Image Processing and the (Art) Historical Discipline

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Preface

In the second chapter of this article, "computers and images", we will introduce some basic concepts of image processing. One can find in depth coverage on all topics included there in many specialized publications. We hope that our perspective: image processing in relation to the (art) historical discipline, answers for our somewhat cursory treatment of these technical issues.

We are convinced that the main issues of image processing in the (art) historical discipline are not technical, but intellectual (What do we study and how do we study it?) and conceptual (How do we present the results of our studies?). With the variation of soft-and hardware available today it is not difficult to get a pictorial information system up and running.[1] Anyone who has recently visited a computer show will know examples of pictorial information systems. Real estate firms have applications which allow the customer to view images of houses currently for sale. These applications are real pictorial information systems in the sense that they contain images (of houses) and information about these images; they allow users to select the images, and they present the selection on the computer screen. The purpose of these applications is straightforward: they offer the user of the system the available information on the topic of his choice, for example "houses with gardens".

In a very general sense the situation sketched above can be compared with that of pictorial information systems in the (art) historical discipline: any pictorial information system must be designed around the idea that such a system, no matter how (un)advanced its technical features, should be informative. That is: it should provide others with the possibility of studying the visual material presented in the system.

However, pictorial information systems in the realm of (art) historical research are set apart from the example cited above, because some very complex issues are involved. Questions we have to deal with include:

- What exactly is the subject of art historical research and what are its sources?
- What information can be distilled from images from the past?
- What are the different, often implicitly held, epistemological and methodological positions in the realm of (art) history?

These and other theoretical questions have seldom been studied systematically in art historical research. We shall have to look at them in some detail before we start discussing the subject of image processing proper. But even before that, we must take a closer look at two important and related concepts we shall use: information and the image as a carrier of meaning.

The first concept is treated in a very interesting way in the book "Silicon Dreams. Information, man and machine" by Robert W. Lucky.

[1] In this article we will refer to computer system containing images in a digitized format as well as textual information about the images and the programs to select images using certain criteria as pictorial information systems.

Information

Lucky loosely distinguishes four levels in the "information hierarchy". From bottom to top: data, information, knowledge and wisdom. Placement in the hierarchy is determined by the extent to which information is organized, distilled and integrated.

Using this concept of the hierarchical arrangement of information, we shall speak about the visual material from the past, e.g. in the shape of digitized images, as "data". We shall use the term "basic information" to denote a first level of organization of the visual material, in particular information about their size, maker, title, location, provenance, keywords about contents, etc. In doing so we comply with common documentation practice. The term "extended information" denotes an even more organized and integrated way of presenting information about visual material. It refers in particular to pictorial information systems containing detailed, systematic, and consistent descriptions of the images.

This hierarchical distinction has the additional benefit of bringing two important methodological issues out in the field:

i) The electronic publication of digitized images — data — without additional information will be of little or no use to anyone in the field of (art) historical research. At first sight this may seem to be a trivial remark, but it bears great weight when we take the issue of project management of pictorial information systems into consideration.

ii We go from one level of the information hierarchy to another by adding information through interpretation. It is a sound scientific principle to present scientific conclusions in such a way that they may be falsified. Therefore, if we agree that pictorial information systems provide extended information, we should supply users of these systems with instruments to check the highly integrated information contained in them against the data used. We will give an example of this when the use of controlled vocabularies to describe the contents of images is explained (section 3.3).

The Image as a Carrier of Meaning

With this concept we enter the proper domain of history and art history. From an epistemological point of view we have to ask the question whether the historical meaning(s) of an image or its contemporary meaning(s) is (are) our subject. This question sometimes is referred to as "the art historical dilemma". The way in which this question is answered has an important effect upon the methods of art historical research and the possible communication of the results of that research (Cf. section 1.3).

From a methodological point of view it is important to know which elements of an image (colour, form, content or a mixture of form and content) make it possible to state that it, or part of it, carries a particular meaning. Moreover, it is important to know whether formal conventions or conventions concerning the contents of images play a part; and if so, whether there are relations between the two conventions? By far the most important issue is how to describe these topics as historical phenomena?

1. General Introduction: Images and Views of Images

1.1. Images

When we speak of images — data — in the context of the (art) historical discipline, what do we mean by this term? Typically, we refer to reproductions of objects. These objects may be paintings, engravings, sculptures, drawings, etc. The reproductions can be anything from drawn copies of objects to digital images.

It is often said that the reproduction of an object is not the same as the object itself; a profound distinction, with which we fully agree. Another matter, also often discussed, is whether the reproduction of an object is always less informative than the object itself. Or, maybe better: "When we are dealing with reproductions of objects, are we always and necessarily handicapped because of the reduction of information?"

We would argue that this is not always and necessarily the case. It depends on the purpose for which the reproductions are used. For many types of research, having reproductions at one's disposal is conditional to the study of the objects. For example, reproductions of objects have the great advantage that they may be arranged and re-arranged according to certain hypotheses. This would hardly be a procedure one could follow using the original objects! Especially not if the hypotheses involve a large number of objects. Of course, there may be cases where one needs to go back to the original object. For example, if the exact setting of a painting in its historical surroundings is relevant to the research. Reproductions are in many cases perfectly suited to study the objects they represent, as art historical practice shows us daily. This discipline relies almost exclusively of handling photographs, slides and drawings, in short reproductions of the objects it studies.

1.2. Collections of Images

A keeper of medieval manuscripts can well see the benefits of having the manuscript collection of his library digitized and stored in the computer. The originals can remain in their climatized vault, while the users of the library are glued to the screens of the computers, studying the images and texts, comparing different manuscripts and perhaps even use certain images to retrieve other but similar images.

Not only would this situation contribute to the preservation of these valuable objects, but it would also make it easier to study these manuscripts at other places. And what to think of the support the computer could offer to the publication of a manuscript once it is digitized? So, when do we start? Well, there are still a few problems to be solved, before we can set off to digitize the visual heritage of the past.

