audio-visual media.[419]

[416] Grindley 2006, p. [3]. http://www.artstor.org (see http://www.artstor.org/webhelp/Add_comments_to_an_image.htm); http://www.artandarchitecture.org.uk (see http://www.artandarchitecture.org.uk/about/image_sets.html); all consulted 18 September 2006.
[417] http://www.flickr.com (see http://www.flickr.com/learn_more_3.gne), consulted 23 November 2006.
[418] Snavely et al. 2006, § 7.2.
[419] Marsden et al. 2006, § 1.2.3.2 on p. 6 & § 3.3 on pp. 29-36.

47: collaboration, image processing, categorisation/ordering, collections

2.8.2. *Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH)*

The Open Archives Initiative (OAI) 'develops and promotes interoperability standards that aim to facilitate the efficient dissemination of content'.[420] One of its major undertakings has been the development of a standard for the querying of metadata on remote systems – otherwise known as 'harvesting'. This is known as the OAI Protocol for Metadata Harvesting (OAI-PMH), and is a well-established technology in the area of institutional repositories.[421]

Harvesting allows users to query the metadata in multiple remote systems using a single search interface, and to view the data returned in a single, unified results screen. The user then follows links to the full records held on the remote systems. The protocol uses XML files to transfer information based on the Dublin Core metadata standard, although extensions are available to serve the needs of different user groups. The benefit to the user is a single interface to multiple collections of data; the benefit to data owners lies in its combination of relatively easy implementation with complete control of the original catalogue record, which continues to be hosted on their own servers and served to users with their own branding.

Whilst OAI-PMH is well-established in the field of text-based institutional repositories (it is automatically provided by most of the major repository systems[422]), very few image collections have exposed their metadata for harvesting. (The potential use of the protocol for sharing images is discussed in the *CLIC* report.[423]) However, the Getty Research Institute has recently released their CDWA Lite metadata standard, an implementation of their Categories for the Description of Works of Art (CDWA) and the Visual Resources Association's Cataloguing Cultural Objects (CCO) in XML which is 'intended for contribution to union catalogs and other repositories using the Open Archives Initiative (OAI) harvesting protocol'.[424] This effectively tailors OAI-PMH to the needs of visual arts researchers, allowing OAI-PMH to harvest much more extensive information of the kind usually sought by visual arts researchers than would be possible using the basic Dublin Core metadata standard alone.

61: collaboration, categorisation/ordering, finding images, collections

2.8.3. *The semantic web*

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[420] http://www.openarchives.org/, consulted 19 December 2006.
[421] http://www.openarchives.org/pmh/, consulted 19 December 2006.
[422] See http://www.openarchives.org/pmh/tools/tools.php, consulted 19 December 2006.
[423] Miller et al. 2206, § 5.1.1 on p. 32, § 7.1.2 on pp. 38-9, § 10.6.3 on pp. 60-61, & § 10.6.5 on pp. 61-2.
[424] http://www.getty.edu/research/conducting_research/standards/cdwa/cdwalite.html, consulted 19 December 2006.

The semantic web is a broad term covering a number of technologies which, combined, are intended to render the world-wide web machine readable.[425] In its existing incarnation (primarily based upon HTML pages), the information on the web can easily be understood by humans, but not by machines. This makes it difficult for the web to answer complex queries which require the collation of different types of information (e.g. item details, stock levels, prices, shop locations and opening hours), often from different sources. The semantic web aims to enable computers to analyse this information and construct the necessary relationships between people, institutions, things, etc. to answer these complex queries in single stages, without extensive tailoring and refining by the humans asking the questions.

The semantic web also aims to minimise the problems caused by using different data standards and vocabularies. The aim is to enable queries for mezzotint, for example, to return data which are labelled as 'manière noire' (a French term for the technique); or for searches for works by 'artists' born before a certain date to retrieve works where artists are labelled as 'makers'. Similarly, it should help distinguish between uses of the same word which have different meanings: 'author' might refer to the author of a web page, or the author of a book whose details are listed on that web page. HTML-based technologies have difficulty in distinguishing between the two. The semantic web requires the knowledge relating to particular areas of interest ('domains') to be formally characterised using ontologies.

The semantic web is based upon a number of separate technologies, all of which are official W3C recommendations.

- eXtensible Markup Language (XML) provides the basic format in which semantic web data is encoded. Structure is imposed on XML data by defining it using the XML Schema language. Both RDF and OWL encode their data using XML.
- Resource Description Framework (RDF) provides a structured way of describing relationships between digital resources and other entities (other resources, people, objects, concepts, etc.), so that these can be read and understood by computers.[426] RDF descriptions of particular ontologies are defined as RDF Schemas.
- Web Ontology Language (OWL) provides a way of marking up more complex ontologies than can be provided by RDF, allowing machines to reason more extensively about data in an area characterised by that particular ontology.[427]

The semantic web is a set of technologies that are still emerging; a major obstacle to their whole-scale adoption is the time and effort required to encode information all over again in machine-readable forms (though this will no doubt gradually be automated). However, some semantically-enabled knowledge management tools are emerging; most notable amongst these are:

- Piggy Bank, an extension for the Firefox web browser that allows users to combine data from several websites in meaningful ways.[428]

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[425] See http://www.w3.org/2001/sw/; there is also a useful summary of the technology's aims and main components on the Wikipedia at http://en.wikipedia.org/wiki/Semantic_Web; both consulted 19 December 2006.
[426] See the links under 'RDF' on http://www.w3.org/2001/sw/, consulted 19 December 2006.
[427] See the links under 'OWL' on http://www.w3.org/2001/sw/, consulted 19 December 2006.
[428] http://simile.mit.edu/wiki/Piggy_Bank, consulted 19 December 2006.

- Haystack, a semantically-enabled personal information organiser.[429]
- mSpace, a system for displaying complex data in straightforward ways but with a highly flexible structure which can be altered by the user as they browse through the data (Figure 53).[430]

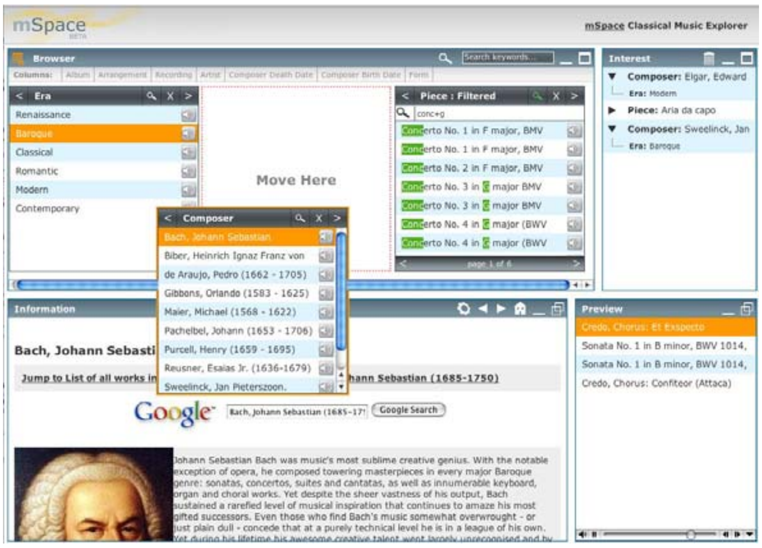

Figure 53. Using mSpace to display complex inter-related information about classical music. mSpace © the School of Electronics and Computer Science, University of Southampton.

Ontology construction is a complex business; but it should be noted that one of the earlier ontologies to be established covered the knowledge domain surrounding museum objects. Known as the CIDOC Conceptual Reference Model (or CIDOC CRM), this is currently available as an RDF Schema.[431] The CIDOC CRM lies behind several semantically-enabled projects which focus upon museums and cultural heritage, the most recent of which is e-Chase (2.9.2), enabling more intelligent cross-searching over datasets created using different standards and vocabularies.

62: interfaces, image processing, categorisation/ordering, finding, collections

2.8.4. Visual interfaces to data

A range of solutions have been proposed in the search for non-verbal ways of organising data, often centring on the use of virtual three-dimensional spaces. This is often linked to the classical and renaissance concept of the 'memory theatre', a mnemonic device in which concepts were associated with objects placed in a virtual space. The CITRIS Gallery Builder (2.1.3) is one of these, whilst physics-based visualisation (2.6.1) – particularly when applied to analysis of website traffic – also uses spatial metaphors to display the relationships between data. Other systems that have come to our attention do not include the collaborative aspect of the CITRIS technology:

[429] http://haystack.csail.mit.edu/, consulted 19 December 2006.
[430] http://mspace.fm/, consulted 19 December 2006.
[431] http://cidoc.ics.forth.gr/, consulted 19 December 2006.

- Hewlett Packard's Virtual Environment Design Automation (VEDA; Figure 54) was developed to automate the process of constructing three-dimensional spaces to in which to place large quantities of digital objects, based upon the objects' metadata, grouping similar classes of object together.[432] The appearance of different areas in the model will vary depending upon their contents; different rules or styles can also be chosen by the user to re-format the virtual environment. The system runs in real time, with views generated on-the-fly. Written in C++ for Windows and using the OpenGL and DirectX APIs, the system was developed using XML databases but should also be able to work with relational databases or three-dimensional object models. Whilst the examples illustrated here seem rather plain and maze-like, they were constructed using only very basic rules; the system is intended to allow the end user to incorporate their own preferences and sensibilities into the environment's design and construction.[433]

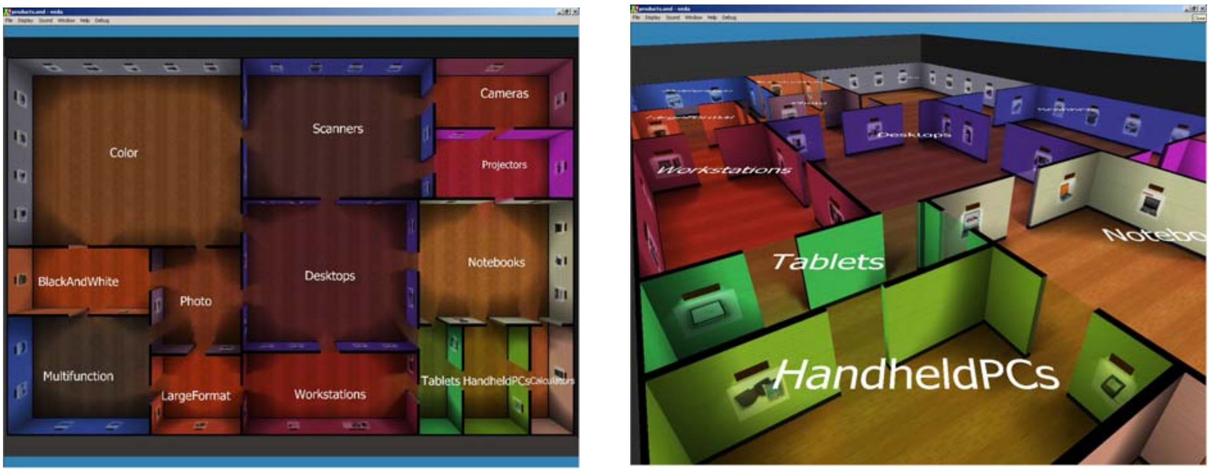

Figure 54. Plan and general view of a three-dimensional interface to data generated on the fly by the VEDA system. Copyright 2006 Hewlett-Packard Development Company, L.P. Reproduced with permission.

- The system being promoted by See-Fish Technology is based upon a similar paradigm, the clustering of digital objects in three-dimensional space according to certain similarities in the data.[434] Their 'See-View' three-dimensional image browsing system bases itself upon image characteristics of the kind used in content-based image retrieval (2.9.1), in order to group images in a three-dimensional space by visual similarity. Users navigate through the space using a virtual reality interface, and click on an image to see the full-size file and any associated metadata.

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[432] http://www.hpl.hp.com/research/isl/veda/index.html, consulted 8 November 2006; Chang & Said, 2004.
[433] Nelson Chang, e-mail communication, 25 January 2007.
[434] http://www.see-fish.com, consulted 11 December 2006.

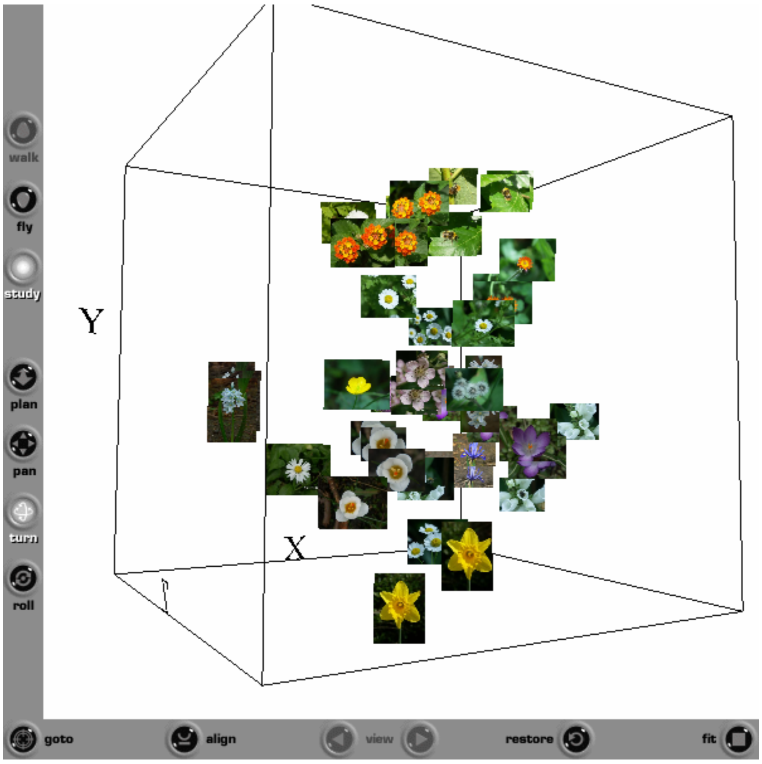

Figure 55. Using See-Fish Technology's three-dimensional system to browse a collection of images, arranged by visual similarity. Individual images © Jon Riley.

- On a more mundane level, MATT Services Ltd are currently marketing Spectasia, a user interface for the Windows desktop which claims to simplify the process of finding items in the Windows environment.[435] It does this by reducing the number of menu layers and providing a much more visual interface to the items, which resembles a receding flat surface with icons placed vertically upon it. The system is java-based, and commercially available.

In their current forms, the most immediate use for these technologies is likely to be as means of browsing collections of objects when one does not know what they contain.

58: categorisation/ordering, finding images

2.9. Finding images

2.9.1. Content-Based Image Retrieval (CBIR)

Content-based image retrieval is the term most commonly used to describe techniques for finding images using their visual appearance, rather than associated textual data; it is also often referred to as 'image matching', and a variety of other terms.[436] Searching is usually carried out by matching a pre-existing image, either chosen from a random

[435] http://www.spectasia.com, consulted 11 December 2006.

[436] A useful introduction to and assessment of the technology is provided in Eakins & Graham 1999. Although many of the projects they mention (see §§ 5.5.1-2 on pp. 29-31) have now wound down, their basic conceptualisation of the issues involved in CBIR remains valid. Significantly, neither Yahoo nor AltaVista now seem to offer an image matching service on their search engines – cf. § 5.6.12 on p. 37.

sample or uploaded by the user, who is effectively asking the system to 'find me an image like this one'. Some systems allow the user to select from a palette of colours or provide some means of sketching an image.[437] In addition, many systems allow users to refine their searches by indicating the relevance of the results returned and re-running the search with these revised criteria.[438] Content-based retrieval for speech, music, video and film is discussed in the recent AHRC Strategy report on audio-visual media.[439]

The technology has the potential for application in crime prevention, military uses, trademark registration,[440] architectural and engineering design, fashion and interior design, journalism and advertising, medical diagnosis (image processing for computer-aided detection of illness and diagnosis), cultural heritage,[441] education and training, home entertainment and web searching.[442] Of these, serious work has been done in the fields of crime prevention, military use, and computer-assisted medical diagnosis and screening. Whilst the reservations that are expressed below of image retrieval are even more true of finding images in multimedia files, particularly video, where the problems are compounded by the large number of single frames which go together to make up a video sequence, video asset management (often in a journalistic context) is also a significant area of current research, and many of the projects which originally began with still image retrieval technologies have developed into video retrieval, where several commercial applications have been developed.[443] However, Eakins and Graham suggested that home entertainment was most likely to be the 'killer application' which would bring CBIR into widespread everyday use.[444] Unfortunately, though, they noted in 1999 that 'much recent work in [CBIR] seems rather derivative, providing research training for PhD students rather than significantly advancing the state of the art'.[445]

Eakins and Graham have produced a useful categorisation of the kinds of query that CBIR might answer. They describe three levels of abstraction:[446]

1. *primitive* features	– e.g. colour, texture, shape, spatial location. Objective and directly observable from images themselves. Largely limited to specialist applications.
2. *derived* or *logical* features	– can be divided into a. retrieval of objects of a given type b. retrieval of individual objects / persons Requires reference to some external source of knowledge about what is represented. Still reasonably objective. Very common form of query.

