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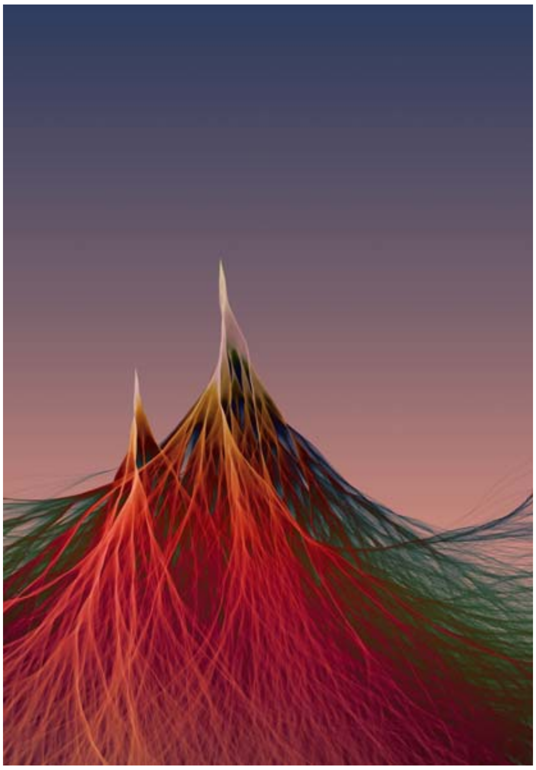
# The Hunt for Submarines in Classical Art: Mappings between scientific invention and artistic inspiration



## Summary of Project

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

## Summary of Project

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.

## Contents



List of illustrations



List of tables

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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

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[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.

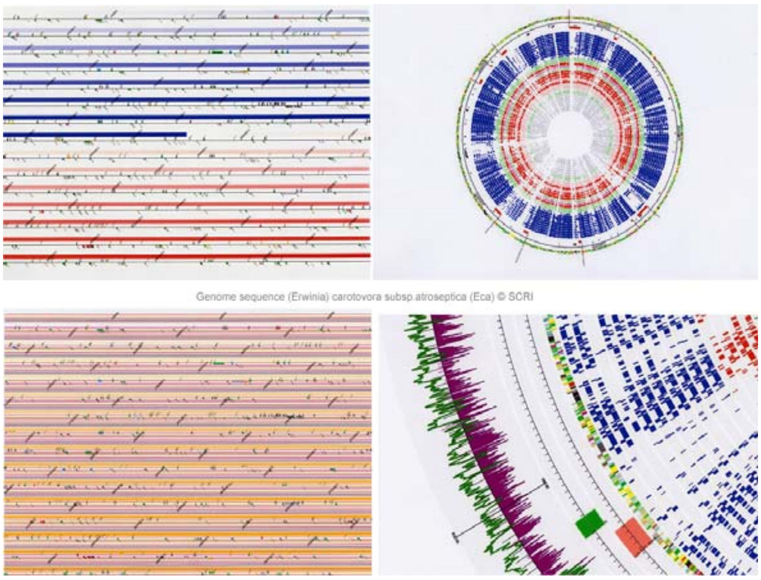


**Figure 1.** The genome sequence of (Erwinia) carotovora subsp.atroseptica (Eca). © 2006 Elaine Shemilt. Genome sequence © SCRI.

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.

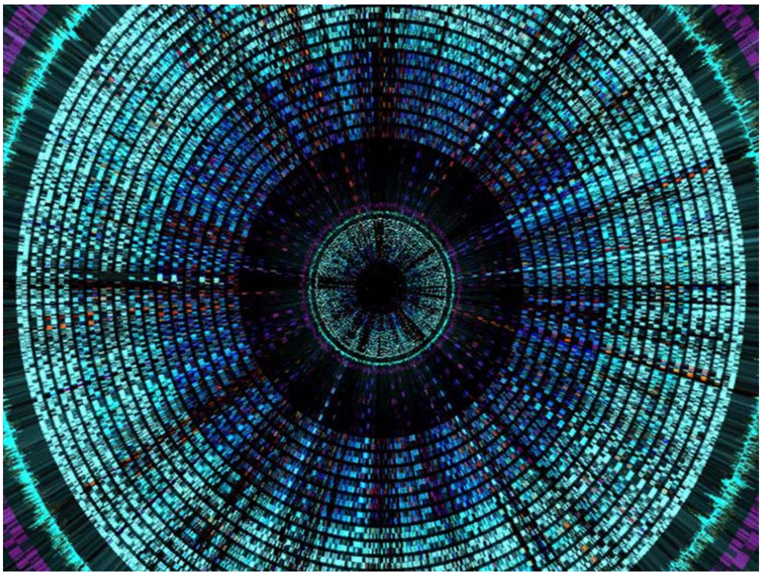

**Figure 2.** Elaine Shemilt, high-definition wide-screen video animation installed at *Inspiration and Discovery*, Visual Research Centre, Dundee Contemporary Arts, March 2006. © Elaine Shemilt.

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.

