High Resolution Images

Anthony Hamber

During the 1980s a number of innovatory electronic digital image input, storage, display and output devices came onto the commercial market. While some of these digital components have made their way into TV quality domestic electronic products, most notably the charge couple device (CCD) used in video Camcorders, the more powerful equipment remained expensive and had a limited number of users. Nevertheless, electronic digital imaging has already shown that it has very significant implications for those who wish to study visual data within a wide range of historical contexts and a number of pioneering electronic image projects took place during the late 1980s and early 1990s.[1] This chapter will examine the context of high resolution digital imaging raise some of the issues which will be central to future developments.

Such have been the rapid developments in the enabling technologies that even the standard personal computer is already moving away from merely being able to handle simple graphics (currently the standard is VGA format) to being able to handle "full-colour" images at a reasonable spatial resolution (perhaps in the order of 800x600 pixel). In the PC world the advent of Windows 3.0, with its ability to handle sophisticated true-colour graphics, has been another part of the perennial catalyst of the pull of technology and the push of market forces. It is therefore clear that a new era in imaging technology is about to begin. However, those who are concerned with the rapidly increasing demands of hard disc space on their PCs made by new operating systems (OS2 v.2.0), interfaces (Windows 3.1) or programs, and are yet to discover the joys of digital imaging, are in a for a substantial surprise. Digital images can take up very large amounts of hard disc space and the provision of storage for large numbers of digital images is key issue which must be addressed at an early stage of any project.

The high resolution image defies precise definition. Those who attempt such definition find themselves either making comparison with existing imaging systems, such as photography and television, or use the capabilities, or more pertently the limitations, of the existing electronic hardware and software base. While, when compared with a 10 x 8in transparency, one would not call a 35mm slide a "high resolution" image the digital equivalent of 35mm slide would, currently, be thus described. These analogies with the physical attributes and functionalities of an existing imaging system such as photography introduce the concept of the current vs. the future capabilities of electronic digital imaging systems. One of the key elements to this concept is the idea of "future-proofness" whereby digital image data originated today will not only be compatible with future systems but will also be sufficient to answer the needs of future user-requirements, requirements which are being constantly redefined and expanded as both users and technologists come to terms with the application of information technology.

The very issue of the application of high resolution digital imaging within historical research is a complex one. Again the use of digital images within arts teaching and research

[1] See ITEM (*Image Technology in European Museums and art galleries database*), Issue 2, European Visual Arts Centre at Ipswich, 1991 for a list of the visual arts projects.

is restricted to either existing conventions or a tendency to head of into the realms of Star Wars where functions may be technically possible but economically not viable. However, it is absolutely essential that the use of proposed high resolution images is detailed before imaging takes place. It is only when these requirements have been evaluated by importance and feasibility that a decision can be made about the necessary spatial resolution and colour bit depth that should be allocated to each high resolution digital image. In some cases it will be necessary to carry out detailed research to discover optimum resolutions for specific functions. It is also a fact that different sized views of the same image may also be necessary. i.e. perhaps a quick look, a small general view, a full-screen general view, and a "high resolution" image to allow panning and zooming or cut and pasting of details. Such different sizes of images have very important implications for all aspects of the design and implementation of a system.

The problematic definition of high resolution imaging is compounded by the high variation in the perception of the capabilities and application of digital imaging systems. This can be said to be true for both the technologist and the non-technologist user. Using the paradigm of photography as a bench mark for the design of digital imaging systems is a two-edged sword. In one respect digital imaging systems permit far greater access, interactivity and potential than conventional photography while in other respects simple existing functions are not yet feasible in the digital world. For instance, projecting, in sequence, 80 35mm slides mounted in a slide projector carousel is a standard teaching practice. In an art history lecture dual projection is the norm. Thus a one hour lecture might have 160 35mm slides. Each 35mm colour slide is the equivalent of around 25 MByte of information (the equivalent of a 3200 x 2600 pixel 24 bit image). A full 80 slot slide carousel would be the equivalent of 2 GByte of data. A 35mm slide mounted in a carousel projector can be called and displayed in under one second. To be able to access and display on screen such an amount of digital information would take at least 10 seconds even if the sequence of images was cashed and, furthermore, it were possible to display simultaneously all the data, which it is not.[2]

Two characteristics are central to the definition of the resolution of the digital image. These are spatial resolution, more loosely referred to as "detail", and measured in pixels, and colour data (or bit depth).

Spatial Resolution

The creation of a high resolution image is the result of the interrelationship of the "resolutions" and characteristics of the constituent parts of an imaging chain which includes the original object, the input device (camera), the storage device and the display/output device. One consistent element in this imaging chain is that the "image" will be examined by the human visual system and thus most imaging systems, such as photography or television, have been developed to create reproductions which look, to the human eye, like the original scene.