The main problems are intellectual (How is it to be done, who will do it and for whom?) and financial (Staff, equipment). Paradoxically, lack of funds does not appear to be a major obstacle in the initial phases of a project involving the digitization of images. What is often underestimated, however, is that in order to provide access to the stored images to various researchers, one needs good, that means detailed, systematic, and consistent descriptions of the contents of these images, preferably supplemented by software to manipulate the digitized images.

Both demands might seem to be a bit farfetched for our keeper of manuscripts. The fact that he is a realistic keeper of a collection will probably make him concentrate on providing the users of his collection with basic information about the objects.

Making precise and systematic descriptions of the contents of all the images in his collection, or providing researchers with software to explore the digitized images are simply not his first priorities. They never were, and it is not likely that the curators of collections of visual material will on a broad scale succeed in getting these activities funded.

One can easily see that large funds will be needed, because, even with the newest techniques and the most up to date hard- and software, the real investment will have to be in (people) either describing the images in order to acquire useful knowledge or designing and implementing the software needed for image manipulation and for the medium of presentation: pictorial information systems. It is here, entering the fields of historical and art historical research, that we are confronted with the main epistemological and methodological problems.

1.3. Researchers and Images

1.3.1. Historians

Images are used more and more in historical research. Historians have discovered that images from the past can contain valuable historical information. Therefore they are inclined to incorporate interpretations of visual material in their historical reasoning. This practice can be traced back to the growing interest of historians for research of the everyday life in the past and with more exotic themes like the history of smells or witchcraft. Studying themes like this, all sorts of sources, previously not often used by historians — images, literature, plays — are consulted.

This growing practice is not without its difficulties and dangers. In order to use images as a historical source, the historian needs access to large quantities of systematically and consistently described visual material. One simply can not build an argument on a few images. Moreover, the historian needs information on how to "read" images. In other words: how does he protect himself against incorrect interpretations (we can think for example of a phenomenon called "eroded" symbolism)? Only large amounts of images, their forms and contents carefully described and analyzed as elements belonging to certain cultural contexts of the past, will provide a safe platform to start from.

If images from the past contain historical information, how do we study these images? And more importantly, who is going to provide the information — both basic and extended — about these images? Historians, who are presently discovering this new area of research, or art historians who traditionally (to be taken quite literally, we are afraid) study visual material from the past? Is the study of the visual material from the past the field where historians fruitfully can draw on the work of art historians? Not yet. In order to explain this lack of cooperation we have to look at some features of art historical research.

1.3.2. Art Historians

In the preface of this article we ideutified three issues responsible for the complexity of the topic of image processing in the field of (art) historical research. We now explore them a bit further.

- What exactly is the subject of art historical research and what are its sources?

Art historians study "works of art" from the past. They do not study all the visual material from the past available to them in any systematic way. Most of their research is based on a predefined subset of the available material. This subset may be labelled "great art". Its selection is based upon aesthetic preferences from the 19th century in combination with an evolutionary view of the autonomous development of art, an idea that can also be traced back to the 19th century and beyond. Admittedly this subset is by no means static, but all modifications nevertheless branch from it. Its existence results in the neglect of what we may call "small art": images of no or little artistic value, that often contain very valuable historical information. The research questions in which historians implicate images, almost force them to be interested in the results of the study of ALL the visual material available from the past.

- What information can be distilled from images of the past?

If one intends to study visual material from the past in a historical way, there are two promising areas of research, from a methodological point of view:

1. The area where a source consists of both image and text. In this case the student has two contemporary and related sources at his disposal to give his descriptions and interpretations a firm historical basis. There are many art historical sources that belong to this category. To name but a few: festivities, shop signs, banners, wedding-poems, emblemata, printer's devices, illustrated books. Most of these belong to the category of "smaller art" and are not made available in a systematic way.
2. The area where forms are studied as carriers of iconographic meaning. Traditionally art historians can be divided into two groups.
    - Those who study works of art as visual phenomena, focussing on how things are depicted (keywords: stylistic research, artistic quality, connoisseur, morphology).
    - Those who study the contents of works of art, focussing on what is depicted. (keywords: iconography, iconology, typology). Only a few art historians seem to be able to bridge this traditional gap and formulate methods that enable them to study forms as carriers of meaning within certain precisely described cultural contexts. An example is Aby M. Warburg who studied "Pathosformel", forms from Antiquity that were re-used in all sorts of cultural contexts. What is especially interesting in his case, is that, while studying this phenomenon, Warburg concentrated on images that could be classified as "small art". These images enabled him to show how certain forms and motives were used and re-used. Because these image were closely linked to everyday life, Warburg could show that he was describing a living tradition in the past. Warburg was always eager to show that his method allowed him to study "works of art" (the "great art" of the art historians) with much more insight than had he started with the "works of art" right away. This brings us again to the fascinating issue of the art historical dilemma.

- What are the different, often implicitly held, epistemological and methodological positions in the field of art historical research?

A crucial epistemological position, commonly held by art historians, researchers of style and iconographers alike, can be formulated as: "Works of art contain historical information as well as the keys necessary to interpret this information". Or, in other words, the direct confrontation between art historian and work of art renders information about the work of art. Whether or not this information can be called information about what has happened in the past, is a question often not addressed. It is this much acclaimed sensitivity of art historians that leads them directly into the boldest hermeneutics and, by definition, away from carefully explaining what has happened in the past.[2]

It is this divergence on the epistemological level between historians, trained to produce statements about what has happened in the past by carefully studying as many elements of that past as possible, and art historians, often engaged in a contemporary discussion with elements from the past, that accounts for the difficult relation between these two groups of researchers.

1.3.3. Historians and Art Historians: Towards a History of Imagery

Assessing the present situation, we may identify a promising field of research: the systematic study of images of the past with the help of the computer. The researchers traditionally occupied with the study of works of art of the past, art historians, do not (yet) show the inclination to cover this field. Moreover, their training rarely provides them with the right epistemological and methodological background or approach. The researchers interested in the results of the study of imagery — historians of various disciplines but also researchers from fields like musicology or botany — do not have the tradition to actually cover the field themselves. At the same time we see that institutions, instigated by the availability of new techniques, begin to think of opening up their collections of images and provide access to their iconography. If historians and art historians fail now to set up intellectual guidelines for such projects, the first efforts in this field might start off on the wrong foot.