[437] Eakins & Graham 1999, § 5.1 on p. 23 and § 5.4.1 on p. 27.
[438] Eakins & Graham 1999, § 5.4.1 on pp. 27-8.
[439] Marsden et al. 2006, p. ii, § 1.2.3.1 on pp. 5-6, § 3.3.4.3 on p. 35, & §3.7.3 on p. 48; see also § 3.5.2 on p. 43.
[440] E.g. the *Artisan* system: Eakins et al. 1998.
[441] E.g. the *Collage* system, at one time installed on the Guildhall Art Gallery's website: Ward et al. 2001, Ward et al. 2005
[442] Eakins & Graham 1999, § 2.5 on p. 9; § 3.2 on pp. 11-12; § 5.6 on pp. 31-7.
[443] Eakins & Graham 1999, § 5.2 on p. 25; § 6.3 on p. 41; § 7 on p. 47. Of the projects described by Eakins & Graham in §§ 5.5.1-2 on pp. 29-31, Virage, the Excalibur Screening Room, VideoQ (developed from VisualSEEk), and Informedia have all been developed to handle multimedia searching.
[444] Eakins & Graham 1999, § 5.6.11 on p. 36.
[445] Eakins & Graham 1999, § 5.7 on p. 37.
[446] Eakins & Graham 1999, Executive Summary on p. 1; § 2.3 on pp. 7-8.

3. *abstract* features – can be divided into

   a. retrieval of particular events or types of activity
   b. retrieval of pictures with particular emotional or religious significance

   Requires complex reasoning and often subjective judgement. Common form of query in various commercial picture libraries.

Current CBIR systems mainly work at the lower levels of abstraction, particularly level 1, where they can address many requirements by matching primitive features. When applied to specific, focussed tasks, then they can also be of use in level 2 logical searches. However, broader logical searches and level 3 semantic searches are still beyond the capabilities of current CBIR systems.[447] This is problematic, as many users still seem to demand that CBIR address higher level queries– 'for essence, meaning, emotion, personality, irony and any number of other states of being or modes of interpretation that are widely represented throughout the realm of art'.[448] The gap between primitive and logical or semantic searches, which is a major obstacle to the widespread adoption of CBIR, has been labelled the 'semantic gap', and is predominantly found between levels 1 and 2.[449]

But this should not lead to pessimism: several questions which can be answered using content-based image retrieval are of use to visual arts researchers, and several of these have not yet been fully exploited by the existing CBIR technologies. CBIR works on matching with similar visual characteristics. These tend to centre around the following level 1, primitive areas:[450]

Characteristic	Use
Colour	Practice-based researchers sometimes investigate particular formal aspects as they try to establish visual solutions to their research problems. Thus, they may seek a series of examples of images with a particular overall colour balance. Combination with searches by shape may allow them to find images which use a particular colour in some part of the image. These searches are usually performed by matching images' colour histograms.
Tone	As above, but seeking similar tonal balance. This can be performed using grey-scale histograms.
Texture	As above, but seeking similar irregular surface patterns. These are assessed using a variety of techniques which characterise and measure texture in several ways.
Pattern	As above, but seeking similar regular surface patterns.
Shape	As above, but seeking similar shapes. By extension, shape-matching provides the possibility of seeking • images with similar global features, which will match images with

447 Eakins & Graham 1999, Executive Summary on p. 1; § 2.6 on p. 10 & § 6.1 on pp. 38-99.
448 Quoting Grindley 2006, pp. [10]-[11]; see also Eakins & Graham 1999, Executive Summary on p. 1.
449 Eakins & Graham 1999, § 2.3 on pp. 7-8.
450 Eakins & Graham 1999, §§ 5.1.1-4 on pp. 23-4.

similar overall compositions, be they direct copies, creative re-workings, or simply satisfactory solutions to similar compositional problems

- images with similar local features, which should match images containing similar motifs, identifying in particular
- copying and re-use of particular motifs
- preliminary studies used for individual motifs in finished works

– all of which are potentially useful for historical researchers.[451] However, shape matching techniques tend to be less effective than colour and texture matching, as they have trouble distinguishing foreground and background features in naturalistic images, and use techniques to identify shapes which do not necessarily match human perceptions.[452] It should be noted that shape-matching images of three-dimensional objects can be problematic unless all the images are taken under standard conditions. However, recent developments in the creation of three-dimensional models from two-dimensional images (see 2.4.3) may render this much more straightforward.

Position — Used to search for images containing objects in particular spatial relationships to one another. Seldom used in isolation, this can be effective in image-matching when combined with other factors.

Other techniques have also been developed which use complex mathematical models of the image in an attempt to characterise some aspect of visual similarity which is apparent to human observers, even if they cannot describe it. These include the use of wavelet transforms, Gaussian derivatives and distributions of local curvature and phase, all of which can characterise an image at varying levels of detail at the same time.[453]

In addition, some work has been done on searching for level 2, derived or logical features, focusing on:

Scene recognition — Identifying the type of scene represented in an image, often as an aid to clarifying the results of searches on level 1 features, and as an aid to

Object recognition — Identifying objects of particular types in images.

These techniques are often implemented in combination with software which enables users to feed back to the system information on the images retrieved, gradually building up a text-based interface to the visual characteristics which reflects actual search terms.[454] In addition, when primitive searching is combined with keyword indexing, useful results at level 2 can be obtained; and there is clearly potential for the combination of CBIR with semantic web (2.8.3) and text-mining techniques, as embodied, for example, in the SCULPTEUR project, discussed below, or e-Chase (2.9.2).[455]

In contrast, very little work has been done on 'level 3' searches, for 'abstract' features.[456]

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[451] Ward et al. 2001.
[452] Eakins & Graham 1999, § 6.1 on pp. 38-9.
[453] Eakins & Graham 1999, § 5.1.4 on pp. 24-5.
[454] Eakins & Graham 1999, § 5.3.1 on pp. 26-7.
[455] Eakins & Graham 1999, § 6.2 on p. 40.
[456] Eakins & Graham 1999, § 5.3.2 on p. 27.

Thus, CBIR contains the potential for aiding the creative research process by enabling researchers to investigate a range of broadly similar formal solutions to particular problems. Significantly, many practice-led researchers think in visual terms (as has been pointed out above); CBIR reduces dependence upon verbal descriptions when searching for images, and so may allow such researchers to search more intuitively.[457] Significantly, Eakins and Graham reported that

> For image database users such as graphic designers, the ability to retrieve specific images is of marginal usefulness. The role of images in stimulating creativity is little understood – images located by chance may be just as useful in providing the designer with inspiration as those retrieved in response to specific queries. In these circumstances search intermediaries are likely to be of little use, and the often capricious performance of CBIR becomes an advantage. The ability of systems like QBIC to display sets of images with underlying features in common, even if superficially dissimilar, may be just what the designer needs, particularly if any retrieved image may be used to start a further search. Such *content-assisted browsing* might turn out to be a valuable, if unforeseen, application of CBIR. There is of course a risk that future improvements in CBIR technology, enabling more accurate searching, will erode its usefulness here![458]

In reducing the need for textual searching, it may also have short-term uses in searching across collections which are catalogued using different vocabularies or languages without requiring the collections to be re-labelled with complex semantic metadata. CBIR also has the potential to expand 'emotional' indexing across a collection automatically, by matching the visual attributes of emotionally-tagged images with similar un-tagged images.[459]

CBIR might also assist art historians in connecting previously unrelated works of art, allowing them to plot the dissemination of particular compositions and motifs through time and space, and thereby investigating issues such as notions of originality, variety and re-use; and it can facilitate the elucidation of the genesis of works of art by connecting partial studies with finished works.

It is important to note that users may wish to search for a variety of different characteristics of an image, and that each of these in effect represents a search for a different kind of feature, in turn performed using a different mathematical technique. The majority of systems have tended to offer a single form of search (perhaps allowing the user to weight several features in different ways), rather than offering a choice of search techniques. There is much to be said, however, for adopting the approach of the Photobook system developed at MIT, which allowed users to select particular feature types according to the search they wished to conduct.[460] Similarly, defining individual forms of interaction with search systems (i.e. individual types of question) for different user-groups will make systems design significantly easier.[461]

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[457] 'For example, a hierarchical CBIR search initiated with a small number of images that have very different characteristics would allow the user to meander through the collection based only on visual criteria. This would provide search capabilities that would expand the breadth and depth of the returned images instead of being a linear exploration.' Ward et al. 2001; cf. Ward et al. 2005, pp. 111-12.
[458] Eakins & Graham 1999, § 7 on p. 48.
[459] Ward et al. 2001; more generally, Ward et al. 2005, p. 111.
[460] http://www-white.media.mit.edu/vismod/demos/photobook/, cited by Eakins & Graham 1999, § 5.5.2 on p. 30 but inaccessible at the time of writing.
[461] Eakins & Graham 1999, § 3.4 on pp. 15-16.

Whilst Eakins and Graham noted the problems caused by the lack of any agreed standards with which to assess the effectiveness of different image search systems,[462] this has in part been rectified by projects such as ImageCLEF, part of the Cross Language Evaluation Forum campaign.[463] However, the visual arts are not seen as a commercially or scientifically vital area of investigation, and so recent visual arts images do not form the basis of these kinds of project.[464] In order for CBIR in the visual arts to be developed further, a series of well-defined tasks and forms of evaluation could usefully be developed, and perhaps integrated into events such as ImageCLEF.

In brief, then, CBIR is effective – not as much as its evangelists claim, but not as little as its detractors argue. The area continues to develop.[465] It will be most useful when asked the kinds of question to which it is most amenable. These are often highly focussed; Eakins and Graham provide an intriguing selection of possibilities, which includes several visual arts areas:

> The ability to retrieve and compare past diagnoses of similar-looking radiographs could provide valuable training for medical students. Retrieval of buildings with similar appearance to compare function, or to trace the development of architectural styles, could be useful for architecture students. Comparison of designs on Etruscan pottery could be of use to trainee archaeologists.[466]

Similarly, Grindley proposes a series of further areas where CBIR may, in future and possibly with manual assistance, be able to run comparisons between images: 'use of posture in figures, clustering of architectural elements, perspective, horizon lines, dimensions, geometry, sight lines …'.[467]

More intriguingly, recent reports suggest that mathematical image-processing can be used to cluster images of paintings and drawings according to the artistic hand that created them, assisting in the process of confirming the authenticity of particular works, or identifying the number of hands at work in a single object or a specific group of works. Lyu, Rockmore and Farid use multi-scale, multi-orientation ('wavelet') decomposition of images of old master paintings and drawings to characterise the image's components in terms of location, orientation and scale, thereby focussing on the subtle forms of individual strokes of the brush, pen, etc.[468] In contrast, Taylor et al. analyse the fractal characteristics of Jackson Pollock's drip paintings.[469] If style can be characterised mathematically, then it, too, should be able to form the basis of CBIR – although Taylor et al.'s technique may be too specific to the peculiarities of Pollock's practice to be applicable more generally as a means of image retrieval.

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[462] Cf. Eakins & Graham 1999, § 6.1 on p. 38.
[463] http://ir.shef.ac.uk/imageclef/, consulted 6 October 2006.
[464] So ImageCLEF 2006 featured collections of medical images and of general photographs, but no visual arts images: http://ir.shef.ac.uk/imageclef/2006/, consulted 6 October 2006.
[465] Eakins & Graham 1999, § 7 on p. 47.
[466] Eakins & Graham 1999, § 7 on p. 49.
[467] Grindley 2006, p. [14].
[468] Lyu et al. 2004; Lyu et al. 2005; for a journalistic account of the technology, see Trivedi 2005.
[469] Taylor et al. forthcoming; but see Mureika et al. 2004, who question Taylor's technique and propose possible alternatives.

It has also been proposed that point clouds of three-dimensional objects generated from two-dimensional images using Microsoft's prototype Photosynth system (2.4.3) could be used as searchable characteristics in CBIR.[470]

Implementation of CBIR in the visual arts has tended to focus on museums and image libraries. Both the Guildhall Art Gallery, in its Collage database, and AHDS Visual Arts, used a system developed by the University of Northumbria at Newcastle, although this is no longer supported following the closure of the University's Institute for Image Data Research.[471] At the moment, the most notable implementation is probably IBM's Query By Image Content (QBIC) system on the website of the State Hermitage Museum, St Petersburg.[472] This allows for searches on user-specified colours or combinations of colours and basic layouts, created with a simple sketching tool. In addition, when viewing an image returned by a text-based search, users are also given the option to view other works 'with similar visual layout'. An alternative method is adopted by the Leiden 19th-Century Portrait Database, 'a database of 21094 Dutch carte de visite studio portraits' drawn from two private collections and the Leiden University Printroom.[473] The system uses an initial random selection of images, which are then marked as 'Ok' or 'Bad' by the viewer; carrying out a search will return more example with characteristics similar to the 'Ok' images, and the process can be reiterated until a set of suitable images is returned.

More experimental systems include the ARTISTE project, which aimed to use high-quality museum images to enable the automatic indexing of objects and very focussed image retrieval (for example, by specifying the colorimetric properties of a particular pigment and running a search for that particular colour).[474] This developed into SCULPTEUR, a project which ran from 2002 to 2005 and combined CBIR and semantic retrieval (cf. 2.8.3) techniques to a collection of images from the Victoria & Albert Museum, and has subsequently been extended to run across several collections at once in the e-CHASE project (see 2.9.2).[475] Users can base their search on textual information, on a series of colours, or on uploaded two- or three-dimensional images. In addition, Grindley describes a system currently under development at the Hamilton Kerr Institute in Cambridge.[476] This uses the FIRE (Flexible Image Retrieval Engine) CBIR system to search a database of digital images of paint cross-sections from oil paintings.[477] Such images tend to be very similar in their overall appearance – the main variants are the thicknesses of the different paint layers, and the sequence of colours from layer to layer – and so the CBIR system can be fine-tuned to focus on the particular aspects in which the images differ from one another. As the cross-sections represent the physical structure of the painted layers, they encapsulate information about the way it was painted, as well as

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[470] http://labs.live.com/photosynth/whatis/smartphotos.html, consulted 19 September 2006.
[471] Collage can be found at http://collage.cityoflondon.gov.uk/collage/app, consulted 18 October 2006; the system is described in Ward et al. 2001 and Ward et al. 2005.
[472] http://hermitagemuseum.org/fcgi-bin/db2www/qbicSearch.mac/qbic?selLang=English, consulted 18 October 2006.
[473] http://nies.liacs.nl:1860/, consulted 18 October 2006. It should be noted that the source material is monochrome.
[474] http://www.ecs.soton.ac.uk/~km/projs/artiste/ and http://www.ecs.soton.ac.uk/~km/projs/artiste/proposal.html, consulted 18 October 2006.
[475] http://www.sculpteurweb.org/, consulted 18 October 2006.
[476] Grindley 2006, pp. [11]-[13].
[477] http://www-i6.informatik.rwth-aachen.de/~deselaers/fire.html (consulted 19 September 2006).

the particular pigments, media and paint mixtures which are being used. Thus, CBIR can be used to identify samples from different paintings which may have been created in similar ways. As Grindley points out, by mapping this information chronologically and geographically, answers can begin to be found to research questions in areas such as the trade in minerals and spices.

There are many CBIR systems, although several are experimental systems rather than fully-functioning or commercially-available products. The Wikipedia page on the subject provides links to a useful cross-section.[478]

48: image processing, categorisation/ordering, finding images

2.9.2. e-Chase and OpenMKS

Much data, including images of interest to researchers in the visual arts, is held in incompatible systems which use different metadata formats and which are indexed using different standards. These are not interoperable, obstructing access to the resources they contain. e-Chase is an EU-funded project which uses semantic web technologies (2.8.3) to unify disparate collections of multimedia objects meaningfully behind a seamless interface.[479] Building upon the earlier SCULPTEUR project, e-Chase has a strong heritage bias, with partners including publishers and image libraries, as well as a broadcaster. e-Chase is based upon OpenMKS, an open source assemblage of off-the-shelf software components which 'allows multimedia content to be taken from multiple sources and semantically integrated and exposed in an interoperable way for use in a variety of applications'.[480] It exploits web services technologies to seamlessly integrate disparate collections – as long as they fall into the same basic ontological field: the system has been implemented using the CIDOC Conceptual Reference Model, an ontology for describing the contents of museum collections.[481] Imminent versions of OpenMKS will include facilities for collaboration, built around shared lightboxes which enable other people to add, remove or annotate content; and the incorporation of content-based image retrieval (2.9.1). Loading one's data into OpenMKS will also make the data interoperable using existing standards, allowing it to be exploited by other web services, including some of those usually considered under the 'grid computing' rubric (2.7.1).

59: collaboration, image processing, categorisation/ordering, finding images, collections

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[478] http://en.wikipedia.org/wiki/Content-based_image_retrieval. To this should be added PhotoBook, developed at MIT and still available to download from http://vismod.media.mit.edu/vismod/demos/photobook/, and the work of the Informedia Project at Carnegie Mellon University on machine understanding of video and film media http://www.informedia.cs.cmu.edu/. In addition, commercial systems include those offered by Virage, http://www.virage.com/content/home/index.html, which will automatically capture, encode and index television, video and audio content from any source and automatically generate metadata; Convera's RetrievalWare Screening Room, http://www.excalib.com/solutions/retrievalware/ScreeningRoom.aspx, which again focuses on video; and Viisage's FaceFINDER, http://www.viisage.com/ww/en/pub/viisage___products_new/viisage___biometrics/facefinder.htm. All sites consulted 18 October 2006.
[479] http://www.echase.org, consulted 6 November 2006.
[480] http://openmks.sourceforge.net, consulted 25 October 2006.
[481] http://cidoc.ics.forth.gr/, consulted 11 December 2006; and see 2.8.3 above.