This is a complex issue since different imaging systems use different techniques to stimulate the human visual system. A colour photograph works on the principle of re-

[2] The The current limiting factor is the spatial resolution of computer monitors. This is discussed in more detail below.

flected light using the theory of subtractive colour mixing whereby white light is filtered using Cyan, Yellow and Magenta filters to produce a gamut of colours. Photographic transparency material works on the principle of transmitted and reflected light, again using the subtractive colour mixing principle. The CRT monitor, used by both television and computers, works on a principle of additive colour mixing by emitted light. These different principles result in different characteristics of different imaging systems which become integral parts of their design and construction.

The primary spatial resolution is that of the original object, say a painting. Even at this level important decisions have to be made before a digital image can be created since some users of a digital imaging system (such as painting conservators or scientists) will wish to have greater spatial resolution than that of the resolving power of the human eye at its minimum focusing distance.[3] Research undertaken on the VASARI project indicated that scanning an original painting at a resolution of 20 pixel/mm would give sufficient information for all the target users which ranged from scientists and conservators to art historians.[4] While this scanning resolution may not satisfy all users its importance is covering as wide a gamut as is economically and practically viable.

These findings run in parallel with both applied and theoretical research into image quality metrics being carried out by both art historians and imaging scientists. The Getty Art History Information Programm has carried out subjective tests to try and define parameters for the image quality of images displayed on CRT monitors. [5] The work centred on evaluation of juxtaposed colour or grey scale images of different spatial resolution on a CRT. The published results are inconclusive and are restricted to CRT display which, as will be indicated below, is just one element in the image chain which creates high resolution images. The complexity of this issue of the definition of a single total quality metric has been raised by Jacobson and Axford who have looked at the possibilities of effectively synthesizing the fundamental attributes of the physical measures of image quality.[6]

The relationship between the level of spatial resolution which is to be imaged from an original and the spatial resolution of the imaging input device (camera) is critical one, and one which has to be immediately addressed. A colour photographic emulsion can resolve up to 80 line pairs (lp/mm) (one black line next to one white line) which is the equivalent of 160 pixel/mm. In the case of specialist black and white negative films the resolving power is far greater up to 500 lp/mm or 1000 pixel/mm. In order to scan an

[3] Kirk Martinez and Anthony Hamber "Towards a colorimetric digital image archive for the visual arts" *Electronic Imaging Applications in Graphic Arts, SPIE Proceedings* Volume 1073, pp.114-121.

[4] Anthony Hamber "The VASARI Project" *Computers and the History of Art*, Volume 1, Part 2, 1991 pp.3-20.

[5] Michael Ester "Image Quality and Viewer Perception" *Visual Resources*, Vol.VII, 1991, pp.327-352.

[6] R.E. Jacobon and N.R. Axford "Towards Total Quality as a means of Assessment of Imaging Systems from the Users Point of View" *Electronic Imaging and the Visual Arts*, The National Gallery, London, July 1992 who cite Colour, Tone (contrast), resolution (detail), Sharpness (edges) and Noise (graininess, electronic).

entire original at a set resolution, the resolving power of the imaging device has either to be able to produce in one exposure a single full view of the object at the set resolution or a number of sub-images may have to be made and then joined (or mosaiced) together to create a full view image.

Each photographic material or film has a set resolving power irrespective of its format. However, a large format colour photographic material (10 x 8 inch) will resolve more detail of a full view of an object than a 35mm format image of the same material and thus for high quality reproduction large format photography has become a standard working practice. A large format colour photographic transparency with a resolving power of 80 lp/mm could create an image the equivalent of 39200 x 31360 pixel. If a full colour (24 bit) digital image is scanned then the file would take up 3.6 GByte. The National Gallery in London has 10 x 8in colour transparencies of all its 2000 paintings. This is the digital equivalent of 6400 GByte.

The CCD electronic digital cameras which began to appear during the 1980s have, to date, employed one of three technologies. The first is the linear array whereby a single line of pixels is moved across the image plane of the camera and a series of exposures are made to build up a two dimension image. A maximum image size of around 6000 x 4000 pixel (the theoretical equivalent of a 35mm colour photographic film) is currently possible with this technology. For a colour image three scans are required, one for the red band, one for the green band and one for the blue band. The accuracy of the repositioning device moving the linear array, usually a Steppe motor, can be inaccurate enough to give an image in which the three bands are in perfect register.

The second CCD technology is the area array in which the photosensitive elements are set in a fixed two-dimensional matrix giving a fixed resolution. Currently, the maximum scanning resolution using this technology is around 2000 x 2000 pixel. This is primarily due to the difficulty and cost of manufacturing perfect single area array chips.

The third technology centres on the principle of moving in two-dimensional steps a low resolution area array CCD over the image plane to build up a high resolution image. High geometric accuracy is achieved by exploiting the characteristics of Piezo crystal. By electrically charging Piezo crystals (between which the CCD sensor is mounted) very accurate 2D movement can be achieved and resolutions of around 3000 x 2000 pixel have been achieved with this technology even when images have been created from several individual camera scans.