Storing digitized images with the help of the computer is one thing. Creating facilities to retrieve them, not knowing what the special interest will be of the persons that want to find them, is quite another. It is theoretically impossible to predict all the questions that researchers will be asking. It is already hard enough to find out what type of information they want at this moment; with so few collections described iconographically, researchers often do not bother to ask detailed iconographic questions at all. So, to guarantee a minimum of reliability and effectiveness, the descriptions of the images in a pictorial information system must at least be systematic and consistent in their level of detail. It goes without saying that the more detailed they are, the better it will be.

Therefore a first guideline reads:

- Create systematic, consistent and preferably detailed descriptions of the contents — defined as both formal and iconographic — of images.

[2] For a more elaborate discussion of these problems see R. Klein, *Form and Meaning. Essays on the Renaissance and Modern Art*, New York, 1979.

Images, considered to be of limited artistic value, may well be of great historical value. They may even turn out to be of great value for art history itself, once the discipline has realized their potential. This holds most strongly if images are documented to have been used for certain occasions by certain groups of people. They also often show the same motives and themes as the so-called great works of art.

So, we may formulate a second guideline:

- The aesthetic quality of individual objects should not be taken into consideration when a particular collection of images is selected to be made available as a source for research.

A good starting point might well be the study of sources that consist of both image and text, like illustrated books. A source in which texts and images are mutually related — e.g. contemporary texts describing the images — provides firmer ground for interpreting the images Using this type of source, we are better equipped to get round a common art historical problem. Art historical arguments are often based on two distinct interpretations, one of an image and one of a text, without a solid historical explanation of the relation between these two sources. Because both images and texts can by definition be interpreted in various ways, it is the task of art history to explain historically what exactly gives it the right to interpret two objects in that particular relation.

Thus, a third guideline reads:

- Concentrate on sources that consist of both images and texts.

1.4. Images and Computers

So far we have not paid attention to two important parties playing a role in the production of pictorial information systems: the computer industry and computer scientists. The reason for this postponement is simple and has been explained in the foregoing sections: when we, keepers of visual collections and researchers working within the field of the humanities, want to study images with the help of computers, the problems we face are first of all intellectual and conceptual. But all this is not to say we are not interested in the products of these two groups. Of course we are, or better: we have to be. If it were not for the fast acceptance of the personal computer within the field of the humanities, this article would not be written.

Computer industry

The computer industry works with markets and products. At the end of a year they balance earnings and spendings and there needs to be a profit in order to survive. We, reserachers working with computers within the field of the humanities, have to rely, to a certain extent, on the products of the computer industry. The simple truth is that history or art history is not considered a market by the computer industry. Therefore we can not influence technical developments. These developments are said to be technology and market driven.

This sounds far more serious than it really is. It just means that since we cannot influence technical developments, we have to rely on the standard products produced. And now for the good news: standard products are low priced. Where hardware is concerned, we can safely state that we, working in an application driven environment (we have to make applications) have benefitted from these market and technology driven developments.

Personal computers, storage devices etc. all became bigger, faster at roughly the same or even somewhat lower prices.

On the other hand, where software (the programs) is concerned things get a bit more complicated. Here the gap between the two environments (technology/market driven and application driven) is bigger. If we want to use the standard products, like DBMS's and editors, developed by the computer industry we have to work with low priced products with static functionalities. If we do not want these static functionalities, and chances are good that we do not want them because the programs were developed with a completely different market in mind, we have two options:

- Develop with the computer industry custom designed products. They will have a user defined functionality, but will also be very expensive.
- Develop our own software and only rely on the computer industry for standard products we can use. It is in this area, an area we can rightly call humanities and computing, that we see interesting developments and products.
  To name just a few:
- computer languages: SNOBOL, SPITBOL and ICON.
- DBMS's: $\kappa\lambda\epsilon\iota\omega$, HIDA/MIDAS.
- Controlled vocabularies/thesauri: ICONCLASS Browser, Art and Architecture Thesaurus, Union List of Artists' Names.

Computer scientists.

It is rare for projects within the humanities to have computer scientists as members of staff. Especially where the user defined functionality of software is concerned, cooperation could be very fruitful. The theme of this cooperation should be the design and production of software for research within the field of humanities: informatics for the humanities. At the moment we see at universities the development of research groups around this theme.

All in all we may distinguish four parties with different objectives:

- Collections of images.
  Collections of prints and drawings, museums and libraries. Collections of photographs. Slide libraries. Main tasks: archiving, presentation, basic registration. In their holdings a complete range from (historical) objects to reproductions of these objects. The collections themselves usually have neither the manpower nor the intention to describe their holdings systematically and in great depth. Their task lies more in what we call basic registration of their holdings, with or without the computer.
- Researchers: historians and art historians.
  While historians are getting more and more interested in images from the past as a historical source, many art historians safely circle around in the limited domain of "(great) works of art", not bothered whether their research can be called historical or even scientific research. Those art historians who want to change this situation and take a serious interest in the study of the main art historical source — the imagery of the past — with the help of the computer, will have to look at collections of visual material, historians as well as computer scientists for support.

- Computer scientists.
  Since problems within the field of the humanities differ fundamentally from the problems addressed by the computer industry when they develop software, computer scientists are needed to develop user defined software for the humanities.
- Computer industry.
  Products and markets. Revenues. Standard products.

The articles in this book deal with the use or study of images and manuscript sources from the past in an automated environment. It is a very promising area of research, provided we take the right steps and are willing to treat the data in such a way that others can benefit from it. One can easily see that the four corners of the square, collections, researchers, computer scientists and the computer industry, are complementary elements.

1.5. Conclusions.

To sum up. The ingredients for successfully generating pictorial information systems in the art historical discipline seem to be:

- Cooperation between the parties involved: computer scientists, the computer industry, historians and art historians and keepers of collections.
- New ways of studying imagery of the past by art historians: systematic and detailed study of images as historical phenomena.
- Sound project management. If the main problems can be identified as financial — it is time consuming and expensive to have educated people study images as historical phenomena in a detailed and systematic way — and intellectual — new (art) historical methods have to be developed — it is useless to begin with spending the larger part of a budget on hard-and software.