2.10. Display

2.10.1. Paper-like displays

This refers to a series of display technologies, being developed by several research centres and manufacturers, with common characteristics.[482] They are:

- lightweight
- potentially flexible
- reflective (i.e. like ink on paper, as opposed to transmissive displays such as CRT or LCD monitors; as they require no illumination of their own, they require little power)
- display good contrast ratios (so they can be read in bright sunlight)
- bistable (i.e. they only require power to change the display, not to sustain it – they are inherently low-power)

In other words, their characteristics are very similar to ink on paper. In addition, some can already be manufactured in long rolls. Paper-like displays are currently being delivered for products which include e-book readers, computer and PDA displays, point-of-purchase displays, clocks and watches, and are being developed for other applications.

Figure 56. Flexible active-matrix displays using Philips' ultra-thin back plane with organics-based thin film transistors, combined with E Ink's electronic ink front plane. Photo: Philips.

The main current technologies fall into three types, electrophoretic, electro-wetting and rotating balls.

[482] Downs 2005 provides a useful overview of the state of the technologies in 2005, as well as an interesting discussion of the design implications of paper-like displays in e-book readers.

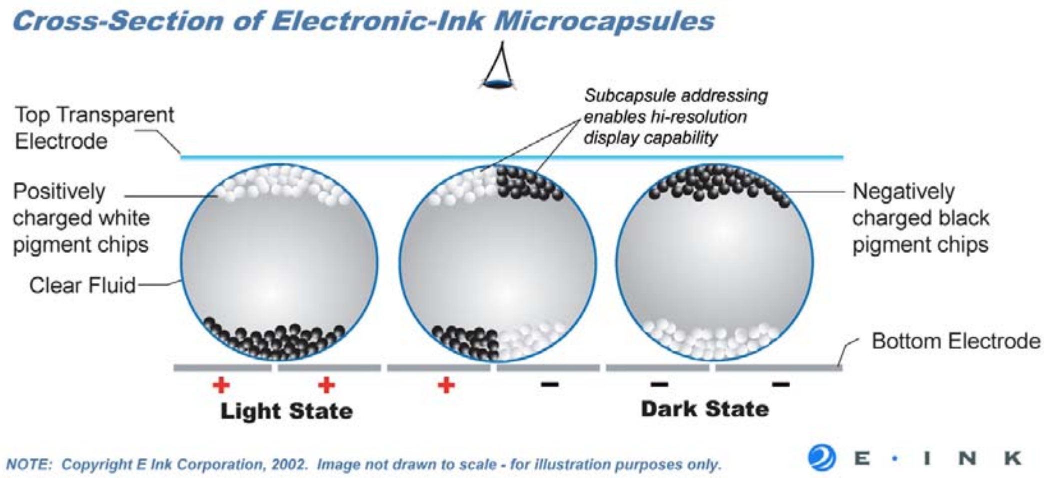

Figure 57. How the E Ink electrophoretic paper-like display system works. Image property of E Ink Corporation.

Electrophoretic displays (Figure 57) are inherently monochrome or bichromal.[483] They use microscopic spheres of two colours, one colour positively charged and one colour negatively charged. A group of spheres of both colours is contained within a sac of gel, and these constitute one pixel. Depending upon the charges applied to the front and back of the gel sac, spheres of one colour will be driven through the gel to the front of the sac, and the pixel will show that colour. By varying the voltage, gradations between the two different colours will be obtained. Initial publication of the technique described resolutions of 600-1200 ppi. The technology has been commercialised by E Ink, working with a number of partners,[484] and at the time of writing their displays have been incorporated into a range of products:[485]

- personal weather forecasters (Ambient Devices 'Weather Wizard')
- clocks (Citizen Watch Co., Ltd and Citizen T.I.C. Co., Ltd)
- watches (Seiko Epson Corporation and Seiko Watch Corporation)
- memory meters on USB flash drives (Lexar Media, Inc. 'JumpDrive Mercury')
- e-book readers (iRex Technologies BV 'iLiad'; Jinke Electronics 'Hanlin eBook' V series; Sony Corporation 'Sony® Reader', Figure 58)
- point-of-purchase displays (licensed exclusively to Neolux, Midori Mark and Teraoka under the trade name Ink-In-Motion™)[486]

E Ink also produce a development kit incorporating a display and the hardware and software required to make a prototype portable device.[487]

[483] See, for example, Comiskey et al. 1998; the commercialised technology is described at http://www.eink.com/technology/howitworks.html, consulted 27 September 2006.
[484] http://www.eink.com, consulted 27 September 2006.
[485] http://www.eink.com/products/customers.html, consulted 27 September 2006.
[486] http://www.eink.com/products/ink_in_motion.html, consulted 27 September 2006.
[487] http://www.eink.com/kits/, consulted 27 September 2006.

Figure 58. Sony® Reader utilizing E Ink Imaging Film™. Image property of E Ink Corporation / photo courtesy of Sony Corporation.

Electro-wetting displays use the principle of electro-wetting, described above (2.3.1).[488] Each pixel comprises a cell containing water and a coloured oil; depending upon the charge applied to the bottom surface of the cell, the oil will either cover entire cell or bunch up into one corner, revealing the substrate beneath. Colour displays can be created either by using a single layer of black oil beneath a grid of red, green and blue filters to mimic RGB liquid crystal displays (LCDs); or by using three layers, with cyan, magenta and yellow dyes respectively. The latter, although more expensive, offers better brightness. It mimics the process used by current printing technologies, although the displays omit the black layer, providing a CMY, rather than a traditional CMYK, combination. In the end, though, as any number of dyes can be used in electro-wetting displays in a variety of combinations, the colours obtainable are potentially almost infinitely variable (Figure 59). Electro-wetting displays are also capable of video frame-rates. Patented by Philips, the technology has been licensed to Liquavista B.V., who seem to be focussing on small-scale colour displays, primarily for portable and mobile devices (Figure 60).[489] They are already quoting resolutions of 160 ppi, roughly the same as newsprint.

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[488] For discussions of electro-wetting technology as applied to displays, see Hayes and Feenstra 2003, Mugele and Baret 2005, pp. R739-40, and Feenstra and Hayes 2006.

[489] http://www.liquavista.com, consulted 11 August 2006; http://www.research.philips.com/newscenter/archive/2006/060419-liquavista.html, consulted 27 September 2006..

Figure 59. A sample of the brilliant colours that can be made with the Liquavista electro-wetting display technology. By varying the dye dissolved in the oil, an unlimited range of colours can be provided. Photo: Philips.

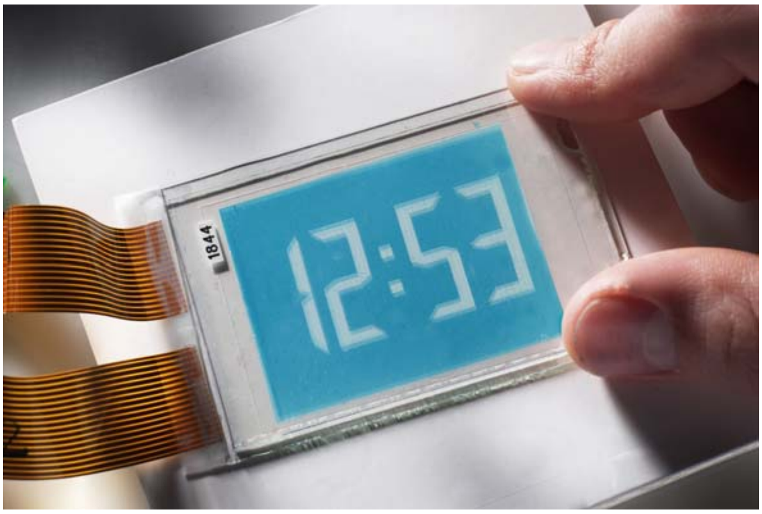

Figure 60. A cyan clock with a 2.5" diagonal, using the Liquavista electro-wetting display. The pixel resolution of the display is 160 ppi. Photo: Philips.

Rotating ball displays, like electrophoretic displays, use tiny balls suspended in a liquid cell.[490] However, each ball carries two colours, one on each side; one coloured side is positively charged, the other negatively charged. Depending upon how the upper and lower surfaces of the containing cell are charged, the balls will rotate to show either one or the other colour to the viewer. The displays are therefore inherently monochrome (strictly speaking, bichromal), although there is presumably potential for using coloured filters or variably coloured balls to produce coloured displays. The conception behind this technology seems to have focussed as much on producing 'electronic paper' as on display devices; thus, prototypes have been produced which can be fed through printers like paper, but cam be erased and reprinted many thousands of times. The 'paper' can even be written on using a charged pencil, and the marks erased by an 'eraser' carrying the opposite charge. In addition, the basic 'display' can be produced by printing, and run off in rolls 10m or more long. The technology was developed by Xerox's Palo Alto Research Center (PARC), who set up a commercial spin-off, Gyricon LEC, to exploit it;

[490] Sheridon et al. 1999; http://www2.parc.com/hsl/projects/gyricon/, consulted 13 July 2006; Downs 2005, pp. 33 & 38, citing http://www.parc.com/research/dhl/projects/paperdisplays/ as of April 2004.

however, Gyricon were suspended at the end of December 2005, and Xerox PARC are now apparently licensing the technology rather than exploiting it directly themselves.[491]

Other, similar products are being produced by companies which are less forthcoming about the precise technologies being used – for example, Magink Display Technologies[492] are currently producing modular large-scale displays aimed at the advertising market, with a series of full-colour 'digital ink' billboards being unveiled in London in the autumn of 2006.[493] They quote frame rates of up to 50 fps.

25: capture, display

2.10.2. Rapid prototyping

Rapid prototyping describes a series of technologies for producing three-dimensional objects directly from computer files without the requirement for major industrial machinery – the fact that some rapid prototyping techniques are referred to as 'three-dimensional printing' gives an idea of the ease of use at which the technologies aim. These technologies are used extensively in industry both to develop prototype components and, occasionally, for the manufacture of short runs of objects.

Data is sent to rapid prototyping machines from CAD software in the established STL file format. All the techniques involve building an object up in layers; existing rapid prototyping techniques are:[494]

- <u>Stereolithography</u>. A laser marks out the shape of a thin layer of the object to be created onto the surface of a vat of liquid light-sensitive plastic ('photopolymer'), which solidifies upon exposure to the laser light. The newly-created solid layer is then lowered slightly so that it is covered with more liquid, and the process repeated so that a new layer bonds to the first one. The process continues until the object has been built, when it can be taken out of the vat, any temporary supports removed and, if necessary, the object cured to ensure its stability.
- <u>Fused deposition modelling</u>. Plastic (usually acrylonitrile butadiene styrene, ABS) or wax is fed to a heated nozzle which effectively draws with the plastic/wax onto a surface. Once one layer has been drawn, the surface is lowered slightly and another layer created. The process is repeated until the object is created, when it is taken off the machine and any temporary reports are removed.
- <u>Selective layer sintering</u>. A thin layer of plastic, ceramic or metal powder is spread over a surface. A laser beam then marks out the shape of one layer of the object to be created, fusing the powder to make a solid object. A new layer of powder is added and the process repeated, and so on until the object is complete. The object is then removed, the loose powder brushed away, and the object allowed to cool. The

[491] http://www.gyricon.us/, consulted 13 July 2006.
[492] http://www.magink.com, consulted 27 September 2006.
[493] http://www.magink.com/piks/news23.pdf and http://www.magink.com/billboard.pdf, consulted 27 September 2006.
[494] http://www.warwick.ac.uk/atc/rpt/Techniques/techniques.htm, consulted 6 June 2006; http://home.att.net/~castleisland/rp_int1.htm, consulted 24 November 2006.

technique creates porous objects, and the objects created may need to be infiltrated with another substance to make them more solid. Direct laser fabrication (2.10.3) is a development of this technique which can create objects out of several metals which have similar physical and mechanical properties to objects produced by traditional casting.

- Three-dimensional printing. Like fused deposition modelling, this technique uses a powder bed, but the powder is glued together with adhesive dispensed from an inkjet head, rather than sintered. Once the object has been created, the unused powder is brushed off, and the object infiltrated with a hardener to improve its handling.
- Laminated object manufacture. A laser or knife is used to cut one layer of the object from a layer of adhesive-backed paper or other thin material. Another layer of paper is then added on top, and the process repeated, and so on until the object is completed. It is then taken off the machine, and the unwanted material removed. The resulting object feels similar to wood, and can be worked and finished in a similar manner.
- Inkjet. In all inkjet techniques, an inkjet head is used to print a layer of wax or plastic and a support material on a surface. The surface is then smoothed, and another layer printed, and so on until the object is complete. It is then taken off the machine, the temporary supports removed, and the object infiltrated if required to make it more robust. Recent developments build upon stereolithography techniques by depositing photopolymers which are then cured by an ultraviolet lamp, resulting in a much more solid object.

The potential size, accuracy, cost, finish and solidity of objects manufactured by the different techniques vary considerably. However, several websites provide useful summaries of the characteristics of the different technologies.[495]

The technology has been exploited by a few practice-led researchers, notably sculptors and jewellers. In particular, the RCA has had a digital manufacturing and rapid prototyping centre, RapidFormRCA, for some time, which is also made available as a service to local industries.[496] It is equipped for stereolithography and fused deposition modelling, and can produce objects in resin, polycarbonate, ABS, starch and wax – the latter creating objects ready for lost-wax or other investment casting. The technology has been used by students on the College's MA course in Goldsmithing, Silversmithing, Metalwork and Jewellery, and the 2006 degree show[497] included several examples. Ana Claudia Crisan Calabria exhibited works created in starch and wax, as well as gold pieces cast from wax prototypes,[498] whilst Lynne Murray's jewellery combined patterned resin objects created using rapid prototyping with more traditional materials.[499] Kyeok Kim

[495] E.g. http://home.att.net/~castleisland/, consulted 27 November 2006.
[496] RapidformRCA: http://www.innovation.rca.ac.uk/PD/rapidform.html; see also http://www.rca.ac.uk/pages/getinvolved/rapid_prototyping_facilities_509.html and http://www.rca.ac.uk/pages/study/rapidformrca_1826.html; all sites consulted 6 June 2006.
[497] Generation: The Summer Show 2006, http://dams.rca.ac.uk/res/sites/Show2006/ (consulted 6 June 2006).
[498] http://dams.rca.ac.uk/netpub/server.np?find&site=Show2006&catalog=catalog&template=genstudent.np&field=Item%20ID&op=equals&value=980, consulted 6 June 2006.
[499] http://dams.rca.ac.uk/netpub/server.np?find&site=Show2006&catalog=catalog&template=genstudent.np&field=itemid&op=matches&value=1177, consulted 6 June 2006; see also http://www.lkmjewellery.com, consulted 27 November 2006.

used the rapid prototyping machine to produce components which for her illuminated jewellery, designed to project patterns onto the body. Jo Hayes-Ward's work is also digitally-generated: *Sintered City* and *Conways Brooch* were created using cellular automata and John Conway's *Game of Life* to develop designs which were then rapid prototyped and cast.[500]

The HEFCE-funded Creating Art with Layer Manufacture (CALM) project, which reported in December 1998, was intended to introduce artists to rapid prototyping techniques.[501] Sculptors such as Keith Brown have exploited the technology's ability to produce forms which were previously difficult or impossible to model or to cast, developing a new sculptural vocabulary which is made possible by the combination of software for the creation of virtual forms and hardware to realise them in three-dimensional objects (Figure 19).[502] Rapid prototyping also offers researchers great flexibility in generating designs before committing themselves to solid objects, and a much greater ability to produce (methodical) variations on themes.

Rapid prototyping technology is increasingly accessible in several forms. Many commercial companies offer rapid prototyping facilities. Several universities offer rapid prototyping services to industry.[503] Rapid prototyping machinery is being acquired by art schools, such as the RCA (mentioned above). Finally, rapid prototyping machinery is becoming increasingly affordable. Extensive links to suppliers, etc., are provided in Andrei Novacs's 'Rapid Prototyping Home Page'.[504] But perhaps most intriguingly, the Replicating Rapid-Protoyper (RepRap) Project, based in part at the University of Bath, is trying to use rapid prototyping to produce a functioning rapid prototyping machine, which will then be able to use the same techniques to produce copies of itself – essentially producing a self-replicating replicating machine, a 'universal constructor'.[505] The intention is to give away the results of the project under a GNU General Public Licence, allowing other investigators to work on the same idea.

Rapid prototyping technology continues to develop, enabling larger and more robust objects to be made out of an increasing range of materials to higher degrees of accuracy more quickly. One recent technology with significant potential for use by practice-based researchers is direct laser fabrication (2.10.3).

50: image processing, display

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500 http://dams.rca.ac.uk/netpub/server.np?find&site=Show2006&catalog=catalog&template=genstudent.np&field=itemid&op=matches&value=1132, consulted 6 June 2006; see also http://www.johayes.com, consulted 27 November 2006.
501 http://www.uclan.ac.uk/clt/calm/overview.htm, consulted 8 June 2006 but no longer available.
502 See http://www.artdes.mmu.ac.uk/profile/kbrown/projectdetails/1 and http://www.artdes.mmu.ac.uk/profile/kbrown/gqallery, both consulted 8 June 2006.
503 E.g. the University of Warwick's Rapid Prototyping & Tooling Centre, http://www.warwick.ac.uk/atc/rpt/, consulted 6 June 2006.
504 http://home.utah.edu/~asn8200/rapid.html, consulted 24 November 2006.
505 http://reprap.org and http://staff.bath.ac.uk/ensab/replicator/Downloads/one-page.pdf, consulted 27 November 2006; and see Randerson 2006 for some of the possible implications of the technology.