In reality, many, if not most, digital images are created not directly from the original but from a photographic reproduction of the original. 35mm colour transparencies are a common source from which to originate digital images as are colour photographic prints. Manufacturers of photographic materials produce published data on the characteristics of films which include the resolving power. However, these resolution tests are based on test objects (black and white line charts) which give the optimum resolving power of a film and an "average" scene is unlikely to be recorded at this level.

Some manufacturers of desktop digital colour photographic transparency scanners have produced scanners which can create an image of over 6000 x 4000 pixel from a 35mm slide, or the equivalent of the optimum resolving power of a colour photographic film.

Experiments have shown that few colour transparencies have that level of resolvable detail and a figure of 3000 x 2000 is a more realistic rule of thumb.

A significant recent development has been the different levels of spatial resolution which are used as standard on the Kodak Photo CD optical storage system. Kodak have selected five resolutions:

Base/16	192 x 128 pixel
Base/4	384 x 256 pixel
Base	768 x 512
4 Base	1536 x 1024 pixel
16 Base	3072 x 2048 pixel

These resolutions are intended to cover a range of display/output devices ranging from a "quick-look" image (Base/16), through television (Base) and high quality output (16Base). Only time will tell whether these resolutions become de facto standards (as has the 35mm photographic format) and prove to be "future-proof". The key issue is whether the 3072 x 2048 pixel format will become the definition for a "High-Resolution" digital image. The "Base" is, as Kodak have indicated, television and this is the same decision made by Philips for their CD-I format in which TV resolution is the highest image resolution available. Whether this "Base" will change to High Definition Television (HDTV) or to a uniform TV/Computer high definition standard may only become apparent at the end of this decade. One point worth bearing in mind is that these resolutions cannot take into account the aspect ratio of the original.

Display technologies and output devices are the most tangible part of the image chain. The cathode ray tube (CRT) monitor still dominates electronic digital image display though various other promising display technologies, such as liquid crystal displays (LCD), are making rapid progress and may, in time, become the primary display technology. However, these new technologies are unlikely to have a significant impact in large-screen monitors (with over a 12in diagonal) until the end of the decade.

A CRT monitor acts as the "window" through which one can examine a digital file. The resolution of CRT monitors is comparatively low when compared with input technologies. The most advanced CRT monitors have a resolution of around 2000 x 1600 pixel. Most workstation monitors are near 1200 x 900 pixel while at the resolution of PC VGA monitors is well below this.

An important consideration which effects the design of the user-interface for a high resolution digital image system is the variety of aspect ratios within the image chain. An original may have any aspect ratio though a general rule of thumb is that any variant can be displayed within a square. This has become a popular design standard for CRT display of images since whatever the aspect ratio of the image it will always appear in the same area of the screen. Unfortunately a square is not the commonly found aspect ratio of input or storage devices. The 35mm photographic format has an aspect ratio of 3:2 a compromise which allows both "landscape" and "portrait" images to be produced. However it is not so easy to change the aspect ratio of electronically produced images as it is with conventional photography, which requires software and a monitor that can be swivelled between Landscape and Portrait viewing modes. Television and computer monitors have an aspect ratio of 5:4 (which matches the old format for motion pictures) while High Definition Television (HDTV) has an aspect ratio of 16:9 (which is the equivalent of the current motion picture format). Clearly the current 5:4 aspect ratio most closely matches the "ideal" square aspect ratio for image display while the 16:9 ratio of HDTV is the rough equivalent of two 8:8 squares. While some designers intend to exploit this "double square" by having images appearing in tandem or one "square" being used as a dialogue/text box, it can be clearly understood that new techniques of image display will be required for HDTV.

The spatial resolution of the monitor can often play a crucial role in the definition of high resolution images. There is no point in scanning a general view of an object at greater resolution than the resolution of the monitor on which the image is to be displayed if the only aim is to show a general view. This raises one of the key issue of high resolution digital imaging, that of future-proof data which is flexible enough to be adapted for changes in both technologies and functionalities. Higher resolution monitors and graphics card which will permit high resolution display will undoubtedly appear. Conversely, pan and zoom functionalities may be required even though a full-view of an object (pixel for pixel) may not be possible.

Another area which requires considerable further research is that of the human factors involved with the creation and use of digital imaging systems. These factors cover a wide spectrum ranging from the intuitive nature of the human-computer interface and the design and evaluation of the utility and efficiency of the functionalities defined by user-requirements to the psycho-physical effect of viewing a CRT monitor at a close viewing distance for an extended period of time.

Colour Data

A key issue in high resolution digital imaging is that of colour, and the perceived quality of colour. Using the additive colour theory the mixture of 256 levels (8 bits) for reach of the three primaries (red, green and blue) it is possible to produce over 16 million colours which will effectively cover all the colours in the visible part of the electromagnetic spectrum. Assigning 8 bits for each colour band results in 24 bit imaging systems being designated "true colour".