2. Pictorial Information Systems: Hardware and Functionality.

2.1. What is a Pictorial Information System?

We feel it is important to describe at this stage as exactly as possible what definition is used for the term Pictorial Information System (PIS) within the context of this book. A Pictorial Information System is the information system that controls and manages the devices for input, processing, storage, communication and output to provide a collection of pictorial data for easy access by its users. (S.K. Chang, 1989) We realize that this broad definition incorporates many if not all activities in the field. It is so to say the marriage of image processing and information system management. One day they had to be reconciled within one definition. Many activities in the field of image processing and information system management cover only a part of the field and even have never the intention to come close to a PIS.

If we look at the most relevant topics related to image processing we should include the following list:

- Digitization.
- Coding and data compression.
- Enhancement and restoration.
- Segmentation.
- Image analysis and description.
- Image understanding.
- Pictorial information management.

Traditionally the first four topics refer to image processing (s.s.). Computer vision includes the first six topics and PIS includes all seven topics. There is a duality of picture representations (data structures) and processing (algorithms, processes). The duality can be considered as the duality of the physical picture representations and the logical picture representations. Physical picture representations are directly related to the picture obtained from the picture input devices. They include the image as represented by a bitmap and/or vectors. Image processing usually deals with the physical picture representation. Logical picture representations are high-level abstracted representations, denoting the relational structures i.e. the logical and semantic relationships among picture objects. Computer vision and pictorial information management usually emphasize logical picture representations.

2.1.1. The Use of Pictorial Information Systems.

It is only in the last five years that the management of non-alphanumeric information, such as digital images, has received the attention it deserves in the subfield of designing and implementing information systems. Information systems that allow handling of digital images require large storage capacity even for images of average complexity. Due to the development of new storage techniques substantial amounts of digital images can now be handled in information systems at affordable prices. In recent years video-boards (dedicated video processors with their own memory) have been developed with a reasonable quality like VGA and Super VGA for the huge MSDOS-market. The size of this market allows for low prices, which brings pictorial information systems within the reach and on the desk of the average small workstation user (the more powerful MSDOS-PC, MacIntosh etc).

The next generation of low cost video boards shows an extreme improvement of the colour quality from 256 different colours (8 bits per pixel) to more than 32.000 different colours (15 bits per pixel). The booming market for graphic user interfaces (the socalled GUI's like XWindows, Windows 3.0 and others) has been faciliated by the fact that the graphics colour card has become standard equipment, replacing the monochrome boards — glowing green screens! — of several years ago. These advances are absolutely 'technology driven' and the humanities field is going to benefit from it in the very same way as from the introduction of personal computers. In other fields this trend has been recognized and acted on much earlier. Pictorial information handling shows a growing list of applications:

- Computer Aided Design.
- Remote sensing of earth resources.
- Cartographic and mapping.
- Geographic data processing.
- Robotics.
- Medical Picture Archiving and Communication System (PACS).
- Office/Document automation.

So, maybe late, but certainly not least: pictures as an historical source: a use of PIS in the humanities.

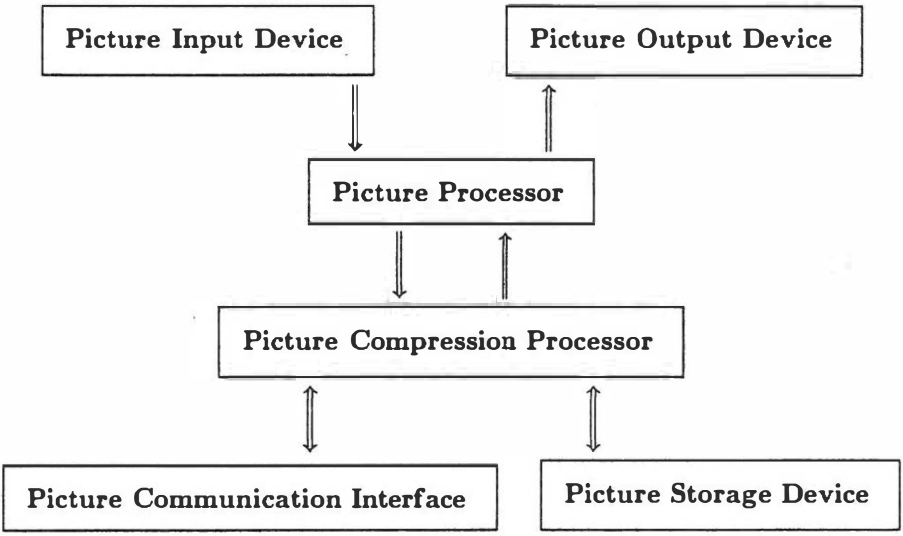

Figure 1: Hardware Requirements for Pictorial Information Systems

2.2. Hardware Requirements for Pictorial Information Systems.

2.2.1. Picture Input

High resolution scanners

Scanners come in different shapes and quality. Quality depends on the dynamic range (the maximal colour variation that still can be detected) and the resolution. Very cheap hand-held scanners exist that are perfectly suitable for personal desktop publishing but do not offer the quality one needs for a serious PIS. The professional scanners can be devided in: drum scanners, flat-bed scanners and slide-scanners. For the drum-scanner the flat material to be scanned should be placed around a cylinder which rolls past a scanning head. Resolution is highest (typically 600-700 dpi) as compared with the other scanners. The flat-bed scanner resembles a simple copier: the flat material is to be placed on top of the scanner and it is scanned by a moving light beam or by the movement of the top part of the scanner that contains the material, depending on the type and manufacturer (typical resolutions range from 300 — 400 dpi). The slide-scanner is a small box that has a slot for 35 mm slides. The slides are scanned at typical resolutions of 500-600 dpi. All the scanners are available for monochrome and full colour images (with different price tags). For scanning coloured images the scanners process the image three times and filter the reflected or transmitted light for the red, green and blue component respectively.