2.10.3. Direct laser fabrication

Direct laser fabrication is a form of rapid prototyping (2.10.2), developed from selective layer sintering. There are two variants to the technique:

1. Blown powder. The laser and powder nozzle move together, with an effect similar to icing a cake. Although this technique can produce larger objects, it uses coarser powder so has lower accuracy; and it cannot accommodate any overhang greater than 30º.
2. Powder bed. A more traditional technique, where successive layers of powder are fused by the laser. Whilst this technique can only make smaller objects, it is more refined and offers greater flexibility in the shapes of the objects it produces.

Direct laser fabrication allows for the direct of manufacture of objects up to about 12" high from metal powder, and can achieve a surface accuracy of 20 µm which, once sand-blasted, is almost shiny, although the surface finish is controlled by the metals used. The objects produced are up to 99% of the density of the solid material from which they made – in other words, they are to all intents and purposes solid, and the objects have a density similar to that achieved by casting. The technology is primarily used with titanium, nickel alloy and stainless steel. Whilst lost wax casting would still be more accurate, it is much more labour-intensive and has physical limitations when compared to direct laser fabrication. In addition, direct laser fabrication is ideal for producing objects from metals which are very difficult to cast, such as titanium. It combines the advantages of rapid prototyping with the ability to produce solid, highly-accurate metal objects.

Powder bed direct laser fabrication facilities are available at the University of Birmingham's Interdisciplinary Research Centre in Materials,[506] and the Laser Group at the University of Liverpool and the Lairdside Laser Engineering Centre.[507]

26: image processing, display

2.10.4. High dynamic range displays

BrightSide Technologies have recently launched the world's first high dynamic range display, the DR37-P, which they claim is the only display able to reproduce 16-bits-per-channel images accurately.[508] The display combines the standard TFT active matrix LCD technology with an individual LED backlight behind each pixel; the intensity of each LED can be modulated as necessary in order to alter the brightness of the pixel. Whilst several aspects of the display have still to be characterised, BrightSide claim their display produces images 10 times brighter and with 100 times the contrast range of conventional displays, with a peak luminance of 3,000 candelas/m^2, and a contrast ratio in excess of 200,000:1. They are aiming the technology at applications such as film and medical,

[506] http://www.irc.bham.ac.uk/facilities.htm, consulted 27 November 2006.
[507] http://www.lasers.org.uk/Liv/applications.htm, consulted 27 November 2006.
[508] http://www.brightsidetech.com/products/display.php, http://www.brightsidetech.com/products/dr37p.php, and http://www.brightsidetech.com/products/info/dr37p_specs.pdf, all consulted 14 November 2006.

geophysical and satellite imaging. The display is of HD 1080 resolution (1920 x 1080 pixels) and has a 37" screen.

To take full advantage of the technology, images have to be captured with an enhanced dynamic range – at the moment, the easiest way to do this is to take a series of bracketed exposures which will capture detail in the highlights, mid-tones and shadows respectively. These can then be assembled into a single, high-dynamic-range image. However, the ability to read out successive images from a CID-based sensor (2.3.2) without clearing the data may lead to the development of sensors capable of producing high dynamic range images in a single exposure, albeit one sampled several times.

51: display

2.10.5. High resolution projectors

Whilst the digital projectors in daily use tend to have a maximum resolution of XGA (as mentioned in 1.13.1 above), specialist equipment is already available at much higher resolutions, culminating in the Beacon 8MP projector manufactured by FakeSpace Systems, which has a resolution of 4096 x 2160 pixels (= 8.85 Mpixels).[509] Clearly, such systems are expensive; but their existence indicates that the decision to use lower-quality systems for the presentation of visual arts research are governed by infrastructural priorities rather than technological ones.

52: display

2.10.6. Projector calibration

As mentioned above (1.13.1), until recently digital projectors were very seldom calibrated. Now, however, calibration devices and software are beginning to be easily available, meaning that projected images should have vastly improved contrast and colour balance. Examples which have come to our notice are:

- The ColorVision Spyder2PRO, which also allows for the profiling and calibration of multiple monitors on a single system.[510]
- The GretagMacbeth Eye-One Beamer, which combines the Eye-One Pro spectrophotometer, a purpose-built holder, and the digital projector module of the Eye-One Match software.[511] GretagMacbeth's Eye-One ColorPoint software is a plugin that enables Microsoft PowerPoint to support colour management.[512]

[509] http://www.fakespace.com/beacon8MP.htm and http://www.fakespace.com/pdfs/solutions/Fakespace-Beacon8MP-A4.pdf, consulted on 27 November 2006.
[510] http://www.colorvision.com/profis/profis_view.jsp?id=602 and http://www.colorvision.com/downloads/datasheets/S2PRO_slim.pdf, both consulted 28 November 2006.
[511] http://www.gretagmacbeth.com/index/products/products_color-mgmt-spec/products_cm-for-creatives/products_eye-one-beamer.htm, consulted 28 November 2006.
[512] http://www.gretagmacbeth.com/index/products/products_color-mgmt-spec/products_cm-for-creatives/products_eye-one-beamer/products_eye-one-beamer_software.htm, consulted 28 November 2006.

53: display

2.10.7. Evanescent displays

The vast majority of digital displays require a physical support, whether they are conventional CRT or LCD monitors, projectors, or paper-like displays (2.10.1). However, technologies have developed which give the illusion that an image is projected into thin air. Suppliers include:

- FogScreen, whose technology is based on a thin screen of water vapour held in a laminar, non-turbulent airflow. The screens work with standard data projectors, can be opaque or translucent, require no additives in the water, and do not feel wet. FogScreen produce two models: the Inia has a fixed screen size of 2 x 1.5 m; the One has a fixed size of 1.5 x 1 m, but is modular and so several units can be combined into a much larger display.[513]
- IO2 Technology, whose Heliodisplay combines a multimedia projector with a 'screen' which they describe only as 'transformed air'. The device offers a 30" screen and a maximum native resolution of 1024 x 768 pixels (SXGA). However, the display is susceptible to waviness caused by disturbances in the projection 'screen', and the manufacturers note that it works best with bold graphics.[514]

Both technologies now enable viewers to interact with the display, effectively using their finger or hand as a mouse. Although both will work with ambient light, they are more effective when placed against a dark background.

54: interfaces, display

2.10.8. Volumetric displays

Three-dimensional displays are comparatively well-established as a technology, but they currently require users to wear some kind of device – either flimsy glasses with red and green, or polarised, lenses for fairly crude displays, or heavier glasses which flicker at high speed. Because of the disparity between the single point at which the eyes must remain focussed to see the display, and the points at which they must converge to perceive the stereoscopic effect, these often cause discomfort in viewers. Apart from holography, the only exception is a technology based on the old lenticular prints, which used a ridged plastic film to present different views of a subject according to the angle from which they were viewed, but these tend to have very limited viewing angles, low resolutions, and again cause discomfort in viewers. Pressure from the home entertainment market is leading research into desktop three-dimensional displays which can be viewed without

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[513] http://www.fogscreen.com/index.php?option=com_content&task=view&id=9&Itemid=14, consulted 28 November 2006.

[514] http://www.io2technology.com/technology/overview.htm; http://www.io2technology.com/salesinquiry.htm; http://www.io2technology.com/faq.htm; all consulted 28 November 2006.

glasses or other additional equipment from a wide viewing angle, and do not cause headaches and eyestrain.[515]

Devices which are either at or near commercial production use two different technologies to provide such displays.

- Swept volume: a rapidly rotating screen, onto which different two-dimensional images are projected when it is in different positions, giving the effect of a continuous three-dimensional image. Despite the striking effect of an image apparently hovering in mid-air, there are significant disadvantages where a major component is required to rotate continuously at very high speed, and the projector is required to produce images at an extremely high frame-rate (around 3,000 fps). Swept-volume displays are currently offered by:
    - Actuality Systems' Perspecta Display 1.9, which combine a rotating flat translucent plastic screen with a three-chip Digital Light Processing (DLP) projector. The display volume is 10" in diameter, with a resolution of over 116 million voxels. Although only using 3-bit colour (8 colours), dithering can increase this to 21-bit colour (2 million colours). The Perspecta is compatible with the OpenGL API, but also uses a new SpatialGL API to take full advantage of the potential of volumetric displays.[516]
    - Felix 3D, whose FELIX display combines a rotating helical white plastic screen with red, green and blue lasers. The display volume is 30cm in diameter, with a resolution of 10,000 voxels, although the Felix team are now pursuing a resolution of approximately 150 million voxels (HiResFELIX). Because of the shape of the screen, some sections of the image are occluded.[517] As a result, the Felix team are also now examining a static volume technique based on laser excitation of fluorescence (see below).
    - Genex, who combine a rotating helical white plastic screen with a DLP projector.[518]
- Static volume: two technologies are being pursued:
    - A series of layered screens, onto which different two-dimensional images are rapidly projected in succession, again giving the effect of a continuous three-dimensional object. This is the technology behind LightSpace's DepthCube, which uses a three-chip DLP projector to illuminate 20 liquid crystal screens, each about 5 mm apart, in succession. The discontinuities between the screens are reduced significantly by using anti-aliasing techniques, and the manufacturers claim an effective resolution of more than 465 million voxels (1024 x 748 x 608 voxels), although the native resolution 15.3 million voxels (1024 x 768 x 20 voxels); colour depth is 15-bit (32,768 colours). This technology requires a lower frame-rate than swept-volume displays, about 1200 fps. The DepthCube is

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[515] For histories and overviews of the technology, see Langhans et al. 1998, § 2; Langhans et al. 2002, § 2; Favalora 2005; Sullivan 2005; and the more journalistic Freedman 2005.

[516] http://www.actuality-systems.com/site/content/perspecta_display1-9.html, consulted 29 November 2006; Favalora et al. 2002; Favalora 2005.

[517] http://www.felix3d.com, and for HiResFELIX http://www.felix3d.com/___---___www___wtfit/index.php?show=HiResFELIX&setlanguage=german, both consulted 29 November 2006; Bahr et al. 1996; Langhans et al. 1998, §§ 3-7; Langhans et al. 2002, § 3.

[518] http://www.genextech.com/pages/600/Display.htm, consulted 28 November 2006; Sullivan 2005.

compatible with the OpenGL API via its proprietary GLInterceptor software, but can also use its own API.[519]

- Stepwise excitation of fluorescence. An atom, molecule, or ion within a large volume is excited with light (usually infra-red); as it de-excites it fluoresces, emitting a photon of visible light. The precise principles behind the excitation and fluorescence vary according to the specific technique being used. By using two intersecting lasers to perform the excitation, any point within the volume can be addressed and light emitted from it. The technology has also been used to excite fluorescence in a volume of rubidium vapour, and in crystals and glass doped with rare earth elements. The particular combination of crystal or glass and doping element dictates the colour of the fluorescence. Felix 3D have produced an experimental system using an erbium-doped yttrium lithium fluoride ($YLiF_4$) crystal. The system works with drawing exchange format (DXF) files. The Felix 3D system is currently monochrome, limited by the small scale of available crystals, and is restricted to vector graphics, although the research team are currently working on raster graphics.[520]

It should be noted that both swept volume and static volume technologies have certain drawbacks. Images of objects can only be translucent, never fully opaque. Some technologies are still experimental, whilst others are approaching the market, although still comparatively immature and expensive; but prices are expected to drop significantly over the next few years as technologies evolve and demand (hopefully) increases. Work is currently underway to incorporate interactivity into volumetric displays, using hand gestures and some form of motion tracking.

55: display

[519] http://www.lightspacetech.com, particularly http://www.lightspacetech.com/Specifications.html, consulted 28 November 2006; Sullivan 2005.

[520] http://www.felix3d.com/ --- www wtfit/index.php?show=SOLIDFELIX, consulted 28 November 2006; Langhans et al. 2003.

3. Project questionnaire

In order to obtain further evidence about researchers' needs, a brief survey was placed on the AHDS Visual Arts website at http://www.vads.ahds.ac.uk/submarines.html on 13 July 2006. Comprising four basic questions relating to researchers' current activities and needs, it was publicised on 14 relevant Jiscmail mailing lists both upon its launch and again at the beginning of the autumn term of the 2006-7 academic year. In addition, a message regarding the questionnaire was circulated to all staff at the University College of the Creative Arts. A link to the questionnaire was also provided from the project homepage on the AHDS Visual Arts website. Copies were distributed at the 2006 Digital Resources for the Humanities and Arts (DRHA) conference.

A second questionnaire, directed specifically at art historians and related researchers, was placed on the AHDS Visual Arts website at http://www.vads.ahds.ac.uk/submarines-ah.html on 31 August 2006. Asking similar questions to the first questionnaire, it was advertised on the H-ARTHIST and other mailing lists and in the October issue of the Bulletin of the Association of Art Historians, with which copies were also circulated. Further copies were distributed at the 2006 Computers and the History of Art (CHArt) conference.

By mid-December 2006, the questionnaire had provoked 73 responses from a range of practice-based and historical researchers. Clearly, the sample was self-selecting, and primarily seems to have drawn a response from researchers already engaging with ICT. But given that the questionnaire sought qualitative, rather than quantitative, information, the sample was sufficient to begin drawing conclusions about the community's research needs, although clearly not a statistically valid representation of the sector as a whole.

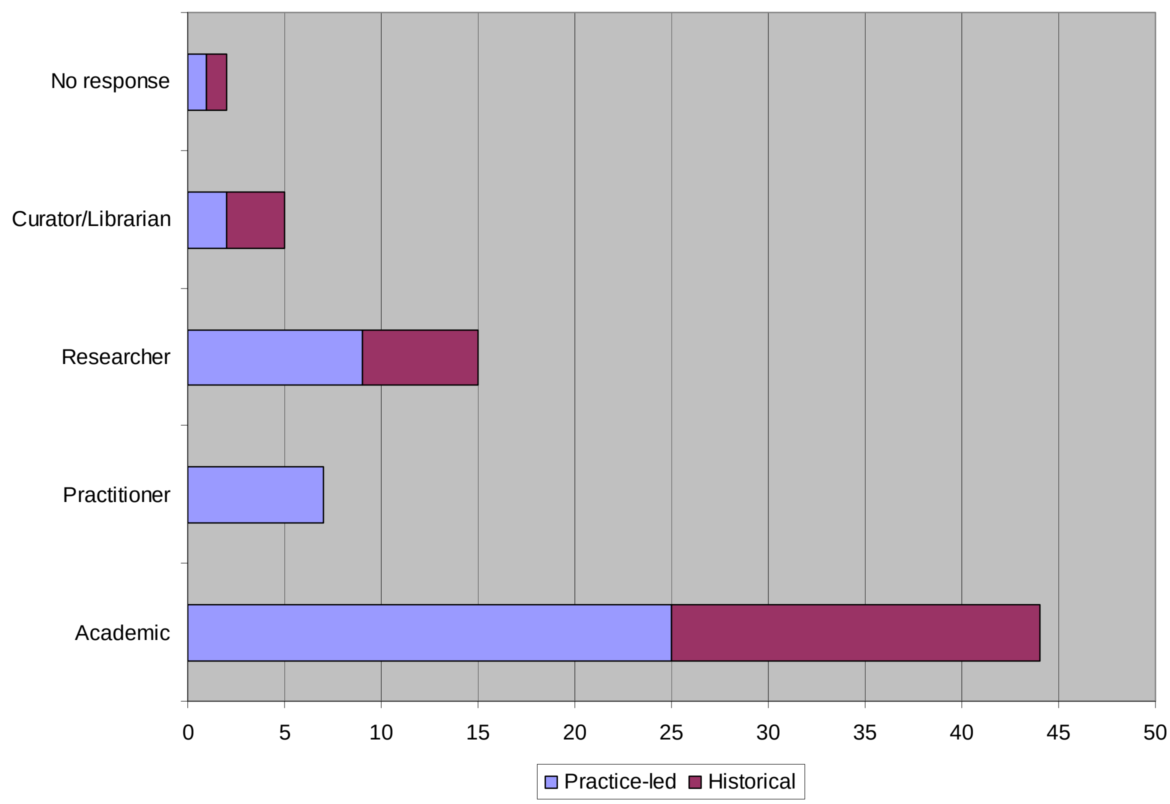

Figure 61. Broad occupational profiles of the survey sample.

As shown in Figure 61, the great majority of respondents classified themselves as academics, i.e. lecturers of one sort or another (44 respondents, 60% of sample). Next were the 15 researchers (21%), followed by 7 practitioners (10%) and 5 curators and librarians (7%). 2 respondents (3%) declined to answer this question. Historians tended to dominate the librarians and curators (40% of sample), but the balance between practice-led and historical researchers amongst the researchers and academics broadly reflected the proportion within the sample as a whole. Obviously, no historical researchers classed themselves as practitioners. (Figure 62 shows a more detailed breakdown of respondents' positions.)