While the theory behind "true colour" digital imaging is comparatively straightforward the reality is somewhat more problematic. This is due to the great number of elements which have to be taken into consideration. One of the primary complications centres on the non-linear behaviour of the many elements which make up the image input-storage-display chain.

1) The spectral sensitivity of the imaging device (CCD chips are notorious for their poor blue sensitivity)
2) The electrical "noise" which reduces the number of accurate bits of data acquired by electronic digital cameras. Thus a 10 or even 12 bit camera may be required to get 8 bits of true data.
3) The gamut of colour which can be displayed on the CRT monitor. This is affected by the types of phosphors used by CRT manufacturers.[7]

[7] The gamut of reproducible colour varies according to different forms of reproduction and

4) Gamma, or contrast, of the various elements which make up the image chain. i.e. the contrast in a painting; the contrast of the colour photographic film which is the copy to be digitized; the gamma of the digital input device (camera); the gamma of the monitor for display; the gamma controls in the software. In some cases where there is a high contrast ratio 8 bit systems may be insufficient and 10 or 12 bits may be required to adequately record the range of luminances in a scene.
5) Not only can an image appear perceptually different when displayed on two different CRT monitors but different programs running on the same machine can produce different results. Thus one may use one program such as Photostyler to input and "correct" an image only to find that it appears in a significantly different form when displayed in another program. It can be far from clear why this is happening but one common cause is the manner in which the different programs use the colour Look-Up Table (LUT).

Input

There are few commercially available digital scanners and cameras which produce images of more than 1000 x 1000 pixel resolution and they are expensive. Furthermore, these devices are slow and it is important to appreciate that creating high resolution digital images is likely to be a time consuming activity for the foreseeable future. For instance a test using an Apple Quadra 900 with 20 MByte of RAM and running Adobe Photoshop took one hour to scan a 35mm slide on a Nikon LS-3500 slide scanner to create a 53 MByte 24 bit image file. Even taking lower resolution images (with a file size of under 1 MByte) still requires several minutes to carry out calibration, pre-scan and then scanning functions. In addition, image processing functions such as cropping or sharpening may be required. This not only adds to the time taken to input an image but also has hardware implications, particularly with respect to additional RAM.

The systems requirements for carrying out digital scanning on a PC or Apple Macintosh are considerably in excess of a "standard" machine. An increase in RAM and provision of sufficient hard disc space are essential. Experience has shown that when working with images of 2000 x 1600 pixel or greater, a PC or Macintosh platform may not have the power to easily carry out image processing functions. Much of the problem lies in the limitations of image processing architectures and the bottlenecks caused by elements of these architectures, notably the computer bus, image bus and processor.[8]

High resolution images of may cause crashes in PC Windows applications and problems have also been encountered with an Apple Quadra 900. This has been in spite of system RAM being 20 MByte. However, while the PC and Apple Macintosh/Quadra have an supply of off-the-shelf programs such as Photostyler and Photoshop little, if any similar commercially available software exists for the UNIX workstation market. The commercially

their individual characteristics. The gamut of a colour film is different from the gamut of a CRT monitor which is in turn different from the gamut of four colour printing. However these gamuts do, to a great extent, overlap. Particularly problematic colours are yellows, browns and purple/magentas.

[8] See Adrian Clark and Kirk Martinez "Image-Processing Architectures" in: *Image Processing* (ed. Don Pearson), McGraw-Hill, London, 1991 pp.141-55.

available image processing software for UNIX machines is primarily limited to libraries of image processing routines. Software has to be written to make these routines run under a windowing environment, such as X11. Until PC and Macintosh/Quadra software is upgraded for use on UNIX machines (as has already taken place with popular PC programs such as dBase and WordPerfect) there will remain a very big gap between the powerful UNIX and the non-UNIX worlds.

Storage & Management

The immediate, short-term and permanent storage of high resolution digital images poses significant problems. In order to run image processing programs additional RAM is a prerequisite in any computer system. The ability of a computer system to place the whole of a high resolution image in RAM or virtual memory is of particular importance when image acquisition and subsequent processing are being undertaken. A practical example might be of benefit.

If a 24 bit image of 1000 x 1000 pixel has been scanned from a 35mm slide but appears to be "unsharp" when displayed on the CRT it may be decided to carry out some image processing to "sharpen" it. Most image-editing programs allow three levels of "sharpening" which are simply referred to as "Sharpen", "Sharpen More" and "Sharpen Heavily". In order to make comparison between these functions it will be necessary to create three "Duplicate" images. The screen thus has four identical version of the digital image file. Then the three sharpening functions can be applied, one to each of the duplicate images. When this has been achieved direct comparison can be made between an unsharpened, a "Sharpened", a "Sharpened More" and a "Sharpened Heavily" image. This has very significant implications for system RAM.