Digital cameras

A copystand camera and video camera resemble the classical camera but deliver a digital image instead of a fotograph. Resolution and dynamic range depend highly on the type of camera and lenses. Technology is making dramatic advances in developing capturing devices at chip level that digitize the caught light in real time and at resolutions that will be close to photo realistic quality in the mid nineties. Since the companies involved aim at a consumer market, prices will be relatively low. A professional digital video camera delivers a resolution of 300 dpi with 24 bit colour information per pixel (16 million colours). Normal video cameras and the attached frame-grabbers (video signal digitizing boards) have resolutions that are around the 100 dpi and quite well coincide with VGA and Super VGA resolutions. Typical colour quality is 256 (8 bit) to 32.000 different colours (15 bit) per pixel. When images are digitized from transparent originals one needs special features like a backlit box with diffusion filter(s).

The number of colours (or dynamic range) and the resolution that the input device can offer are the technical features most relevant when selecting the most appropriate type of capturing device.

2.2.2. Picture Processor Device

The graphics board in a (micro-)computer represents the picture processor device. The graphics boards or adapters vary appreciably in functionality, performance and price. These boards are responsible for the resolution and colour palette of the image that is represented on the monitor. The market for graphics cards is rapidly evolving, due to the growing interest of users in graphic applications. Many companies are active in this market developing proprietary video processors and boards.

Standalone processors for capturing and processing images These days the graphics board in any (micro-)computer is equiped with a dedicated on-board (mostly proprietary) video processor that usually has its own memory banks (1Mb or more) to store the different colour representations of the digital image. The output signal is commonly complying RGB standards which enables a variety of monitors to be attached. The primary function is to display an image that is stored digitally in the video memory of the board. The more extensive boards have additional hardware for functions as panning, zooming and pixel processing. Boards can also be equiped with capturing features: they enable the sampling of a video signal coming from a video camera having NTSC or PAL output. These boards can digitize a video image in real time, capture and freeze the image on user command in the video memory. Typical resolutions range from VGA 800 x 600 with 256 colours/pixel to 1024 x 1024 with 16 million colours/pixel for the higher ranked boards. The more sophisticated graphics boards allow high refresh rates (60 - 72 Hz) of the outputted image and produce a flicker free image.

Array processors for pixel by pixel processing The top rank video boards allow connection to dedicated array processors (essentially number crunching processors) for high speed pixel processing. They off-load the CPU for example with standard logical operations on the video memory and boost performance on heavy image processing tasks. These boards are relatively expensive because they are much less a consumer market article then graphics boards are.

Optimized software tools are needed to exploit the ultimate performance of a graphics board. Special device driver software comes with all boards to interface the board to the operating system and graphics user interface that is choosen.

2.2.3. Picture Output Device

As soon as an image is digitized and usually already during the digitizing process itself we feel the urgent need of looking at the digital copy of the 'original'. Reproducing the digital image, altered or not by image processing techniques, is crucial. Many different techniques have been developed to visually reproduce a digital image.

Colour graphics raster display

All computers have at least a (graphics) monitor attached and many users have a colour monitor that can function as the (colour) graphics raster display. The resolution and dynamic range of the display have to be in accordance with the attached video board. The dynamic range refers to the number of different colours (or shades of gray) that can be represented by any one pixel. We have to realize that colours are not consistent across display devices, so one monitor may give a more realistic image then the other. The colour presentation highly depends on the phosphors used in the display screen, surrounding colours, ambient light, backlight etc. The refresh rate of the image is critical for a stable displayed image.

Laser- and photoprinters

In general we are not satisfied with only a digitally visualized image when we cannot capture that image in a non-volatile way. Devices have been developed to reproduce a hardcopy of a digitally processed image. First of all images can be printed using bitmap printers or plotters in the case of vectorized images. Laser printers reach a resolution of 300 - 400 dpi and are therefore very well capable to reproduce the image at the needed resolution. Laser printers that can print coloured images have become available, although the colour resolution is not optimal yet. The technology is coming from advanced colour copiers, which became very quickly popular with counterfeiters and in due time we may assume that this technology will be brought to perfection. The best results can be reached with photoprinters that combine photographic techniques and processes with a high resolution digitally displayed image.

2.2.4. Picture Compression Processor

An average image of a VGA screen (800 x 600) will take up 384 Kbytes of storage with 8 bit colour information per pixel and a 24 bit image will take about 1 Mbyte of storage. Any means to reduce this amount with minimal loss of information is welcomed. Image size not only has consequences for storage but also for telecommunications. In the humanities field image compression is a particularly important issue because of the need of high quality pictures.

Dedicated microprocessor for compression and decompression of bit-images Compression is necessary to remedy the storage and telecommunication problem. Many different algorithms and techniques have been developed: in software and even with dedicated hardware. The multimedia market has inspired chip-manufacturers to design special chip sets that allow compression and decompression at extreme high speed. Lossless compression will typically give reductions of no more than 3:1 times, however reductions of 1:50 with an acceptable loss of information are feasible due to special hardware. Compression boards are available at resonable prices which allow the user to choose the reduction factor desired given the allowed information loss. Within a couple of years special chips will be part of the main computer board to reduce storage needs.

2.2.5. Picture Communication Interface

Transferring a single 1 Mbyte image across a 2400 bps communication line will cost approximately 70 minutes. Even on a 64 KHz line the transfer time of 2 minutes is not a very attractive perspective if you want to browse a remote pictorial database.

Baseband datacommunication hardware

Baseband networks such as token ring (twisted pair) and ethernet (coax cable) based networks are most popular and well spread in the academic domain covering wide area networks. The throughput of these networks is heavily challenged when 1 Mbyte images are transferred. These networks have typical transfer speed of 8 - 10 Mbps and allow therefore transfer at reasonable speeds when all other network traffic is low. The transfer speed is lowered appreciably due to communication protocols and depends highly on the buffering in the local network card. Network cards are available at low prices and come with special drivers for the operating system. Installation and tuning is, however, work for telecommunication specialists.