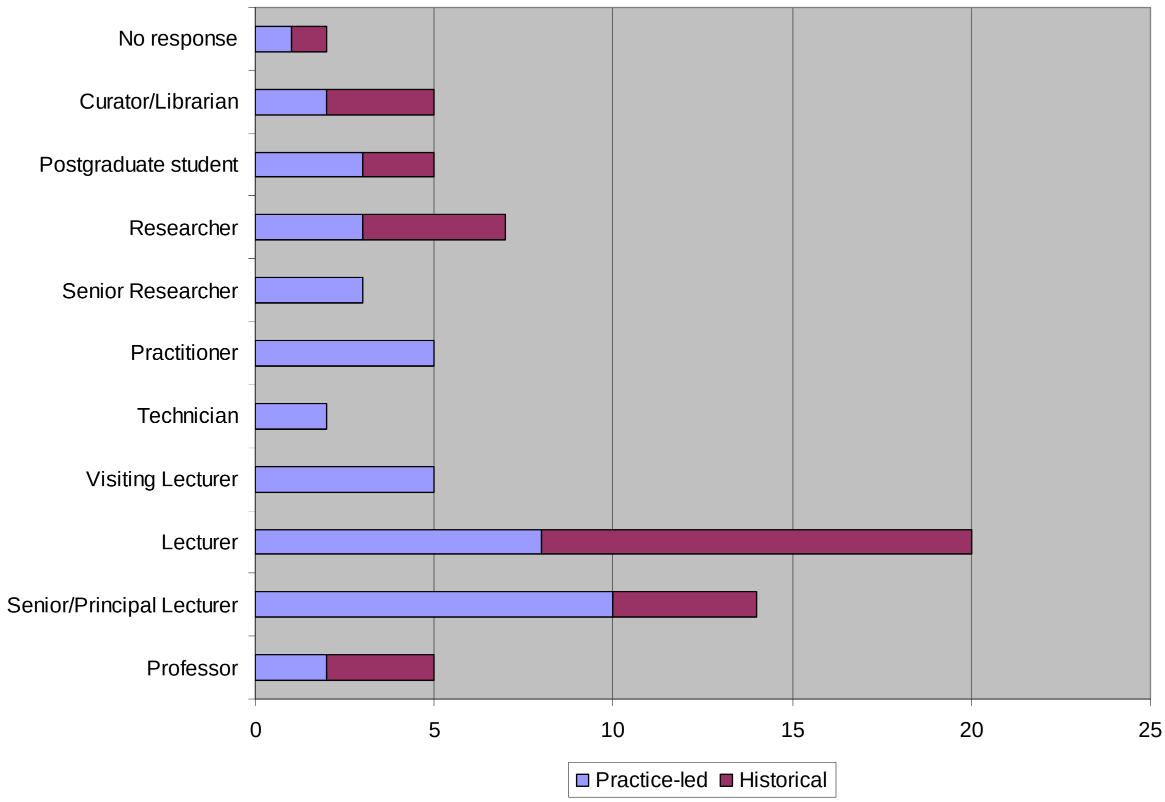

Figure 62. Detailed occupational profile of survey sample.

The vast majority of respondents work for higher education institutions (62, 85% of sample – see Figure 63). 1 practitioner worked in adult education, and another in the commercial sector. 2 historical researchers worked as freelances. 1 historical and 1 practice-led researcher worked in the museum/library/archive sector. 5 respondents declined to give information about their institution.

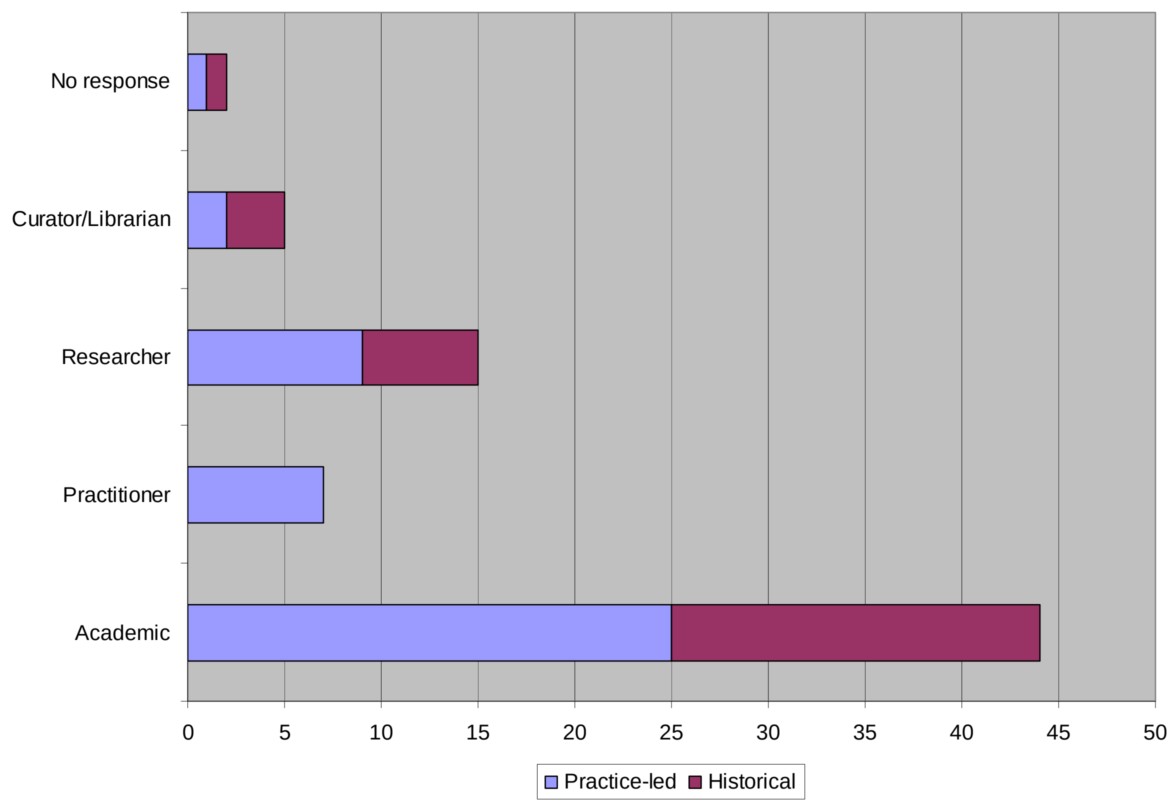

Figure 63. Institutional profile of survey sample.

3.1. Content

The questionnaire asked:

```
1. Do you use digital imaging technologies in your current practice
   and/or research? Y/N

   If 'Yes', what technologies do you use?
   If 'No', why not?

2. Are there things you'd like to do in your practice and/or research
   which you cannot do at the moment? (Please enter anything, whether
   you think it might relate to digital technology or not.) Y/N

   If 'Yes', please describe them.

3. Do you think digital technologies could help you to do them? Y/N

   If 'Yes', how could digital technologies help?

4. Is there anything else you would like to tell us in connection
   with digital imaging technologies and artistic practice?
```

In addition, respondents were asked to list their position and the type of institution they belonged to, as well as providing brief contact details if they wished to be contacted with further news of the project.

3.2. Invitations to respond

3.2.1. First e-mail list message for practice-led researchers

Message circulated to the following Jiscmail lists on questionnaire going live on 13 July 2006:

- ADM-HEA
- AHDS-ALL
- AHDS-VISUALARTS
- ARLIS-LINK
- ART-ALL
- ART-TECHNOLOGY
- ARTDESLIB
- ARTNET
- CADE
- CHART
- CRAFTS
- INTUTE-ARTSANDHUMANITIES (formerly ARTIFACT)
- TASI
- THE-DIGITAL-PICTURE

> The Arts and Humanities Data Service (Visual Arts) is running a one-year research project, funded by the AHRC, which aims to map advanced digital imaging technologies to the needs of practitioners in the visual arts. The project is called The Hunt for Submarines in Classical Art.
>
> You can have your say about visual arts needs by going to http://www.vads.ahds.ac.uk/submarines.html.
>
> It has been apparent for some time that certain forms of art and craft practice rely heavily upon digital imaging technologies, and that using these technologies can be stimulating and productive. However, for many practitioners, it is very difficult to find out about the latest technologies, and how to secure access to them. Equally, scientists may well develop technologies which could benefit creative practice, but be completely unaware of how practitioners could exploit them. The project aims to bridge this gap by producing a report and a database which will make a series of connections between these two spheres.
>
> If you are a practising artist, we would like to hear from you, whether or not you use digital imaging technologies in your practice, and whether or not you think it might help you in your practice in the future - it will be just as important for us to know that there are no visual arts needs as it will be to know that there are many.
>
> All the data we receive will be anonymous, although you can send us your name and e-mail address so that we can send you news of the project's findings, or let you know if we come across any technologies which we think might help you. We will not use the addresses we gather for any other purpose, although we may use comments submitted in our report and other material.
>
> For more information about the project as a whole, please go to http://www.ahds.ac.uk/visualarts/projects/submarines/.
>
> I look forward to reading your comments.

With best wishes,

Rupert Shepherd

3.2.2. First e-mail list message for historical researchers

Message circulated to the following e-mail lists on the dates specified.

List name	Date sent
AAH-HE-ISSUES@jiscmail.ac.uk	20 October 2006
ARCH-HISTORY@jiscmail.ac.uk	17 October 2006
ART-LINE@yahoogroups.com	20 October 2006
DESIGN-HISTORY@jiscmail.ac.uk	17 October 2006
H-ARTHIST@h-net.msu.edu	20 October 2006
MAT-REN@jiscmail.ac.uk	20 October 2006
SAARCH@jiscmail.ac.uk	17 October 2006
WEDGWOOD@jiscmail.ac.uk	20 October 2006

The Arts and Humanities Data Service (Visual Arts) is running a one-year research project which aims to map advanced digital imaging technologies to the needs of researchers in the visual arts. The project is called The Hunt for Submarines in Classical Art. It is funded by the Arts and Humanities Research Council (AHRC) and based at the Farnham campus of the University College for the Creative Arts at Canterbury, Epsom, Farnham, Maidstone and Rochester.

You can have your say about art historians' needs by filling in the online questionnaire at http://www.vads.ahds.ac.uk/submarines-ah.html.

Whilst the benefits of digital imaging in the fields of conservation and scientific analysis have been apparent for some time, the advantages that digital imaging can bring to other forms of art-historical research are less well-known. For many researchers, it is very difficult to find out about the latest technologies, and how to secure access to them. Equally, scientists may well develop technologies which could benefit research, but be completely unaware of how researchers could exploit them. The project aims to bridge this gap by producing a report and a database which will make a series of connections between these two spheres.

If you are a researcher in art history or a related field (e.g. design history, history of architecture, etc.), we would like to hear from you, whether or not you use digital imaging technologies in your research, and whether or not you think it might help you in your research in the future - it will be just as important for us to know that there are no art historical needs as it will be to know that there are many.

All the data we receive will be anonymous, unless you decide to tell us your name and e-mail address so that we can send you news of the project's findings, or let you know if we come across any technologies which we think might help you. We will not use the addresses we gather for any other purpose, although we may use comments submitted in our report and other material, where they will remain anonymous. We may also share anonymous comments with the Methods Network, http://www.methodsnetwork.ac.uk, who are working on similar issues.

For more information about the project as a whole, please go to http://www.ahds.ac.uk/visualarts/projects/submarines/.

Thank you for your time – we look forward to reading your thoughts!

3.2.3. Second e-mail list message for practice-led researchers (beginning of autumn term 2006-7)

Message circulated to the following Jiscmail lists on the dates specified, after the beginning of autumn term 2006-7.

ADM-HEA	24 October 2006
AHDS-ALL	24 October 2006
AHDS-VISUALARTS	24 October 2006
ARLIS-LINK	26 October 2006
ART-ALL	26 October 2006
ART-TECHNOLOGY	26 October 2006
ART-VISUAL	1 November 2006
ARTDESLIB	1 November 2006
ARTNET	1 November 2006
ARTNET-ALL	24 October 2006
CADE	24 October 2006
CHART	3 November 2006
CRAFTS	3 November 2006
INTUTE-ARTSANDHUMANITIES	3 November 2006
PRACTICE-LED	6 November 2006
TASI	6 November 2006
THE-DIGITAL-PICTURE	6 November 2006

The following message was posted during the summer vacation, when I realise that many list members would have had other things on their mind. Now that the new academic year is well underway, I'm circulating it again, with apologies and thanks to those who have already responded; and, of course, apologies for the inevitable cross-postings.

The Arts and Humanities Data Service (Visual Arts) is running a one-year research project, funded by the AHRC, which aims to map advanced digital imaging technologies to the needs of researchers and practitioners in the visual arts. The project is called The Hunt for Submarines in Classical Art.

You can have your say about visual arts needs by going to http://www.vads.ahds.ac.uk/submarines.html.

It has been apparent for some time that certain forms of art and craft research and practice rely heavily upon digital imaging technologies, and that using these technologies can be stimulating and productive. However, for many researchers and practitioners, it is very difficult to find out about the latest technologies, and how to secure access to them. Equally, scientists may well develop technologies which could benefit creative practice and research, but be completely unaware of how researchers and practitioners could exploit them. The project aims to bridge this gap by producing a report and a database which will make a series of connections between these two spheres.

If you are a researcher in the visual arts, we would like to hear from you, whether or not you use digital imaging technologies in your research or practice, and whether or not you think it might help you in your research or practice in the future - it will be just as important for us to know that there are no visual arts needs as it will be to know that there are many.

All the data we receive will be anonymous, unless you decide to tell us your name and e-mail address so that we can send you news of the project's findings, or let you know if we come across any technologies which we think might help you. We will not use the addresses we gather for any other purpose, although we may use comments submitted in our report and other material, where they will remain anonymous.

For more information about the project as a whole, please go to http://www.ahds.ac.uk/visualarts/projects/submarines/.

I look forward to reading your comments.

With best wishes,

Rupert Shepherd

3.2.4. University College for the Creative Arts email

Email sent to all staff at University College of Creative Arts on 28 July 2006:

Please feel free to circulate this message to anyone you think may be interested who is not on the main staff e-mail list, particularly sessional staff.

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The Arts and Humanities Data Service (Visual Arts) is running a one-year research project, funded by the AHRC and based at the University College's Farnham campus, which aims to map advanced digital imaging technologies to the needs of practitioners in the visual arts. The project is called The Hunt for Submarines in Classical Art.

You can have your say about visual arts needs by going to http://www.vads.ahds.ac.uk/submarines.html.

It has been apparent for some time that certain forms of art and craft practice rely heavily upon digital imaging technologies, and that using these technologies can be stimulating and productive. However, for many practitioners, it is very difficult to find out about the latest technologies, and how to secure access to them. Equally, scientists may well develop technologies which could benefit creative practice, but be completely unaware of how practitioners could exploit them. The project aims to bridge this gap by producing a report and a database which will make a series of connections between these two spheres.

If you are a practising artist, we would like to hear from you, whether or not you use digital imaging technologies in your practice, and whether or not you think it might help you in your practice in the future - it will be just as important for us to know that there are no visual arts needs as it will be to know that there are many.

All the data we receive will be anonymous, unless you decide to include us your name and e-mail address so that we can send you news of the project's findings, or let you know if we come across any technologies which we think might help you. We will not use the addresses we gather for any other purpose, although we may use comments submitted in our report and other
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material, where they will remain anonymous.

For more information about the project as a whole, please go to http://www.ahds.ac.uk/visualarts/projects/submarines/.

I look forward to reading your comments.

With best wishes,

Rupert Shepherd

3.3. Responses to questions

Responses have been numbered according to the order in which they were received. Each response's number is followed by:

- The type of respondent (practice-led or historical). This is based upon which of the two questionnaires was returned, personal knowledge of the respondents or the institutions to which they belong, and the contents of the response.
- A standardised indication of the respondent's role and seniority, using the following terms:
    - Professor
    - Senior/Principal Lecturer
    - Lecturer
    - Visiting Lecturer
    - Technician
    - Practitioner
    - Senior Researcher
    - Researcher
    - Postgraduate student
    - Curator/Librarian
    - No response
- The type of institution to which respondent belongs, using the following terms:
    - HEI
    - Adult Education
    - Museum/Library/Archive
    - Independent
    - Commercial
    - No response

1. Practice-led, Professor, HEI.

`Do you use digital imaging technologies in your current practice and/or research?` Yes

`If 'Yes', what technologies do you use? If 'No', why not?`
generative media, high end projection systems, custom interactive interfaces, all based around computing

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
Have a research team working for me full time.

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
As my practice is entirely concerned with using digital systems it is unimagineable I could do this work without them.

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

2. Practice-led, Senior/Principal Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
Photoshop (image creation, storage, maipulation), Powerpoint (public presentations), Final Cut Pro (video and sound editing), embedding digital images in Word for papaers written for publication

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
1. easily retrieve digital images for lectures--too time consuming, copyright hassles, locational sourcing diffiulties, etc. Good old slide carousels are infinitely easier. 2. authour my own web pages

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
1. not sure--is there an easier way? 2. definitely--but I have no time to stop to learn this given other pressures at the moment.

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

3. Practice-led, Senior/Principal Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? No

If 'Yes', what technologies do you use? If 'No', why not?
because I don't understand digital print tecnology? prints in exhibitions are listed as wierd technologies that I can't find on any industry websites.

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
my practice needs to include digital imaging. I'm ok with a camera, but i need more advice on drawing programmes to use with industrial 3d processes- otherwise i may as well make the 3d object myself.

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
If I can have MDF forms watercut from drawings, I don't have to make templates, and I won't die from dust in my studio.