Currently one of the main stumbling blocks in electronic digital imaging is the plethora of image file formats. The problem centres not just on the fact that there are a variety of formats such as TIFF, TARGA, PICT, BMP etc. but that there are variants within each format. These differences and the precise description of the image file formats are not clearly described in the documentation issued with commercially available software or available through online help. Thus one may find that a digital image file created and stored by one program cannot be imported into another program on the same machine even though the file format may appear to be the same. Work being carried out by the International Standards Organization (ISA SC24) aims to produce an international Image Processing and Interchange (IPI) standard with an Application Programmer's Interface (API) and Image Interchange Format (IIF).[9] However, this may be some way off and market forces have already resulted in the development of commercially available image file formats conversion programs (such as CAMEO IMAGE), though these too may not recognise all variants of all image file formats.

The large amounts of storage space required for digital images has resulted in a considerable amount of work being carried out on coding (or image compression) techniques. The problem here is that again there is a lack of true compatibility between industry standards.

---

[9] Adrian F. Clark "An International Standard for Image Processing and Interchange" *IAPR Newsletter*, Volume 14, Number 1 1991.

During the past few years much has been written about an image compression technique called JPEG, an acronym for the Joint Photographic Experts Group which has been working on an international standard algorithm for digital still image compression.[10] A sister standard, MPEG (Motion Picture Experts Group), is an algorithm for an international standard algorithm compressing moving digital images.

At the time of writing (Summer of 1992) JPEG has yet to be fully ratified as an ISO standard. MPEG is even further away from this point. However, JPEG compression has now become a standard feature in many image processing programs running on a variety of computer platforms. These are versions of JPEG and there remains the possible problem of incompatibility between the different versions. Thus system and platform independent JPEG image files is still some way off.

An important consideration in the coding and compression of digital image files is the difference between lossless and lossy techniques. To date algorithms for lossless coding, in which a decompressed (or restored) image file is bit for bit identical to the file prior to compression, has indicated that only a compression ratio of around 2:1 can be expected. This is known as JPEG Baseline mode. Lossy compression refers to greater compression ratios which result in some information being lost during the coding/decoding process. Furthermore, the JPEG compression ratios are not mathematical ratios but image quality factors, though using a JPEG compression factor as a mathematical ratio can give a rough idea of changes in image file size. Thus a JPEG compression quality factor of 10 will result in the compressed file being roughly 1/10th the size of the original file. A JPEG compression quality factor of between 10:1 and 20:1 gives a decoded image which the human eye would find difficult to perceive as being different from the original.

However, the degree of compression is highly subject dependent and an important consideration in the creation of any digital image database is whether lossless coding is essential or not. This again is an important element in the creation of future-proof data.

The situation regarding JPEG is compounded by the existence of other digital image coding techniques which are frequently proprietary. Programs such as Photostyler allow image files to be stored in LZW compressed format. Kodak uses an encoding technique called PhotoYCC on Photo CD. The emergence of these different encoding techniques is problematic for the general user since it is far from easy to discover how one technique relates to another and, indeed, how compatible or incompatible they might be.

The storage of digital data also involves key issues such as the stability and permanence of the storage medium and the practical realities of data backup. In spite of the statements made by manufacturers, it is far from clear what sort of life expectancy one can expect from the various forms of digital data storage media. Magnetic disc is perhaps the least reliable of these but its comparatively low cost and high data transfer rates mean that it remains the primary initial storage medium for digital images. The claims for the archival stability and permanence of optical storage media such as WORM, CD-ROM etc. vary enormously ranging from 10 years to as many as 100 years. Given the rate of development in digital storage media during the past decade it may be that any concern about archival permanence of optical media is unwarranted in that new storage technologies (such a

[10] The draft standard is ISO/IEC 10918-1.

holography) could make existing technologies redundant by the end of the decade. This is of little comfort to those who experience catastrophic failure of an archival storage device. In reality many digital image databases stored on optical media are backed up on magnetic disc and magnetic tape.

The practical issues involved in creating, storing and managing a high resolution digital image database are still very considerable. Firstly, there are no fully integrated image/text databases. Working within the PC world one must scan an image and store it as an 8 character DOS file before linking it to a database which can handle images as external files. Superbase 4 and Toolbook, both Windows 3.0/3.1 applications can handle 24 bit digital images. Superbase 4 treats the image as an external file though images can be saved in a Form Design. In Toolbook, which bears direct comparison with Hypercard in terms its use of object-orientated programming, it is possible to save the image on a card thus integrating the two data sets into a single object. However, this is not the case with Hypercard which still handles images as external files.

Future image processing programs will require input, processing and image/text databasing functions in one seamless and integrated program. The programs could also include search/retrieval functions based on textual as well as visual description of image content.[11]

Given the size and complexity of digital image databases it is likely that in the not too distant future they will form part of an open, networked, distributed imaging environment making full use of an object-orientated user interface. Strack and Neumann have recently outlined such an open imaging environment in which devices (image sources and destinations), operators (derived from a commercial image processing library), and images (of different data types) are managed and presented uniformly to the user.[12] However, these theoretical system designs are quite some way away from the current practial realities of creating and managing high resolution image databases.