Broadband Multimedia LAN-connection

Broadband networks operate at higher speeds up to 300 Mhz and allow various signal sources such as hifi audio, video and real time speech signals to be transmitted simultaneously. They are therefore much more appropriate for transmitting high quality digital images. Baseband networks, however, are so far more widespread. The construction of fiber optic based networks (Fiber Distributed Data Interface) will encourage the use of broadband networks in the near future and will solve speed bottlenecks due to bulk volume datatransmission of high quality digital images.

2.2.6. Picture Storage Device

Storing digital images demands high capacity storage devices. As we have shown before a high quality digital image will easily take up 1 Mbyte of storage, whether it be memory or disk space. If one has to store a 1000 images, not a large collection by the way, one should have access to a device of at least 1 Gigabyte.

Magnetic disk

It is obvious that in an environment of desktop workstations (PC's or something bigger) magnetic (hard-)disks with gigabyte-capacity are no standard equipment yet. However during the digitizing process one needs access to magnetic disks with high volume capacity. Average harddisk capacity doubles yearly and costs decrease yearly about 20reached its physical limits, so this will go on for an other 5 years and we will see our (new) computers be equiped with more and more harddisk space. Gigabyte capacity disks have become affordable and access times have been improved to an average value of 16 ms. With a high capacity harddisk one needs also high capacity backup devices. Due to the combination of magnetic tape and digital interfacing technology backup devices using video tapes (EXABYTE) and audio tapes (DAT-recorders) have become available for background storage at high volumes (typically between 1 and 2.5 Gigabyte)

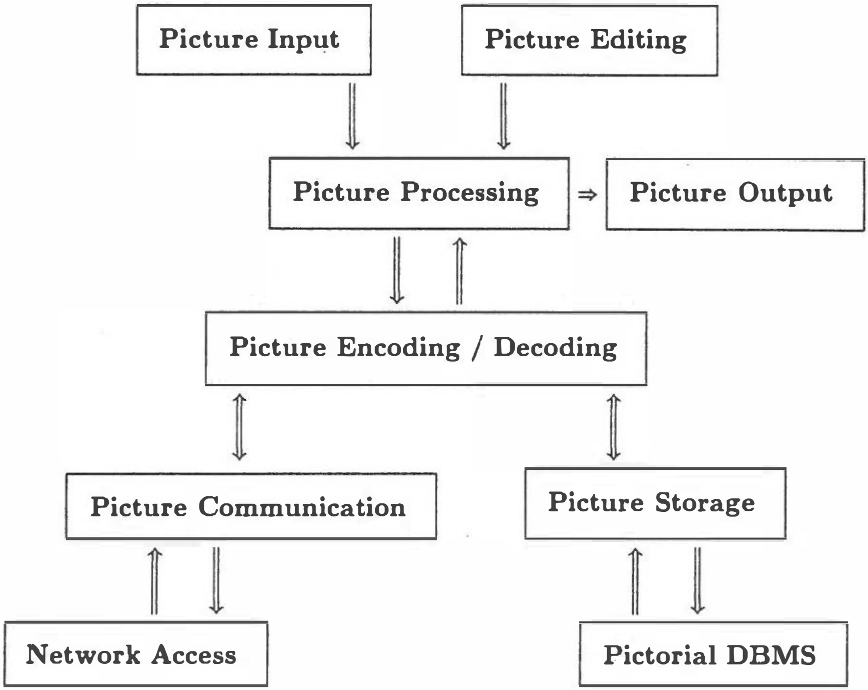

Figure 2: Functional Requirements for Pictorial Information Systems

Optical media

The most promising development is with the optical media. Although the video-disk did not become a consumer market article yet the CD-ROM for audio did very well. Optical media come in many different disguises: analog or digital video-disk, CD-ROM and WORM (Write Once Right Mostly). A CD-ROM has a storage capacity of 600 - 800 Mbytes and is an attractive storage medium when the data have to be distributed in some quantity. The production costs of CD-ROMs have reached a level that is acceptable for many projects. The (present) major disadvantage of the CD-ROM is the high access times and low data transfer rates compared to magnetic disks. However, the 'home entertain' market pushes technology in the right direction with new standards and techniques (DVI, CD-I, CDROM-XA etc) that combine data compression features (with dedicated build in hardware) and the optical medium. If there is one beneficial aspect about the present 'multimedia hype', it will bring us quick access to volume digital data at low cost.

2.3. Functional Requirements for Pictorial Information Systems

2.3.1. Picture Input

Capturing or digitizing of images is the first elementary stage in the imaging process that treats the relevant material in such a way that the computer can store and process the digital images afterwards. With all objects there is the particular concern about not harming the object during this process. Sources of harm include light and heat during substantial time coming from the digitizer or capturing unit during the actual input process. The vulnerability of the object and the time needed during the inputting fase have to be balanced carefully. Depending on the input device the object might be exposed to intense light and heat for at least several minutes. Although the suppliers market offers a growing whealth of solutions for very different budgets, to make the right choice is not a matter of money only. Choosing the appropriate input device is a crucial one since it is the quality bottleneck, afterall it is not to be expected very likely that a whole collection of material is to be digitized again soon. Digitizing should be done in a resolution and format that will anticipate needs well in the future.

Digitizing images from paper or film

Many factors come into play in selecting a flatbed- or drum-scanner such as the type of material, the ultimate display resolution and colour range of the material (grayscale or full colour). Economic considerations like equipment costs and scanning time play a major role when thousands of images have to be inputted.

Capturing of images from objects

When considering possible sources of harm the digitizing process is usually less harmfull than the process of actual moving the object from its storage location to the capturing area: a copystand or video camera. Three-dimensional or very large two-dimensional objects pose an extra problem since the digital image of the whole object has to be reconstructed from different smaller images that have only covered parts of the original.

Not only the scanning or capturing speed itself is important, the throughput of the whole scanning process is more likely to represent the crucial time factor. Handling of the images, linking the physical images to the digital images, quality tests, storing on disk of the digitized image in different resolutions for different purposes, etc highly influence the total throughput time. When thousands of images have to be digitized this can become a critical factor that has to be dealed with in the project management.

2.3.2. Picture Editing

Once the image is digitally available it usually needs some further preprocessing before it can be added to the pictorial database or processed in later research stages.