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

4. Practice-led, Practitioner, No response.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
photography, multimedia

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
3d moving typography

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

5. Practice-led, Curator/Librarian, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
Scanning- flat bed (Epson and Mustek) and slides (Cyberview) - on demand or specific projects; Photoshop/Paintshop Pro - enhance quality of image for ad hoc digital publication; Online searches for images of artists' output; Collect e-ephemera

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
YES YES YES i have always been interested in CBIR because i am interested in how to retreive images of work that has been produced by unknown artists, where subject description is inadequate (eg 'abstract'). I have around 100,000 slides I want to enhance access to and want to involve CBIR that goes beyond colour and shape.. though I admire the work on the Hermitage's web site. Also the quality of the slides is variable and I need ways of retreiving the original quality of the image without needing to spend a long time doctoring each image. i need a way of running cd's of images and works that are donated by artists to be dropped into a cataloguing system (library OPAC) too. Sorry to be vague.

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
see above...

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

6. Practice-led, Visiting Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
Digital Camera and photoshop system. I also scan directly from negatives to obtain a digital scan for print purposes. I am not generally very pleased with the results or consistency of results from digital production - particularly when trying to achieve large scale works in print. Comparisons to digital imaging make negative and print production vastly superior still, particularly at large scale and in terms of cost.

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
To produce high res large scale prints, consistently. I would like to have easy access to a high res scans and printing facilities. A digital file has some advantages over analogue once produced, such as consitency of production through a perfectly balanced digital file. However, it is ridiculously expensive for scan and print facilities at the pro end of the market, and I suspect kept so by the manufacturers.

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
See previous answer

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

7. Practice-led, Senior/Principal Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
I use a whole range of software and hardware, nothing particularly ground breaking. i'm involved in teaching design for digital media, design and code web pages and I'm a consultant designer to a company that designs and installs retail screens.

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
I have an immediate need to know how to limit the range of blooth [Bluetooth] hardware. This is an example of regular little issues that crop up.

Do you think digital technologies could help you to do them? No

If 'Yes', how could digital technologies help?
Don't really understand the context of the question.

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

8. Practice-led, Practitioner, No response.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
Digital Camera, Laptop computer

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.

Do you think digital technologies could help you to do them? No

If 'Yes', how could digital technologies help?

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

9. Practice-led, , HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
digital film and photography (FCP, Adobe design Suite, Aperture)

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
Working on more complex video work and working in high definaition

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
Yes, but the problem is you feel like you are constantly chasing new technologies.

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

10. Practice-led, Visiting Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
digital camera,scanner and printer to make photo-marquetry

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
turn a photograph of a bird into a 3D 'object that can be rotated and resized

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
not sure

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

11. Practice-led, Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
photoshop and whatever suits the job

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? No

If 'Yes', please describe them.

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
large size printing

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

12. Practice-led, Senior/Principal Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
Scanner/digital camera/video

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
mapping time

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
tracking timeframes?

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

13. Practice-led, Lecturer, Adult Education.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
pc

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
Discover cutting edge images

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
By circulating images on the net

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

14. Practice-led, Senior Researcher, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
A wide range of 3D and 2D imaging technologies, 3D laser scanning, haptic interaction devices, augmented reality devices, motion tracking, computer vision tech.

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
grid computing and on-line databases

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
They are digitial, but we currently lack network support for advanced activities such as these

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

15. Practice-led, Technician, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
flatbed scanner, digital camera

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? No

If 'Yes', please describe them.

Do you think digital technologies could help you to do them? No

If 'Yes', how could digital technologies help?

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

16. Practice-led, Senior/Principal Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
Using the fusion of random digital photographic images to excercise and enhance creating thinking processes.

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
I would like to find a publisher that understands the richness of this idea to young creatives. I would also like to know how to produce an Ebook with website to share crerative thinking with others worldwide.

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
I know that my ideas are sound and grounded within current critical thought. It capitalises on the convenience of digital technologies for a continuous flow of image making and generates fresh outomes whilst exercising the creative mind. It would help if I knew how to see the captured images on-screen before capture and manipulation begins?

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

17. Practice-led, Senior/Principal Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
Still and moving digital images - Also scanning of (conventional) photographic/drawn images into programmes which offer the possibility of manipulation.

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
To work more with moving digital images through - access to equipment/facilities/technical help eg editing, and to be able to explore ideas relating to projection/presentation/installation.

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
Specific manipulation of images and 'resting' of work made through access to equipment and facilities. Possibly courses/workshops which deal not only with 'how to' but also sessions engaging with what is/might be possible.

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

18. Practice-led, Visiting Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?

Creation of software application program which involves programming in C, C++, Win32 and OpenGL. Also, until recently I was programing a haptic co-location API (Reachin) installation, using C++, OpenGL, Python and VRML. (XDirect)

Are there things you’d like to do in your practice and/or research which you cannot do at the moment? Yes

If ‘Yes’, please describe them.
1) Locate a sympathetic group of artist researcher who program and are enthusiastic about 3D visualisation, 3d drawing, colour etc. 2) Locate a research institute/University sympathetic to my research ideas about 3D drawing using haptic technology.

Do you think digital technologies could help you to do them? Yes

If ‘Yes’, how could digital technologies help?
My research ideas were developed from my artistic practice (fine art painting and printmaking) and my teachin in HE fine arts institutions and I consider that it is not a simple question of digital technologies helping but of considering digital technologies as a new medium that sits alongside and also combines with the traditional mediums.

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

19. Practice-led, Senior/Principal Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If ‘Yes’, what technologies do you use? If ‘No’, why not?
Computer aided design (2D & 3D modelling)CAM -Rapid Prototyping, Laser scanning & displacement mapping

Are there things you’d like to do in your practice and/or research which you cannot do at the moment? Yes

If ‘Yes’, please describe them.
Work with a more intuitive haptic interface that isn't precribed /limited by software engineers perceptions of how it will be used. This would help enable the sensitivity of the jewellery to retain the qulaities my 'hands', as wel as my 'eyes' can help me judge.

Do you think digital technologies could help you to do them? Yes

If ‘Yes’, how could digital technologies help?
With greater reflection on hand knowledge and craft practice.

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

20. Practice-led, Practitioner, No response.

Do you use digital imaging technologies in your current practice and/or research? Yes

If ‘Yes’, what technologies do you use? If ‘No’, why not?
I am not a digital or new media artist, but digital imaging is essential in my practice - for documentation, dissemination and a s a sort of extended studio, allowing me to play with images that feeds into my drawings and installations. To this end I use photoshop, digital camera, scanner, transparency scanner, and the web

Cost and availablity is always a factor - I prefer to buy a new technology (e.g. camera) and wortk with it, rather than hire the services of someone/a time slot and have to know exactly what I want to do with it - the difference between an artist and a film director I guess...

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
More fluid methods of sharing images over the internet, cheaper faster web connections (frustration of having to compress images, or wait a long time to send a print quality file). I plan to get a camera phone - to use as a kind of sketch book (e.g. on a site visit when I don't have a camera and want to record a particular feature that I may use in my work). / A particular issue with my work, which is small (even tiny) scale drawings and sculptures, installed quirkily in large architectural spaces) is documenting the work easily and convincingly - a conventional method would be to take two photos of a work installation view and detail - with my work, this doesn't work - installation views typically show a blank wall with a few specks on it, detail views show a 'pretty' image with no sense that this isn't simply a luxury object.

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
In particular, I am looking at short vid eo/animated clips which can be web mounted - giving a sort of viewers perspective but at present I find the quality limitations of making a file portable enough outweigh the advantages. / I am also experimenting with blogging technology (for example the ability to email direct to my blog) as a way of disseminating 'work in progress' - I expect my next move will be to take images of a days work in the studio, email them from my phone to my blog to work at at home, or away.

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

21. Practice-led, Practitioner, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
Mac + PC computers, laser disc, DVD; Software: image processing, motion graphics, video editing and custom software; input devices: infrared and electrical field sensors , , ,

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
Record full color uncompressed high resolution motion pictures; control camera movement

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
software and hardware outside the mass market

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

22. Practice-led, Postgraduate student, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?

Photoshop, Final Cut Pro

Are there things you’d like to do in your practice and/or research which you cannot do at the moment? Yes

If ‘Yes’, please describe them.
Realistic simulation of light effects on the body that are generated by the positioning of various miniature and small scale light sources in relationship to the body.

Do you think digital technologies could help you to do them? Yes

If ‘Yes’, how could digital technologies help?
They could facilitate the modelling and experimentation stage of my work with wearbale light features

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

23. Practice-led, Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If ‘Yes’, what technologies do you use? If ‘No’, why not?
wireless video cameras networked to gps tracking devices; rfid; digital photo & video cameras; photo manipulation softwares (photoshop etc); max/ msp jitter; pure data

Are there things you’d like to do in your practice and/or research which you cannot do at the moment? Yes

If ‘Yes’, please describe them.
research into biometric identification digital processes and surveillance equipment used by security industry

Do you think digital technologies could help you to do them? Yes

If ‘Yes’, how could digital technologies help?
theoretical critical research & practice (project development)

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

24. Practice-led, Senior/Principal Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If ‘Yes’, what technologies do you use? If ‘No’, why not?
Digital Photography and video

Are there things you’d like to do in your practice and/or research which you cannot do at the moment? Yes

If ‘Yes’, please describe them.
Mimicry of an animals point of view and perspective on the human world

Do you think digital technologies could help you to do them? Yes

If ‘Yes’, how could digital technologies help?
By the simulation of an animal's perception once the components and forms of vision have been identified.

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

25. Practice-led, Senior Researcher, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
just about everything, imaging and database software; digital video editing including digibeta for archiving

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
have access to cheap wireless broadband anywhere anytime

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

26. Practice-led, Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
Photoshop

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
documenting my practice and presenting it as research in a way that is not necessarily conventional written research

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
...more sophisticated editing of fim/images, DVD making etc.

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

27. Practice-led, Researcher, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
Image Manipulation software: Adobe CS2 package, Freehand, Flash. Also patternmaking software for clothing, i.e. PAD, Gerber, etc.

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
Generate real time, moving, manipulatable images in a web-based environment that can be captured as instances and downloaded at high resolution for output to wide format digital printing devices.

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
file format conversions and screen capture technology....

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

28. Practice-led, No response, No response.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
Digital camera, colour scanner, image editor

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
Send large images over the internet more easily, and also print out large images in colour more cheaply (I think that's being done, giclee etc, but it's expensive)

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
For sending, maybe data compression?

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

29. Historical, Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
digital / dv camera, computer / software / vle

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
editing existing film material - too much copyright projection built into digital formats

Do you think digital technologies could help you to do them? No

If 'Yes', how could digital technologies help?
don't think that this is a digital matter as much as an attitude to image ownership which inhibits intellectual exchange

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?
yes, frustration that too many low res images (film and photography) and projectors mean that image quality continues to be an issue

30. Historical, Researcher, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
I use a digital camera to take pictures of buildings and store them on my computer. I use my computer and a data-projector to present these images for teaching or seminars.

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
Further comparison with international architecture.

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
There are already databases of architectural images, which I use, but more would be good.

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

31. Historical, No response, No response.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
Mainly digital camera

(not sure what the question means, but make extensive use of DAMS (iView Media Pro) to catalogue digital image collections which may be direct digital image, or scanned source.

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? No

If 'Yes', please describe them.

Do you think digital technologies could help you to do them? No

If 'Yes', how could digital technologies help?

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

32. Historical, Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If ‘Yes’, what technologies do you use? If ‘No’, why not?
a) internet research for literature and images from databases on the net, e.g. prometheus-bildarchiv.de
b) software for presentation of digital images, e.g. MSPowerPoint,
c) graphics editors and scanners for digitalisation and manipulation of images and graphics design, e.g. Photoshop/InDesign
d) development of web-based e-learning scenarios.

Are there things you’d like to do in your practice and/or research which you cannot do at the moment? Yes

If ‘Yes’, please describe them.
anotation of metadata not only to images as a whole but also to details in digital images, creation of image maps and use of digital images in e-learning-scenarios, use of geodata in the analysis of topologies in urban history and architecture

Do you think digital technologies could help you to do them? Yes

If ‘Yes’, how could digital technologies help?
gathering of historically relevant geodata by gps and digital geodaetics and analysis in gis-software in order to visualise historical topologies in interactive aerial photos and maps.

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

33. Historical, Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If ‘Yes’, what technologies do you use? If ‘No’, why not?
digitized 'slide' libraries, internet resources, such as the metropolitan museum of art timeline and the cal state university library of images

Are there things you’d like to do in your practice and/or research which you cannot do at the moment? Yes

If ‘Yes’, please describe them.
would like digitized database of images that is searchable based on various criteria, such as: 1. design basics (media used, colors, 2-d vs. 3-d); cultural context (categories of makers, purposes, disposition of object/performance, etc.) the reason i want this is because i teach world art and it is important to have access to the four quarters of the earth and time periods from 100,000bce to the present.

Do you think digital technologies could help you to do them? Yes

If ‘Yes’, how could digital technologies help?
1. many items have never been catalogued and those which are catalgoued are not yet linked in a useable way. 2. searachable linked databases are essential for world art research and online teaching of world art. 3. oceania is particularly under represented. 4. digital technologies have the power to be egalitarian and serve scholars and students internationally.

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?
if there is a way i may help you in creating a world art database, please let me know.

34. Historical, Professor, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
Computer vision. Animation.

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? No response

If 'Yes', please describe them.
Since I collaborate with well-financed research teams (e.g. Microsoft) I can get round lack of funding.

Do you think digital technologies could help you to do them? No response

If 'Yes', how could digital technologies help?

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?
Most of the existing use of computers is unimaginative, unadventurous and non-visual.

35. Historical, Curator/Librarian, Museum/Library/Archive.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
Images, databases.

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
The problem lies essentialy with a backlog of inputting - digital images, records to databases (e.g. inventories) etc. Scale is often also a problem - digital images (like print) do not indicate size.

Do you think digital technologies could help you to do them? No response

If 'Yes', how could digital technologies help?

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

36. Historical, Senior/Principal Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
- Image Google on the web (all the time)
- Powerpoint presentation (well, strictly speaking, this is teaching not research)

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
Difficult to say not knowing what the options are. Downloading entire vintage films or film clips is one. Getting a higher quality image is the other.

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
I don't know. I am not technically adept enough.

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

37. Historical, Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
digital images for research; internet pedagogical webpages for teaching.

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
Have quick and easy access via digital images to any work of art I want to write about; including multiple views and digital video of the works of art in their physical surroundings (public spaces, musuem spaces, etc.)

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
Digital videos would allow for more convincing analysis of physical contexts of works of art. Multiple views the same.

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?
Just as art historical research often takes on databases and digital archives, so too should the wealth of digital images be made easy to use. Note: not all databases allow quick and easy cutting and pasting into powerpoint. This is vital for professional presentations.

38. Historical, Senior/Principal Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
Digital photography and scanning of photographs

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
I need to catalog my visual resources so they can be cross-referenced and easily searched by date, author, location, style, and media.

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
By providing a visual resources catalog functioning in a way similar to bibliographic reference software.

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

39. Historical, Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
CAD drawing of buildings and sites, RAW photography, HDR photography, QTVR panoramic photography, ColorGeniusEX (Screen Cezanne Elite scanner), PostgreSQL database catalog of objects with Java interface, translating into SQL the Getty cataloging recommendations

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
Video documentation of public rituals, CAD flythrough reconstructions of historic sites.

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
High Definition Video would be useful, requiring the expenditure for the appropriate camera, a considerable hard disk space and a dedicated CPU and monitor. More useful would be a talented camera operator. Ditto modelling software for CAD Flythroughs, which would need even an array of computers for processing data. Again, even more important would be an array of talented CAD draughtspersons to measure, enter and prepare the data.

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?
Common standards for color management and for cataloging would allow more institutions and individuals to swap data. What about an open-source approach to visual knowledge?

40. Historical, Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
digital images of works of art--the web. Photoshop

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
I'm limited by the quantity and quality (resolution) of digitally reproduced images. Certain kinds of digital imagery simply aren't available. Also limited in regard to time-based imagery.

Do you think digital technologies could help you to do them? No

If 'Yes', how could digital technologies help?
It is not a question of technology so much as it is a question of access and file sharing.

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

41. Historical, Senior/Principal Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?

tiff and jpeg files, dataprojector, digital camera

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
I need a properly organised visual database - i.e.: a good and felxible software package to organise my considerable database in such a way that material is easy to find.

Do you think digital technologies could help you to do them? No

If 'Yes', how could digital technologies help?

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?
The need for software packages particularly for art history teaching. Databases that are easy to search and catalogue.

42. Historical, Professor, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
digital camera (canon eos 350)
scanner (nikon coolscan 5000, for slides from my archive)
prometheus

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
I'd like to have a technology which stops the loss of quality in the technical change from analogue (slide) to digital: e.g. shifting lines in architectural photography, distorted colours and above all formats (architecture, sculpture).

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

43. Historical, Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
Web browser, powerpoint, digital camera, photoshop

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
search for image by non-verbal content

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?

I believe there are some 'form' searching technologies (e.g. as used by Guildhall Print Library).

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?
More training in their use welcome. E.g. photoshop, diagram design, etc. Many scientists are much more adept than us.

44. Historical, Researcher, Independent.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
Scanner, Digital Camera, div. Software

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
take fotos in situations with little light (churches) without heavy equipment

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
by becoming more sensitive for little light

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

45. Practice-led, Practitioner, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
video camera, webcams, photoshop ,final cut pro, google earth, digital camera, freefall

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
receive unedited satellite images or data and have the software to interpret/produce them myself.
Use non-mouse navigation such as hand gestures, or walking

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
I know these technologies exist, I know the researchers who've developed them, but its heaps of negotiation to have access to use them and tons of luck.