Output

Over recent years there as been a steady rise in the number of high quality output peripheral devices which can be attached to computers. These vary from 35mm slide writers with 4000 line resolution to thermal transfer or dye sublimation hard copy printers. All these peripheral devices are currently extremely expensive, one Kodak printer costing just under £ 20,000. However, the rise of these printers, and the fact that their overall quality has risen dramatically points, towards the continued need for high quality hard copy (which in turn implies "high resolution" input) and the probability that demand for such devices will quickly reduce prices.

Some of these printers are extremely sophisticated and may include a dedicated CPU and software which will interpolate the digital data in a "low" resolution image file to

[11] See C.H.C. Leung and J.N.D. Hibler *Architecure of a Pictorial Database Management System*, Report for the Research and Development Department, The British Library, 1991 and William Vaughan "Paintings by Number: Art History and the Digital Image" in: *Computers and The History of Art* (ed. A. Hamber, J. Miles and W. Vaughan), Mansell, London, 1991 pp.74-97.

[12] R. Strack and L. Neumann "Object-orientated image database for an open imaging environment." *Electronic Imaging and the Visual Arts*, The National Gallery, London. July 1992

produce a print which has the full resolution of the printer. Conversely the printer will sub-sample data from a "high" resolution image file to reduce the resolution to match the full resolution of the printer device. This is a process used by Kodak for hard copy output from the Photo CD format.

The ability to produce limitless number or identical 35mm slides or hard copy prints from the same digital image file is an exciting prospect for slide librarians having to face a member of staff or student who has lost or damaged an irreplaceable image. On the other hand it send shudders down the spine of lawyers, publishers and copyright holders.

Issues Concerning Copyright

It may seem somewhat ironic that high resolution digital image databases, their use and their functionalities may initially be restricted by legal rather than technical considerations.

Two issues are particularly prominent. Firstly is the level of potential piracy permitted through digital imaging techniques whereby an exact and easily repeatable copy can be made of a digital file. Secondly is the complex issue of electronic copyright and reproduction right. Work is underway to address both issues and it is essential that academic users of digital images and digital image databases made themselves heard during the ensuing debate. In the UK art historians made a fundamental mistake in not being represented in the discussions which resulted in the 1988 Copyright Act which makes the making of slides from published material which is still in copyright either impractical or uneconomic. A similar situation must not be allowed to arise for the use of the digital image for teaching and research purposes.

Algorithms to prevent illegal copying are being developed and an EEC project named CITED - Copyright in Transmitted Electronic Documents - (ESPRIT II Project No.5469) is examining ways of safeguarding copyright material that is stored and transmitted in digital form.

The issue of electronic reproduction right and reproduction fees is one which is difficult to clearly define due to the immature nature of the market and the fundamental differences between electronic and traditional publishing. Even the most simple of questions has yet to be addressed. For instance, is an academic institution legally entitled to turn its 35mm slide library into a digital image database for teaching and research? If not, what is the situation regarding reproduction fees? Is the fee dependant on the spatial resolution of the digital image? On the colour bit depth? On the number of times the image is retrieved/displayed? On a flat fee in the form of a one off payment? On an annual fee? What is the situation regarding including digital images in students essays or programs? What is the situation regarding making hard copy print outs?

These questions also interrelate with the issue of the electronic publishing of texts, graphics, and audio to produce multimedia applications, whether they be commercial or otherwise.

Conclusion

High resolution digital imaging is now a practical and economic reality. Yet much work needs to be done to help nurture this new field. Standards need to be clearly defined to help the holders of the information, the originators of the digital images and the users create an environment in which the potential of the digital image can be effectively exploited for wide variety of commercial and educational applications. The experience of the past ten years has shown that user involvement is a key element in the evolution of systems and the commercial markets which will make them economically affordable. The user can not only play a pivotal role in the design of systems software and hardware but also in shaping the forms and functions of the application of high resolution digital image.

Halbgraue Reihe
zur Historischen Fachinformatik

Herausgegeben von
Manfred Thaller
Max-Planck-Institut für Geschichte

Serie A: Historische Quellenkunden

Band 14

Erscheint gleichzeitig als:

MEDIUM AEVUM QUOTIDIANUM

HERAUSGEGEBEN VON GERHARD JARITZ

26

Manfred Thaller (Ed.)