Editing existing image

This process is called picture editing: colours are adjusted, corners or parts that are not relevant can be cut off, textual information can be added to the image to ensure unique labels or to mark areas of special interest etc. Special graphics editing software to enable these activities is available with all different computer platforms. All graphics user interfaces have these tools available as a standard option and they offer in general a lot more functionality then only editing the image such as all kinds of paint tools. A well known low level tool is for example 'Paintbrush' from Microsoft, which is standard in

Microsoft Windows environment. More sophisticated tools like 'Photo styler' (Aldus) and 'Paint shop' (Adobe) allow professional editing and have a seamless link to the digitizing or capturing activities.

Creating new images

The need for sophisticated graphics editing and paint tools stimulated the development of professional packages known as 'Paintboxes' that combine the most sopisticated video-chips and software to support the creative design process. A Paintbox offers photo-realistic quality and many software tools to create, merge or edit high resolution new or existing images. The main use is for professional photo-labs as a retouching tool and with advertising companies. Artists have discovered this medium and generate new graphic art, that has found its way to art-galeries and museums.

2.3.3. Picture Processing

Picture processing is the collective term for many different operations that a digital image can undergo. The choice of operation depends entirely on the effect or result that is aimed for. We will not exhaustively enumerate all different operations that have been developed, but instead shortly refer to a limited number to show the potentials.

Picture transformation

Due to the fact that the image is stored digitally this digital information can be modified by mathematical operations. Transformations allow us to uniformly alter the entire picture. Typical operations are geometric transformations of scale, translation and rotation. These operations allow us to zoom in and out on parts of the image, to copy or translate parts of the image to an other locality within the image itself and to change the orientation of the area of interest.

Enhancement of a picture

Many operations can be performed to enhance a digital picture. Operations on groups of pixels can sharpen or smooth the image depending the result one is after. For example the subtraction of a weighted average picture from the original usually will achieve a deblurring effect. Only local averaging an image can reduce noise and has a smoothing effect. Operations with extreme effects can show compositional features of the image.

Segmentation techniques

Picture segmentation is the technique of decomposing a picture into meaningful parts to separate objects from the background and to distinguish among objects. Segmentation techniques are a first step in pattern recognition because the result is logically linked groups of pixels that discern an object from the background.

Edge or boundary detection

Many algoritms have been developed that support edge-detection within an image. For example by using a mathematic algorithm called Laplacian operator lines can be detected and an image can be deblurred. The nice property of this operator is that it yields the same results regardless of the orientation of the picture. The effect is that it first gets an averaged image that is later subtracted from the original. The combined effect is to sharpen the boundary lines of an image.

Pattern recognition

With the above techniques depicted objects can be isolated, features extracted and with a pattern classifier identified. This works well with optical character recognition (OCR). Although pattern recognition has much attention in the field of image processing and the results are encouraging, pattern recognition will not play a major role when we envisage the complex visual art historical resources. It will take a long time before pattern recognition can deal with these complex images and what is more with the complex questions reseachers will come up with. There is quite a large difference in complexity between finding squares and circles in a thousand images or retrieving representations of particular types of the Virgin and Child.

2.3.4. Picture Output

One should realize that the displayed image or the hardcopy of it is always a surrogate image that serves retrieval or image processing purposes but hardly ever replaces definitively the original. The potential use of the digitized images dictates the resolution and colour at which the image is to be displayed. With every pictorial information system a mix is needed of different quality (resolution and dynamic colour range) output devices to anticipate the different use of the information system.

Displaying/Printing a picture

Although images may be digitized at very high resolutions, they do not have to be displayed or reproduced at the very same resolution or with the very same colour information as they were digitized. In many cases a simple surrogate image (of low resolution) will do perfectly well in an early stage of inspection. When browsing through a pictorial database surrogate pictures will show enough detail to allow recognition of features of interest. After selection of a particular set of images in this way, the limited set of images of interest can be displayed at higher resolutions for further inspection. Time can be saved by speeding the retrieval process without potential loss of information. Hard-copies on laserprinters serve in the very same way in most cases the purpose of documenting the images of interest and will do fine in the later publication to show the issue.

Zooming and Panning

Many video boards allow zooming and panning of the image at high speed. If these features are not available at hardware (chip) level, they can nevertheless be simulated with software routines, but not at high speed because of the extra computing overhead. These features allow us to inspect images at different levels of detail and allow high resolution digital images to be displayed at a appreciable lower resolution without loosing the overview.

2.3.5. Picture Encoding/Decoding

Although storage is a major issue with pictorial information systems, the use of compression and decompression techniques should be as transparent as possible to the ultimate user.

Compression and decompression of images

During the design stage of the PIS, decisions have to be made about compression methods in relation to the information loss that accompanies compression of data. Decompression is time consuming and has at least to equal out the gain in overall storage capacity at the cost of (some) information loss. Taken into account the earlier remarks about surrogate images the information loss will usually not be the major issue. The speed reduction during the image display fase as a result of the necessary decompression of the image has to be taken into consideration because the user is confronted with it every time a (part of an) image is displayed and that can be very annoying. On the other hand when the images are stored on a CD-ROM with low transfer rates the decrease in file size of the compressed image speeds up the transfer rate of the image. With a hardware decompression board the time gained during transfer of the compressed image is higher then the time consumed with decompression! When images are available on a baseband network server compression usually is an attractive solution for gaining transfer speed when hardware decompression is availble on the clients workstation.

2.3.6. Picture Communication

Distribution of the PIS on CD-ROM is a serious alternative to picture communication although specific network functions can never be replaced by a small silver platter it might very well be a cost effective alternative when CD-ROM players become as cheap as floppy disk drives.

Transmission of images to workstations or computers

The issue of image size has been raised earlier and becomes critical when images have to be transmitted over datacommunication lines. The concept of a client-server architecture is attractive when a large amount of images and expensive output devices (such as plotters, laser-and photo-printers) have to be accessed by many users. Instead of increasing the clients workstation power the PIS can be reached as a network function and data and images are transferred to the client and displayed on the clients workstation. Resources (disks and output devices) can be shared better this way and (dynamically) connected to the clients workstations depending on the needs. The type of network and its topology are critical with respect to transfer speed and reliability.