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?
Very little information seems to make its way out of Vancouver, I think its partly the way they like things...but MAGIC at the University of British Columbia has some amazing new kit, huge high resolution screens, wall size and they're looking for art projects, Sid Fels is the guy there.

46. Historical, Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
ARTstor, ripping images off the Web, Photoshop, PowerPoint

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
find enough good images of contemporary art and design

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
Textbook publishers, for example, need to provide images with their textbooks.

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

47. Historical, Researcher, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
scanned some primary material - images & text - into computer

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
have all my photocopied primary material - newspaper articles and pictures, in digital format for inclusion in database, eventually in a website

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
scanning, searching, retrieval of images/text

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?
in order to do any of this i have to learn how - would be good to have more training in universities or departmental technie to help research staff

48. Historical, Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
Internet

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
Better knowledge of works of art in museums and private collections, better possibilities for research

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
see above

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

49. Practice-led, Technician, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
D-SLR photography, miniDV video, High-Definition video, webcams.

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
explore gigapixel photography, high-speed videography and interactive video compositing.

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
Digital technologies provide the boundaries my work aims to push.

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

50. Practice-led, Senior Researcher, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
We have a range of equipment: Sony HD video camera, Nikon D2X digital still camera, Epson 4880 scanner and a Lieca HD3000 ScanStation (portable 3D scanner).

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
To streamline the digital scanning to 3D model process. Our current method is good but I would like to find a faster route.

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?
Portable 3D scanners are expensive but amazing to use. They are capable of quickly and accurately scanning a complicated building or surface. We are using the equipment for the development of a highly detailed 3D model of Glasgow. We would have an incredibly difficult time without it!

51. Practice-led, Visiting Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
Photoshop and Powerpoint

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
I would like to be able to 'attach' any caption information shown along with an image on-screen (say, in a museum's online collection) as and external caption 'label' - that is, without having to go the way of Photoshop and 'File Info' (often having to copy and paste info in there myself, as it is not always embedded in the original file for downloading). As I use this mainly for teaching and for keeping visual reference files for my own research, being able to see the caption information alongside the image at all times (if I want) would be immensely useful. There exists software that can do this (browsers used by electronic picture desks for example) but this is not generally available or suitable for academic research and teaching.

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
See above.

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

52. Practice-led, Postgraduate student, HEI.

Do you use digital imaging technologies in your current practice and/or research? No

If 'Yes', what technologies do you use? If 'No', why not?
Not enough information and access to resources in order to choose the proper tools.

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
I don't know because I don't have access to the information needed to make an informed decision.

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
Better mapping tools for the study of works of art (relational mapping), possibly social-science tools used for network-theory methods

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

53. Historical, Curator/Librarian, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
Excel spreadsheet with jpegs inserted.

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
There must be a better way than just Excel with an image pasted into it! Without spending £30,000 on "Capture", or downloading one of those pieces of software that people use to store their holiday photos on. They are not fit for my purpose, at least.

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
Surely researchers of art history must have devised a way to combine text and image - surely we could pool our knowledge and avoid having to buy in expensive software... I am working as one of a team of cataloguers of drawings and ideally I would like to pool my research and share it via the web with my fellow cataloguers wherever and whenever.

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

54. Historical, Postgraduate student, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
Maps and fotos of ancient spain in any digital format

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
access and work in space of digital in ancient and historic maps and fotos

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
for comparition,study and presentation

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

55. Practice-led, Visiting Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
I scan images (from printed sources) and display them in powerpoint presentations for lectures and conference papers.

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? No

If 'Yes', please describe them.

[sic] Show stills and short extracts from films.

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
I'm sure the tehnology is there - I just haven't tried it.

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

56. Historical, Professor, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
nikon digital camera; nikon cool-scan slide scanner; small digital camera; flatbed scanner

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
quicker slide scans

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
MORE AND CHEAPER STORAGE! we have to scan 100,000 slides for a start- and crashed the Faclty server! cheaper faster more efficient slide scanners; higher quality flatbed scanners that are cheap; easier, clearer processing; making it easier to keep resolution when transferring images.

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?
instruction books are completely terrible- badly written and incomprehensible; labels, buttons, menus are tiny and impossible to read

57. Practice-led, Researcher, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
photoshop, flash, after effects, 3d studio max

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
make good quality interactive 'art' games more easily

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
well, a toolset and engine that would allow me to create game or digital story environments easily and intuively. but as far as we can see there is not one that exists which is why we are trying to build the tools ourselves.

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

the digital realm extends the pallete into the interactive, however, artist should be aware of the many dead herrings in this areas but also look to tap into interactivity's huge potential

58. Practice-led, Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
PC Windows XP, broadband, a wide range of creative software.

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
Outdoors projection, GPS location-aware art, sound art, better and bigger pictures, generative shadow-puppets.

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
All kinds of things that require money - would like a 16:9 HD video camera for stills capture, a portable digital projector and laptop for outdoors projections, and a wide range of hardware to play with. Software is cheap/free (bittorrent), having a web site is about £80 per year, hardware is expensive. Also money for travel, attending conferences, making exhibition-quality works.

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?
Have had work shown at international conferences, expos, been a lead artist on major arts projects - still can't get Arts Council funding. The sooner they're abolished the better.

59. Practice-led, Postgraduate student, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
scanning and digital photography

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
Access microscopic images of plants which can be digitally manipulated to create works of art

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
Electron microscopes could provide source material which can be manipulated on a computer

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?
The use of computers and audio/visual software is becoming increasingly prevalent in the development of works of art

60. Practice-led, Professor, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
digitisation of vhs to dvd; image capture from web, didtial camera etc to powerpoint etc

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
access to historic TV material and metadata

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
databases; portals to collections; enhancement of BUFVC system around the 'box of broadcasts' and databases like TRILT

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?
need for statutory deposit for electronic media and archiving of websites

61. Practice-led, Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
digital camera, scanner, video camera

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
Motion capture; sending images to mobile phones

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

62. Practice-led, Researcher, Commercial.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
Laser scaning technology

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
Usability and "images" recycling

Do you think digital technologies could help you to do them? No

If 'Yes', how could digital technologies help?

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

63. Practice-led, Curator/Librarian, Museum/Library/Archive.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
scanning, image editing, databases, photography

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? No

If 'Yes', please describe them.

Do you think digital technologies could help you to do them? No

If 'Yes', how could digital technologies help?

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

64. Practice-led, Senior/Principal Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
Digital print related media as related to Fine Art Printmaking; Industrial Sign making and Vinyl cutting

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? No

If 'Yes', please describe them.
Laser cutting and similar technologies as used by industry

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
Technical and material support to help realise new projects

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?
I am interested in the place of digital technology within Printmaking as a Fine Art medium and its links with the historic tradition of print to use new technology as a vehicle for ideas

65. Historical, Senior/Principal Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?

dv camera of exhibitions

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
transfer existing slide resources into digital format; share resources with other institutions

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
enable us to set up a database of current exhibitions

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

66. Historical, Postgraduate student, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
my digital camera, digital images from the internet for comparison

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
download proper high resolution images where one can zoom in

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
as above

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?
(digital) images of (large european) museums are still much too expensive to buy. One must encourage museums/print rooms to provide research images at reduced prices

67. Practice-led, Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
Digital camera, video, data projection, computer, printer(black and white, colour, large format,Photocopier)photoshop, panorama stitching,

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
get close enough to subjects seperated by water and below me

Do you think digital technologies could help you to do them? No

If 'Yes', how could digital technologies help?

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?
I used to rely on traditional photography and commercial printing as I was unable to produce my prints within my own knowledge base. technology has freed me from these restrictions.

68. Historical, Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
Slide scanning; Use of AHDS databases

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
Greater access to archival material overseas (I am based in Australia, but researching individuals who were born and spent part of their lives in the UK)

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
More materials in databases; more sophisticated search strategies.

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?
My current research project simply would not have advanced to its current stage if it was not for:
a. the AHDS database, which contains images of work by the woman I am researching; and
b. a library in the US which had the catalogues/finding aids of some of its manuscript collection online. By using items accessed in these collections I was able to confirm that two seemingly unrelated individuals were the same person.
This would have been impossible without access to that information by electronic means.

69. Practice-led, Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
Raster Graphics- photoshop & CorelPainter, Vector Graphics CorelDRAW & Illlustrator, Pagination- InDesign. Wacom Tablets, Digital cameras & Epson Archival Bubblejet Printers

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
Large format Imaging like 1m X1,5 m. I cannot afford the printers and the cost of getting printing done at digital printerss in Australia is expensive. You have to know somewone with access to a lage format printer.

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
As Above

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

I have been using digitalimaging technolies in my arts practice since 1985. Originally I output the images using traditional printmaking processes, Etching, Photplymer Relif prints and screen prints. Since 2000 the majority of my output has been digital. The main problem I see with digitaly imaginf is
1 The cost of large format printing
2 The archival qyualities of the various printing processes.

70. Historical, Curator/Librarian, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
I want to create an Access database on which to make a drawings catalogue. There are digital images available to me from our Institute's website, which I have downloaded into a file. What I need to know is how to create a link between my database and my images file.

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
Has anybody had experience of linking their database with their images file?

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?
If someone out there has an answer to my query, could they please get in touch with me.

71. Historical, Researcher, Independent.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
Digital photographs, PowerPoint, scanned images, drawings in WordDraw

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
Obtain digital images of medieval manuscripts more often and more easily from on-line sources

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
If libraries had more resources for digitising projects

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?
Digital imaging technologies have made my research much easier. Improvements in colour reproduction are looked forward to.

72. Historical, Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
Photoshop; CAD

Are there things you'd like to do in your practice and/or research which you cannot do at the moment?

If 'Yes', please describe them.

Do you think digital technologies could help you to do them?

If 'Yes', how could digital technologies help?

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?

73. Historical, Lecturer, HEI.

Do you use digital imaging technologies in your current practice and/or research? Yes

If 'Yes', what technologies do you use? If 'No', why not?
CD Roms, Google Images, Grove Art's Bridgeman, University websites, Museums and Art Gallery websites
Digital camera slides from books or realia

Are there things you'd like to do in your practice and/or research which you cannot do at the moment? Yes

If 'Yes', please describe them.
Using powerpoint presentations of images: to have images formatted automatically for comparison
Find images more quickly and store them for easy retrival.
I would like huge systems that offer images from interdisciplinary sources but available when a facility is turned on. This would enable images to break outside just 'art history' and into broader realms which might have applicability to new or unknown types of knowledge which involves art history.
I want access to more remote or presently unavailable images.

Do you think digital technologies could help you to do them? Yes

If 'Yes', how could digital technologies help?
But I don't have the expertise.
Perhaps the internet will supply better quality images

Is there anything else you would like to tell us in connection with digital imaging technologies and artistic practice?
Fast retrival and close details of images and objects.

Lack of time does not help this submission.

4. Terminology

4.1. Units of measurement – the SI prefixes

The SI (Système International d'Unités) prefixes are used to indicate multiples of basic units (metres, seconds, grammes, litres, etc.). The symbols and their meanings for the range of multiples covered by this report are listed in Table 7 below.

Symbol	**Prefix**	**'Short scale'**	**'Long scale'**	**Decimal equivalent in SI writing style**	**10^n**
T	tera	trillion	billion	1 000 000 000 000	10^{12}
G	giga	billion	milliard	1 000 000 000	10^{9}
M	mega	million		1 000 000	10^{6}
k	kilo	thousand		1 000	10^{3}
h	hecto	hundred		100	10^{2}
da	deca	ten		10	10^{1}
(none)	*(none)*	one		1	10^{0}
d	deci	tenth		0.1	10^{-1}
c	centi	hundredth		0.01	10^{-2}
m	milli	thousandth		0.001	10^{-3}
µ	micro	millionth		0.000 001	10^{-6}
n	nano	billionth	milliardth	0.000 000 001	10^{-9}
p	pico	trillionth	billionth	0.000 000 000 001	10^{-12}

Table 7. The SI prefixes.

Source: extracted and re-drawn from http://en.wikipedia.org/wiki/SI_prefix, consulted 5 January 2007.

4.2.

The electromagnetic spectrum

The following figure indicates the relative positions and wavelengths of the main parts of the electromagnetic spectrum, including those discussed in this report.

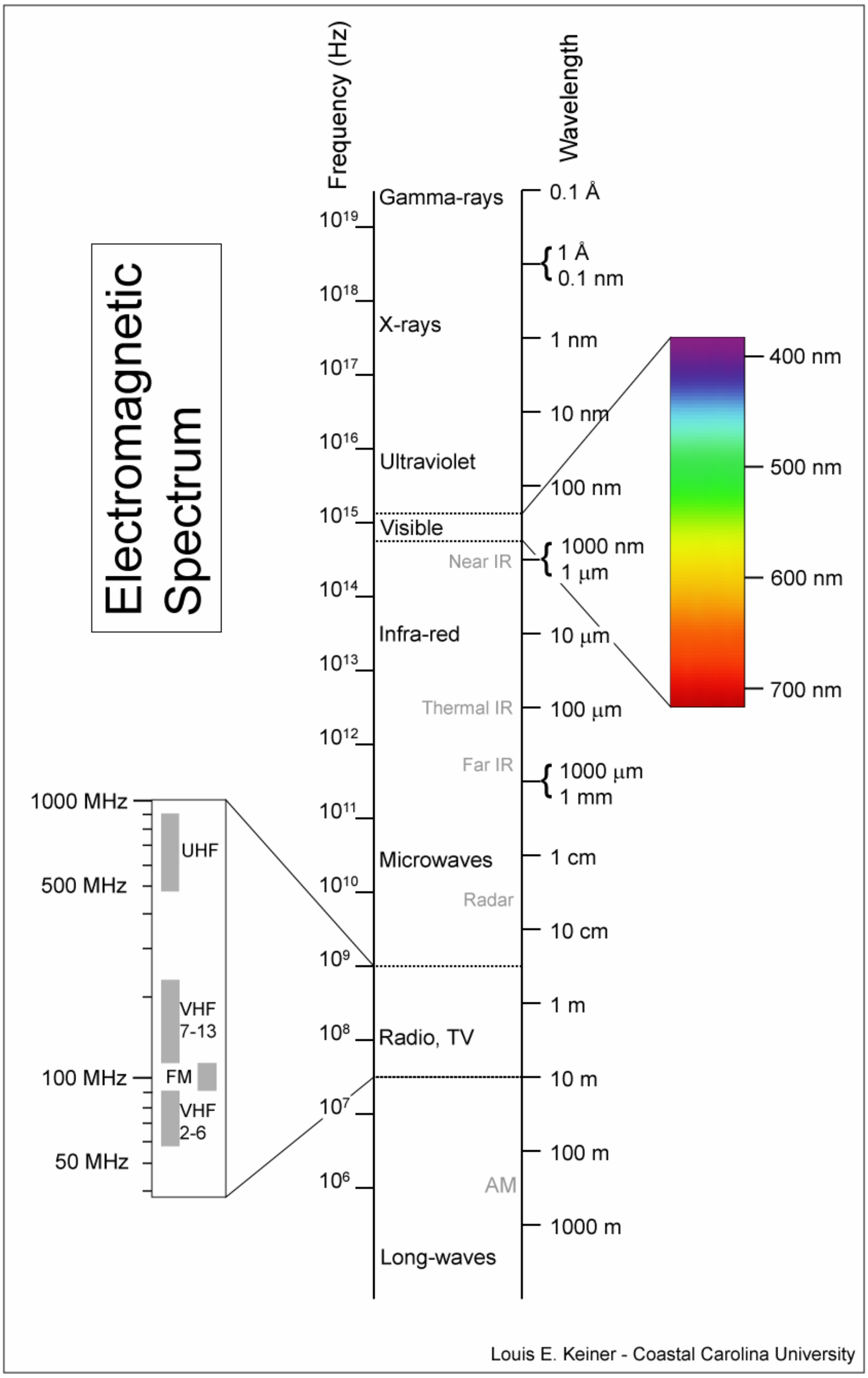

Figure 64. The electromagnetic spectrum.

Source: http://en.wikipedia.org/wiki/Image:Electromagnetic-Spectrum.png, downloaded 4 January 2007. Image created by Louis Keiner. This image is licensed under the Creative Commons Attribution ShareAlike License v. 2.5: http://creativecommons.org/licenses/by-sa/2.5/

4.3. TMA – Too Many Acronyms

The following abbreviations and acronyms are used in this report. The list also includes a few terms which may be unfamiliar to readers. The SI prefixes c, d, da, G, h, k, M, m, n, p, T, and μ are defined in 4.1 above.