Images and Manuscripts in Historical Computing

Max-Planck-Institut für Geschichte
In Kommission bei
SCRIPTA MERCATURAE VERLAG

St. Katharinen, 1992

Printed in Germany
Druck: Konrad Pachnicke, Göttingen
Umschlaggestaltung: Basta Werbeagentur, Göttingen
ISBN: 3-928134-53-1

Table of Contents

Introduction

Manfred Thaller

This book is the product of a workshop held at the International University Institute in Firenze on November 15^{th}, 1991. The intention of that workshop has been to bring together people from as many different approaches to "image processing" as possible. The reason for this "collecting" approach to the subject was a feeling, that while image processing in many ways has been the "hottest" topic in Humanities computing in recent years, it may be the least well defined. It seems also much harder to say in this area, what is specifically important to historians, than to other people. In that situation it was felt, that a forum would be helpful, which could sort out what of the various approaches can be useful in historical research.

To solve this task, the present volume has been produced: in many ways, it reflects the discussions which actually have been going on less, than the two companion volumes on the workshops at Glasgow and Tromsø do. This is intentional. On the one hand, the participants at the workshop in Firenze did strongly feel the need to have projects represented in the volume, which were not actually present at the workshop. On the other, the discussions for quite some time were engaged in clarifying what the *methodological* issues were. That is: what actually are the topics for scholarly discussion beyond the description of individual projects, when it comes to the processing of images in historical research?

The situation in the area is made difficult, because some of the underlying assumptions are connected with vigorous research groups, who use fora of scholarly debate, which are only slightly overlapping; so, what is tacitly assumed to hold true in one group of research projects may be considered so obviously wrong in another one, that it scarcely deserves explicit refutation.

We hope, that we have been successful in bringing some of these hidden differences in opinion out into the open. We consider this extremely important, because only that clarification allows for a fair evaluation of projects which may have started from different sets of assumption. So important, indeed, that we would like to catalogue here some of the basic differences of opinion which exist between image processing projects. The reader will rediscover them in many of the contributions; as editor I think however, that sumarizing them at the beginning may make the contributions — which, of course, have been striving for impartiality — more easily recognizable as parts of one coherent debate.

Three basic differences in opinion seem to exist today:

(1) Is image processing a genuine and independent field of computer based research in the Humanities, or is it an auxiliary tool? Many projects assume tacitly — and some do so quite outspokenly — that images on the computer act as illustrations to more conventional applications. To retrieval systems, as illustrations in catalogues and the like. Projects of this type tend to point out, that with currently easily available equipment and currently clearly understood data processing technologies, the analysis of images, which can quite easily be handled as illustrations today, is still costly and of uncertain promise. Which is the reason why they assume, that such analytical approaches, if at all, should be undertaken

as side effects of projects only, which focus upon the relatively simple administration of images. Their opponents think, in a nutshell, that while experiments may be needed, their overall outcome is so promising, that even the more simple techniques of today should be implemented only, if they can later be made useful for the advanced techniques now only partially feasible.

(2) Connected to this is another conflict, which might be the most constant one in Humanities data processing during the last decades, is particularly decisive, however, when it comes to image processing. Shall we concentrate on levels of sopbistication, which are available for many on today's equipment or shall we try to make use of the most sophisticated tools today, trusting that they will become available to an increasingly large number of projects in the future? This specific battle has been fought since the earliest years of Humanities computing, and this editor has found himself on both sides at different stages. A "right" answer does not exist: the debate in image processing is probably one of the best occassions to understand mutually, that both positions are full of merit. It is pointless to take permanently restrictions into consideration, which obviously will cease to exist a few years from now. It discredits all of us, if computing in history always promises results only on next years equipment and does not deliver here and now. Maybe, that is indeed one of the more important tasks of the *Association for History and Computing*: to provide a link between both worlds, lending vision to those of us burdened down by the next funding deadline and disciplining the loftier projects by the question of when something will be affordable for all of us.

(3) The third major underlying difference is inherently connected to the previous ones. An image as such is beautiful, but not very useful, before it is connected to a description. Shall such descriptions be arbitrary, formulated in the traditionally clouded language of a historian, perfectly unsuitable for any sophisticated technique of retrieval, maybe not even unambigously understandable to a fellow historian? Or shall they follow a predefined catalogue of narrow criteria, using a carefully controlled vocabulary, for both of which it is somewhat unclear how they will remain relevant for future research questions which have not been asked so far? — All the contributors to this volume have been much to polite to phrase their opinions in this way: scarcely any of them does not have a strong one with regard to this problem.

More questions than answers. "Image processing", whether applied to images proper or to digitalized manuscripts, seems indeed to be an area, where many methodological questions remain open. Besides that, interestingly, it seems to be one of the most consequential ones: a project like the digitalization of the *Archivo General de Indias* will continue to influence the conditions of historical work for decades in the next century. There are not only many open questions, it is worthwhile and neccessary to discuss them.

While everybody seems to have encountered image processing in one form or the other already, precise knowledge about it seems to be relatively scarce. The volume starts, therefore, with a general introduction into the field by J. v.d. Berg, H. Brandhorst and P. v. Huisstede. While most of the following contributions have been written to be as self supporting as possible, this introduction attempts to give all readers, particularly those with only a vague notion of the techniques concerned, a common ground upon which the more specialized discussions may build.