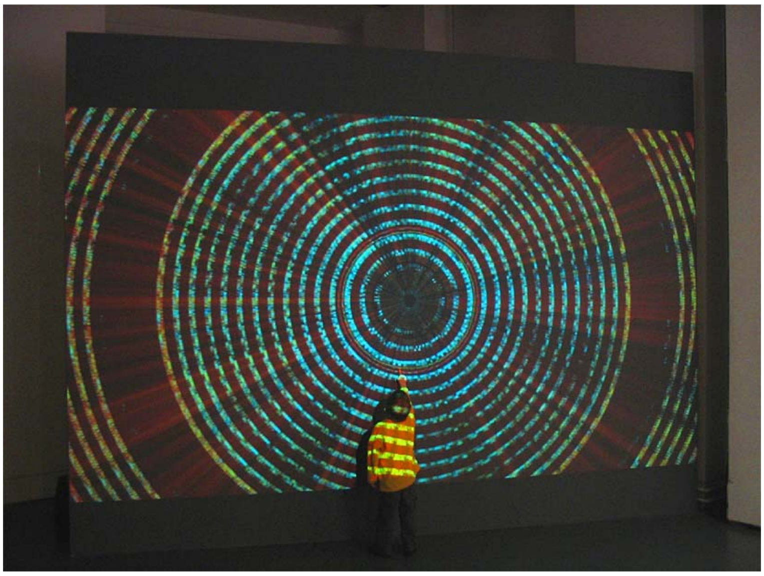

**Figure 3.** Elaine Shemilt, high-definition wide-screen video animation installed at Inspiration and Discovery, Visual Research Centre, Dundee Contemporary Arts, March 2006. © Elaine Shemilt.

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 (**Error! Reference source not found.**), 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.

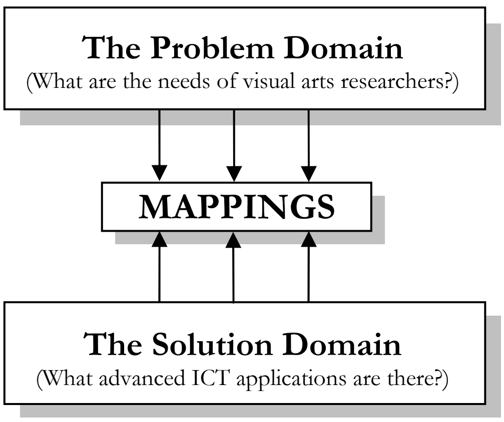


**Figure 4.** Simplified strategy for mapping ICT applications to visual arts research needs.

## 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. <u>Collaboration.</u> 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]

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[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.

[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 **Error! Reference source not found.** on page **Error! Bookmark not defined.**)

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.

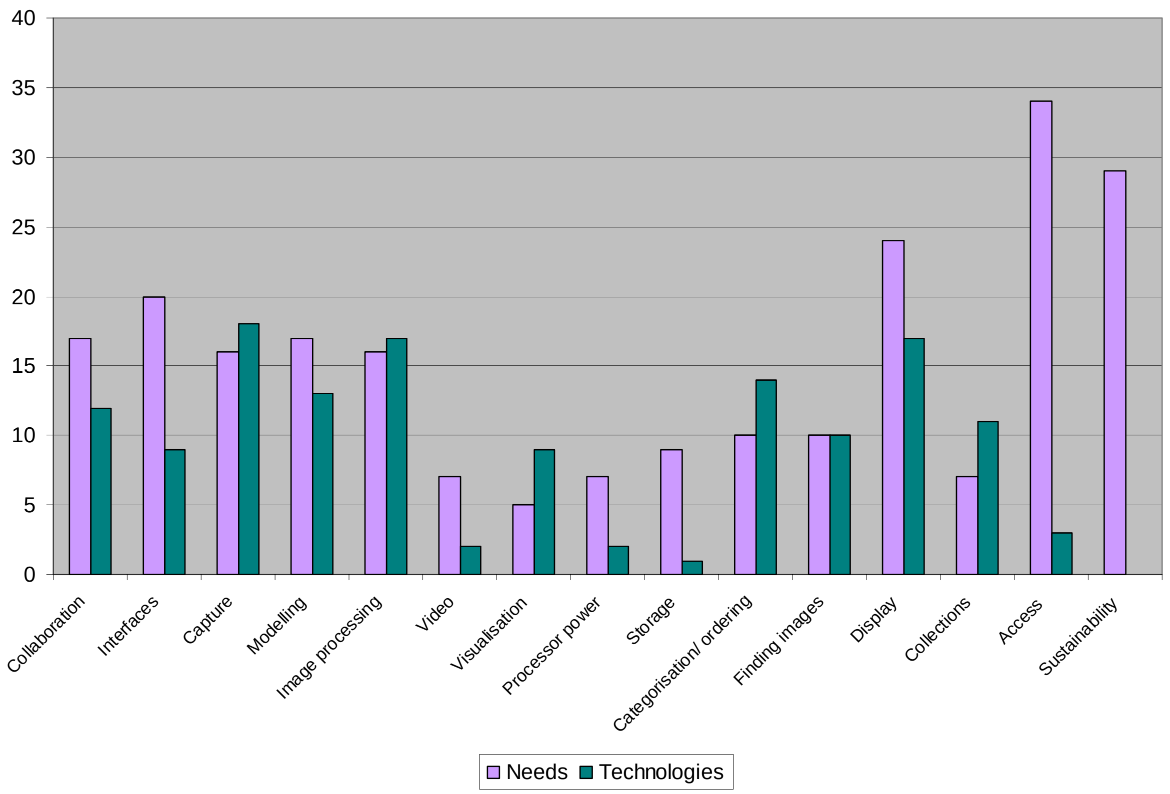


**Figure 5.** Individual needs and technologies compared, both divided into categories.

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).