2DEG	2 Dimensional Electron Gas.
3DOF	3 Degrees Of Freedom. Used to describe haptic interfaces which provide feedback in 3 linear directions (up-down, left-right, in-out) (2.2.1).
3DVisA	3D Visualisation in the Arts network
6DOF	6 Degrees Of Freedom. Used to describe haptic interfaces which provide feedback in 3 linear directions (see *3DOF* above) and in the corresponding 3 rotational directions (2.2.1).
ABS	Acrylonitrile Butadiene Styrene. A kind of plastic used by some rapid prototyping (2.10.2) devices.
ACDT	Academic Computing Development Team (Oxford University Computing Service).
AHDS	Arts and Humanities Data Service.
AHeSSC	Arts and Humanities e-Science Support Centre.
AHRB	Arts and Humanities Research Board.
AHRC	Arts and Humanities Research Council.
AMUC	Associated Motion-capture User Categories. An e-Science (2.7.1) research project based at the University of Newcastle.
API	Application Programming Interface. A software interface used by a computer system to handle requests made by a computer program.
applet	A small piece of software that runs inside another program (often a web-browser), usually extending its capabilities
ARTISTE	A research project which aimed to provide 'an integrated art analysis and navigation environment' (see 2.9.1).
avatar	An internet user's online representation of themselves. Often used of two- or three-dimensional images or models.
AVI	Audio Video Interleave. A multimedia file container format used to hold audio and video files.
B	Byte. A unit of measurement for data storage in computers, usually comprising 8 bits (1s or 0s) of computer data. Usually prefixed by one of the SI prefixes (4.1).
BMP	BitMaP. A *raster* graphics file format.
BOINC	Berkeley Open Infrastructure for Network Computing. A distributed computing system (see 2.7.2).
CACHe	Computer Arts, Contexts, Histories, etc. A research project based at Birkbeck College.
C++	A highly-popular general-purpose programming language.
CAD	Computer-Aided Design.
CADE	Computers in Art and Design Education.
CALM	Creating Art with Layer Manufacture. A project which introduced artists to rapid prototyping techniques.

CAT	Computerised Axial Tomography. (See also *CT*).
CAVE	Cave Automatic Virtual Environment. A form of immersive virtual reality environment.
CBIR	Content-Based Image Retrieval. See 2.9.1.
CCD	Charge-Coupled Device. A form of electronic light sensor.
CCH	Centre for Computing in the Humanities (King's College, London)
CCO	Cataloguing Cultural Objects. A data standard developed by the *VRA*.
CDWA	Categories for the Description of Works of Art. A data standard developed by the Getty Research Institute.
CGI	Common Gateway Interface. A protocol for connecting external applications with an information server, commonly used to send data from a database on a web server to a web browser.
CGI	Computer-Generated Imagery.
CHArt	Computers and the History of Art.
CID	Charge Injection Device. A form of electronic light sensor (2.3.2).
CIDOC	Comité International pour la Documentation. The International Committee for Documentation of the International Council of Museums.
CIDOC CRM	The *CIDOC* Conceptual Reference Model. An ontology developed by CIDOC.
CIE	Commission internationale de l'éclairage. The International Commission on Illumination.
CITRIS	Center for IT Research in the Interest of Society (University of California at Berkeley).
CLIC	Community-Led Image Collections. A research project reporting to the *JISC* Images Working Group; its report is Miller et al. 2006.
CMY	Cyan Magenta Yellow. A three-colour printing model.
CMYK	Cyan Magenta Yellow Key. A four-colour printing model, where 'key' is black.
CODEC	COmpressor-DECompressor, COder-DECoder, or COmpression/DECompression algorithm. A means of encoding and decoding digital media files.
CRT	Cathode Ray Tube. The technology used in old televisions and computer monitors.
CRUMB	Curatorial Resource for Upstart Media Bliss. An online resource for potential curators of new media art.
CT	Computed Tomography. A *tomographic* imaging technique using x-rays. (2.3.12 and 2.3.13; see also *CAT*.)
CVRO	Cultural Virtual Reality Organisation.
DCMS	Department for Culture, Media and Sport.
DIAMM	Digital Image Archive of Medieval Music. A research project compiling an archive of images of manuscripts of medieval music.
DirectX	A collection of *API*s used to handle multimedia on Microsoft platforms.
DLP	Digital Light Processing. A technology used to create the image in high-resolution digital projectors, based upon a semiconductor chip covered with an array of tiny mirrors.
DOF	Degree Of Freedom. Used to describe the number of dimensions in

	which haptic interfaces provide feedback. (2.2.1; see also *3DOF* and *6DOF*.)
DRHA	Digital Resources in the Humanities and Arts. An annual conference, until 2005 simply Digital Resources in the Humanities.
Dublin Core	A highly generalised, very flexible and extremely widely-used metadata standard.
DVD	Digital Versatile Disc. A format and medium for storing data on optical discs.
DXF	Drawing eXchange Format. An interoperable format used for *CAD* files.
ECCO	Eighteenth-Century Collections Online. A commercial corpus of electronic texts.
e-Chase	Electronic Cultural Heritage made Accessible for Sustainable Exploitation. A project to unify several discrete databases of heritage material using semantic technologies. (2.9.2)
Eclipse	An open-source software development platform.
EEBO	Early English Books Online. A commercial corpus of electronic texts.
EEG	Electro-EncepheloGram. A display of the electrical activity in the brain.
EPOCH	European research network on Excellence in Processing Open Cultural Heritage.
fEITER	Functional Electrical Impedance Tomography of Evoked Responses. A novel *tomographic* method of imaging brain activity using electrical impedance. (2.3.3)
FELIX	A volumetric display system (2.10.8).
FIRE	Flexible Image Retrieval Engine. A content-based image retrieval system (2.9.1).
fMRI	Functional Magnetic Resonance Imaging. The use of *MRI* to examine the functioning of live organs.
fps	Frames Per Second. A measurement of video and cine frame-rates.
FTE	Full-Time Equivalent.
GB	GigaByte. 1,000 Megabytes or 1,000,000,000 bytes (see *B*, and 4.1 above).
GIMP	*GNU* Image Manipulation Package. An extensively-featured open-source image editing program, focussing on *raster* graphics.
GIS	Geographic (or Geospatial) Information System. A series of technologies for digitising, displaying and working with digital data which can be mapped to points on the earth.
GNU	GNU's Not Unix. An open-source computer operating system. Various forms of the licence under which GNU has been released have been extensively used by the open source community.
GPS	Global Positioning System. A satellite navigation system which enables a small receiver to give its position relatively precisely anywhere in the world; GPS receivers can often also store a route they have followed.
GVA	Gross Value Added.
HASTAC	Humanities, Arts, Science, and Technology Advanced Collaboratory. A consortium of researchers across these fields.
HATII	Humanities Advanced Technology and Information Institute (University of Glasgow).

HD	High Definition. Usually used of video and television signals.
HEFCE	Higher Education Funding Council for England. A quango.
HiResFELIX	A high-resolution version of the *FELIX* volumetric display (2.10.8).
HP	Hewlett-Packard.
HP2	A proprietary data-compression *codec* created by *HP*.
HRI	Humanities Research Institute (University of Sheffield).
HTML	HyperText Markup Language. The basic markup language used to create webpages.
IC	Information and Communication.
ICT	Information and Communication Technologies.
i-DAT	Institute of Digital Art and Technology (University of Plymouth).
IEEE	Institute of Electrical and Electronics Engineers. A professional association.
IIP	Internet Imaging Protocol. A protocol for serving images to websites. (2.5.1)
ImageCLEF	Image Cross-Language Evaluation Forum. An infrastructure established to develop systems for searching images tagged with metadata in various languages (or without using metadata at all, i.e. using content-based image retrieval, 2.9.1)
InGaAs	Indium Gallium Arsenide. A substance used in some photosensitive cells.
INOA	Istituto Nazionale di Ottica Applicata. A research institute.
IP	Internet Protocol. A protocol used to transmit packets of data across a network.
IS	Information Systems.
ISEA	Inter-Society for the Electronic Arts; or International Symposium on Electronic Art. The former organises the latter.
ISO	International Organization for Standardization. Used in this report for a standard method of defining the sensitivity of photographic emulsions, ISO 5800:1987.
IT	Information Technology.
JANET	Joint Academic NETwork. The UK's computer network for education and research.
Java	A cross-platform programming language.
JavaScript	A scripting language widely used in websites.
JISC	Joint Information Systems Committee. A UK body supporting the use of *ICT* in further and higher education, originally established to deal with networking and specialist information systems issues.
Jitter	See *Max/MSP*.
JPEG	Joint Photographic Experts Group. A committee working on formats for digital images, which gave its name to a lossy compression method (a *codec*) and a file format for containing the resulting data, optimised for tonally-rich images.
JPEG 2000	An image compression standard intended to supersede the *JPEG* standard.
LAIRAH	Log Analysis of Internet Resources in the Arts and Humanities. An AHRC ICT Strategy project; its report is Warwick et al. 2006.

LCD	Liquid Crystal Display. A form of thin, flat, low-power digital display.
LED	Light-Emitting Diode. A semiconductor that emits light when an electric current is passed through it. The light is usually concentrated in one colour, and can be created anywhere from the near-ultraviolet to the infrared (see 4.2 above).
m	Metre.
MARC	Methodology for Art Reproduction in Colour. A research project, evolving from *VASARI*, dealing with very precise imaging of paintings. (2.3.7)
MARCEL	Multimedia Art Research Centres and Electronic Laboratories. A network of research centres and performance and exhibition spaces, often communicating using Access Grid (2.1.1) and e-Science (2.7.1) technologies.
Max/MSP	A signal processing program, often used by digital musicians. Combined with Jitter, it can be extended to process video signals.
MB	MegaByte. 1,000,000 bytes (see *B*, and 4.1 above).
MiMeG	Mixed Media Grid. A social sciences e-Science research project. (2.1.4)
MIT	Massachusetts Institute of Technology.
MITH	Maryland Institute for Technology in the Humanities.
MOLAB	Mobile LABoratory. A mobile collection of experts and technologies dedicated to the in-situ, non-destructive examination of artworks.
MP3	*MPEG-1* Audio Layer 3. A digital audio *codec* and related file format, incorporating lossy compression.
MPEG	Moving Picture Experts Group. A committee working on formats for digital moving images, which gave its name to a series of data standards and *codecs*.
MPEG-1	A series of audio and video compression standards and *codecs*, and associated software, developed by the *MPEG*, for digital video of roughly *VHS* tape quality.
MRI	Magnetic Resonance Imaging. A method of non-invasive imaging which relies upon the property known as 'spin' in the hydrogen nuclei of water molecules; often used for medical imaging.
Nd:YAG	Neodymium-doped Yttrium Aluminium Garnet. A crystal used in lasers, usually producing light at a wavelength of 1064 nm (in the near infra-red – see 4.2).
OAI	Open Archives Initiative. An initiative developing and promoting interoperability standards facilitating the efficient dissemination of digital content.
OAI-PMH	*OAI* Protocol for Metadata Harvesting. An *XML* based protocol for exposing and harvesting metadata from digital repositories. (2.8.2)
OCT	Optical Coherence Tomography. A form of *tomographic* imaging relying upon the production of interference patterns by light from two beams travelling nearly-identical lengths. (2.3.15)
OCVE	Online Chopin Variorum Edition. A project aiming to assemble and compare digital versions of early editions of Chopin's works.
OPAC	Online Public-Access Catalogue. Primarily used of online library catalogues.

OpenGL	Open Graphics Library. A cross-language and cross-platform specification for an *API* for writing applications that produce three-dimensional graphics.
OpenMKS	An open source assemblage of off-the-shelf software components which exploits web services technologies to seamlessly integrate disparate collections of multimedia content. (2.9.2)
OUCS	Oxford University Computing Services.
OWL	Web Ontology Language. A markup language for disseminating ontologies via the world-wide web, used in some semantic web (2.8.3) implementations.
PARC	Palo Alto Research Center. Xerox's research and development laboratory.
PbO-PbS	Lead Oxide – Lead Sulphide. A substance used in some photosensitive cells.
PDA	Personal Digital Assistant. A small, hand-held, computer.
PDF417	Portable Data File 417. A very common two-dimensional barcode format.
PEM	Path-Enhanced Media. Used by *HP* to describe a combination of multimedia files and continuous path data, as created by their PathMarker system. (2.3.4)
PET	Positron Emission Tomography. A medical *tomographic* imaging technique which uses a radioactive tracer ingested by the patient and scintillator detectors.
PIG	Personal Interface to the Grid. A low-cost means of using the Access Grid. (2.1.1)
pixel	PICture Element. A single point in a *raster* image.
PNG	Portable Network Graphics. A *raster* digital image format incorporating lossless compression.
ppi	*Pixels* per inch. Used to denote the sampling resolution of digital image sensors.
PTM	Polynomial Texture Mapping. A technique for generating intermediate images from a finite number of related images. (2.3.10)
PtSi	Platinum Silicide. A substance used in some photosensitive cells, sensitive far into the infra-red (see 4.2).
QBIC	Query By Image Content. A *CBIR* system developed by IBM.
RAE	Research Assessment Exercise.
raster	A way of encoding a digital image so that it is made up of an array of *pixels*, defining a certain set of properties (such as colour or intensity) for each pixel.
RAVE	Resource-Aware Visualisation Environment. An e-Science (2.7.1) research project developing techniques for minimising bandwidth when transmitting visualisations over networks.
RAW	A variety of often-proprietary image file formats which store minimally-processed image data taken directly from an image sensor.
RCA	Royal College of Art.
RDF	Resource Description Framework. A series of specifications, originally stored in *XML*, providing a means of outlining the semantic

	relationships between individual pieces of metadata.
RePAH	Requirements for Portals in the Arts and Humanities. An AHRC ICT Strategy project; its report is Brown et al. 2006.
RepRap	Replicating Rapid-prototyper. A project to build a self-replicating machine using rapid prototyping (2.10.2) technology.
RGB	Red Green Blue. A three-colour model for reproducing colour, usually on illuminated displays such as TV s and monitors.
RSS	Rich Site Summary, Really Simple Syndication or *RDF* Site Summary. A family of formats which use *XML* to publish frequently-updated digital content via the internet.
SCULPTEUR	Semantic and Content-based mULtimedia exPloiTation for EURopean benefit. A research project combining semantic web (2.8.3) and *CBIR* (2.9.1) technologies to aid in the retrieval of data concerning museum objects.
SEM	Scanning Electron Microscope. A very high-magnification microscope which uses beams of electrons, rather than visible light, as its imaging medium.
SETI	Search for Extra-Terrestrial Intelligence. A research project which exploited grid computing (2.7.1) to process large amounts of radio-telescope data.
SI	Système International d'unités (International System of Units). The modern form of the metric system, which has produced a standard set of prefixes for units of measurement (4.1).
SIGGRAPH	The Association for Computing Machinery's Special Interest Group for Computer GRAPHics. A professional association which organizes a large annual conference and trade fair.
SIRIS	Scanning Infra-Red Imaging System. A very high-resolution infra-red camera, used to image works of art. (2.3.9)
SPIE	Society of Photo-Optical Instrumentation Engineers (now officially known as SPIE - The International Society for Optical Engineering). A professional association.
SSM	Soft Systems Methodology.
STL	Standard Tessellation Language. A file format used to send data to rapid prototyping (2.10.2) machines.
SXGA	Super eXtended Graphics Array. A computer display standard featuring a monitor resolution of 1280 x 1024 *pixels*.
TFT	Thin-Film Transistor. A form of transistor often used in combination with Liquid Crystal Displays (*LCD*s) in computer monitors.
TIFF	Tagged Image File Format. A widely-used container file format used for digital *raster* images.
tomography	The imaging of three-dimensional objects so that a three-dimensional image is produced, usually through reconstruction of a series of single slices through the object
URL	Uniform Resource Locator. In the context of this report, a web address.
USB	Universal Serial Bus. A widely-used standard for connecting external devices to computers.
v	Version. Used of computer software.

VASARI	Visual Arts System for Archiving and Retrieval of Images. A research project focussing on very high-fidelity capture of images of works of art. (2.3.7)
VASIG	Virtual Archaeology Special Interest Group.
VBA	Visual Basic for Applications. A Microsoft programming language and development environment for its Office products.
VEDA	Virtual Environment Design Automation. A technology for generating virtual three-dimensional environments on-the-fly in order to display data contained in a database. (2.8.4)
VERMEER	Virtual EnviRonMent for Education, Exploration and Research. A data management system for museum data (see 2.3.7).
VHS	Vertical Helical Scan (though often thought to stand for Video Home System). A recording and playing standard for analogue video cassette recorders.
VIPS	*VASARI* Image Processing Software. Software developed specifically to manipulate very large digital image files in a museum context. (2.2.3)
VISTA	VISualisation and Technology Centre (University of Birmingham)
VizNET	Visualisation NETwork. A collaboration between a number of visualisation centres in the UK, with the intention of providing a visualisation support network across the nation.
VLE	Virtual Learning Environment. A software system which helps deliver online education to students.
voxel	A combination of 'volume' and '*pixel*', i.e. a 'volume element'. A single point in a three-dimensional *raster* image.
VR	Virtual Reality.
VRA	Visual Resources Association. A professional organisation for those working with image media. It has given its name to a metadata standard developed for describing digital reproductions of images, often of works of art.
VRE	Virtual Research Environment. A software system which provides a digital environment in which to carry out research activities, often collaboratively.
VRML2	Virtual Reality Modelling Language version 2. A standard file format for representing three-dimensional interactive vector graphics.
wiki	A website that allows users to add, edit and remove content. The most famous manifestation is the Wikipedia, http://wikipedia.org.
XGA	eXtended Graphics Array. A computer display standard, usually used to refer to a monitor resolution of 1024 x 768 *pixels*.
XML	eXtensible Markup Language. A highly flexible and interoperable markup language, often used to exchange data over the internet.
XRF	X-Ray Fluorescence. An imaging technique based upon the emission of x-rays by an object that has been bombarded with high-energy x-rays or γ-rays. (2.3.16)
$YLiF_4$	Yttrium Lithium Fluoride. A crystal used in lasers, producing light at wavelengths in the near infra-red (see 4.2).
Zoomifyer	A proprietary system for publishing zoomable and navigable images on websites.