The contributions that follow have been written to introduce specific areas, where handling of images is useful and can be integrated into a larger context. All authors have been asked in this part to clearly state their own opinion, to produce clearcut statements about their methodological position in the discussions described above. Originally, four contributions were planned: the first one, discussing whether the more advanced techniques of image processing can change the way in which images are analysed and handled by art historians, could unfortunately not be included in this volume due to printing deadlines: we hope to present it as part of follow up volumes or in one of the next issues of *History and Computing*.

The paper of M. Thaller argues that scanning and presenting corpora of manuscripts on a work station can (a) save the originals, (b) introduce new methods for palaeographic training into university teaching, (c) provide tools for reading damaged manuscripts, the comparison of hand writing and general palaeographic studies. He further proposes to build upon that a new understanding of editorial work. A fairly long technical discussion of the mechanisms needed to link images and transcriptions of manuscripts in a wider context follows.

F. Colson and W. Hall discuss the role of images in teaching systems in university education. They do so by a detailed description of the mechanism by which images are integrated into Microcosm / HiDES teaching packages. Their considerations include the treatment of moving images; furthermore they enquire about relationships between image and text in typical stages in the dialogue between a teaching package and a user.

W. Hall and F. Colson argue in the final contribution to this part the general case of open systems, exemplifying their argument with a discussion of the various degrees in which control about the choices a user has is ascertained in the ways in which navigation is supported in a hyper-text oriented system containing images. In a nutshell the difference between "open" and closed systems can be understood as the following: in an "open system" the user can dynamically develop further the behaviour of an image-based or image-related system. On the contrary in static "editions" the editor has absolute control, the user none.

Following these general description of approaches, in the third part, several international projects are presented, which describe in detail the decisions taken in implementing "real" image processing based applications, some of them of almost frigthening magnitude. The contributors of this part were asked to provide a different kind of introduction to the subject than those to the previous two: all of them should discuss a relatively small topic, which, however, should be discussed with much greater detail than the relatively broad overviews of the first two parts.

All the contributions growing out of the workshop came from projects, which had among their aims the immediate applicability of the tools developed within the next 12 - 24 months. As a result they are focusing on corpora not much beyond 20.000 (color) and 100.000 (b/w) images, which are supposed to be stored in resolutions manageable within $\leq$ 5 MB / image (color) and $\leq$ 0.5 MB / image (b/w). The participants of the workshop felt strongly, that this view should be augmented by a description of the rationale behind the creation of a large scale project for the systematic conversion of a complete archive. The resulting paper, by P. González, describes the considerations which lead to the design of the *Archivo General de Indias* project and the experiences gained during the completed stages. That description is enhanced by a discussion of the strategies selected to make the raw bitmaps accessible via suitable descriptions / transcriptions / keywords. A critical appraisal, which decisions would be made differently after the developments in hardware technology in recent years, augments the value of the description.

The participants of the workshop felt furthermore strongly, that their view described above should be augmented by a description of the techniques used for the handling of images in extremely high resolution. A. Hamber's contribution, dealing with the *Vasari project*, gives a very thorough introduction into the technical problems encountered in handling images of extremely high quality and also explains the economic rationale behind an approach to start on purpose with the highest quality of images available today on prototypical hardware.

As these huge projects both were related to institutions which traditionally collect source material for historical studies, it seemed wise to include also a view on the role images would play in the data archives which traditionally have been of much importance in the considerations of the AHC. E.S. Ore discusses what implications this type of machine readable material should have for the infrastructure of institutions specifically dedicated to Humanities computing.

Image systems which deal with the archiving of pictorial material and manuscript systems have so far generally fairly "shallow" descriptions. At least in art history, moreover, the rely quite frequently on pre-defined terminologies. G. Jaritz and B. Schuh describe how far and why historical research needs a different approach to grasp as much of the internal structure and the content of an image as possible.

Last not least R. Rowland, who acted as host of the workshop at Firenze, describes the considerations which currently prepare the creation of another largescale archival database, to contain large amounts of material from the archives of the inquisition in Portugal. His contribution tries to explore the way in which the more recent developments of image processing can be embedded in the general services required for an archival system.

This series of workshop reports shall attempt to provide a broader basis for thorough discussions of current methodological questions. Their main virtue shall be, that it is produced sufficiently quick to become available, before developments in this field of extremely quick development make them obsolete. We hope we have reached that goal: the editor has to apologize, however, that due to the necessity to bring this volume out in time, proofreading has by neccessity be not as intensive as it should have been. To which another shortcoming is added: none of the persons engaged in the final production of this volume is a native speaker of English; so while we hope to have kept to the standards of what might be described as "International" or "Continental" English, the native speakers among the readers can only be asked for their tolerance.

Göttingen, August 1992