2.3.7. Network Access

When connected to a network one expects some basic functions to be present such as file transfer, remote login, list servers, e-mail etc. As for the user these functions have to be as transparent as possible, whether the user accesses his local disk or the network disk he should not notice the difference.

Network functions

One of the advantages of networks is the sharing of resources. Therefore one of the most appropriate functions that serves PISs is the access to a CD-ROM jukebox. A CD-ROM jukebox is a multidisk CD-ROM player that logically can combine physically different CD-ROM disks to one large disk. It can be loaded with many disks typically 8 to 16. Since pictorial databases demand large storage capacity access to a rather expensive device as a CD-ROM jukebox seems a logical network function. Facilities for transferring image files to special output devices such as laser- and photo-printers are considered standard functions.

One can only speculate on the impact of the major advance that will be made when keepers of digital visual resources are connected to the academic networks and the remote access of visual material will become available on international scale.

2.3.8. Picture Storage

The large storage volume that PISs require does not have to be repeated here, it has been emphasized in the above paragraphs.

Access on *given storage medium*

Access to the storage device that holds the PIS's data should not be different from accessing a local disk. Device drivers for CD-ROM players are available that allow this transparent access. However, the design of the PIS heavily depends on the use of a particular storage device such as a CD-ROM player which imposes special requirements. Since CD-ROM is a read only and rather slow device the implementation of the datamodel of the PIS should account for that. Deliberate redundancy, extra indices, partitioning and dynamic buffering on local magnetic disk or in memory of heavily used data all help to get around the CD-ROM constraints.

2.3.9. Pictorial DBMS: Logical storage and retrieval

When designing pictorial databases two problems have to be solved: manipulation of a large number of images and manipulation of images of great complexity. Traditionally, researchers working in the field of image processing have concentrated on working with a few images. However the kind of applications we are confronted with today require that a system is capable of handling a large number of complex images. From this it follows that research must concentrate on new techniques suited for efficient and flexible retrieval of information, texts and images, from large pictorial databases.

The design of a pictorial database must integrate tabular data (text), graphical data (vectors) and image data (bitmaps). One should realize that there is a difference between the logical image and the physical image. The logical image can be regarded as a model of the real image. It is defined as a (hierarchically) structured collection of picture objects and textual information (semantically) describing it. The logical image can be stored as relational tables in a relational database management system and manipulated using a query language. Inquiries concerning the attributes of picture objects can also be handled by this database management system. Once a logical picture has been identified as useful, that is after retrieval using the available information, the corresponding physical image can be generated on the output device by retrieving it from memory. In fact the presentation of the physical image is the easy part. It is based on a relation between the stored image and the textual information about this number, or, to make things a bit more tangible, a simple number refers from stored image to textual information and vice versa. Software solutions may differ according to the actual implementation of the above mentioned principle. Sometimes software (for example PicturePower by PictureWare Inc.) separates the storage of bitmap images, using an image store, from the database management system. This allows for quick and easy access by a special interface for PC-based database management systems like dBase. Other database management systems use attributes called BLOBs (Binary Large OBjects). These are particularly useful for storing the bitmaps. All other information will be stored in the conventional database records and fields. As said before, storing images in a database management system is only the simple part of the story, retrieving them in an efficient way is something completely different. The next chapter will deal with that problem extensively.

2.4. Conclusions

The field of image processing is strongly technology driven and those who are not familiar with it are easily impressed by the latest technological achievements. The technology is improving so fast that any project that starts with a certain level of equipment is outdated within a couple of years. This means that every project that has the pretention to last for many years has to develop a special policy to ensure investments in equipment and personnel, since a dependency on (specialized) technology can be fatal. Only projects that are organized in such a way that switching from one technology to an other are possible, can keep up with future technological developments.

3. Images, Texts and Computers: Describing Images

3.1. Retrieval of Images: The Basic Need to Provide Textual Keys to Retrieve Images

In the preface of this article we stated that it is hard to see how the electronic publication of digitized images without additional information, can serve any (art) historical research interest. In section 1.3 we concluded that art history should leave its anthological methodology and abandon aesthetic criteria when selecting material for research.

So, on the one hand we would like art history — or whatever we would call this discipline — to put 'all' the visual material of the past at our disposal. On the other hand, we want it to preprocess — describe — it, before we begin to study it. These two statements add up to the following paradoxical question: "What is left to be studied in material that has already been described in detail?" The answer is simple: everything!

To explain this, we must return to what was said before about the different stages of the organization of information: data, basic information, and extended information.

Simply digitizing a large amount of images without any additional information is no solution. But even distributing digitized images together with basic information about them — the second level — is no real solution. Suppose we define the basic, factual information about objects as consisting of:

- name of collection or institution.
- inventory number.
- indication of object type.
- keywords related to content.
- title.
- description of object.
- maker.
- date.
- material.
- size.
- frame.
- provenance.[3]

[3] This enumeration is based upon: Jeanne Hogenboom, *Basisregistratie voor collecties voorwerpen en beeldmateriaal*, Rotterdam, 1988.

Such descriptions, without which one can not manage a collection of visual material at all, allow us to group images according to traditional art historical categories.[4] This approach, however, will not produce a pictorial information system that may adequately serve research within the realm of cultural history. It is highly likely that the questions that will be posed in such a context, will transcend the information offered in the aforementioned documentation categories[5]

Let us look at the following example: A maritime historian, interested in 17th century scenes of harbour activities, wants to see whether Dutch landscapes of that period contain information on this topic. He wants to search on "harbour activities" in 17th century Dutch landscapes, a straightforward question by any standard. Consulting the basic information — the second level — stored in the image databank of an imaginary documentation institute, chances are that our historian would have to transform his question into something vaguer. He would have to make a detour, for instance, by asking for Dutch 17th century landscape painters, whom he knows to have depicted river and coastal views. Or he may try to find all depictions of cities and villages he knows to be or to have been at the coast or on a river. In other words: he would probably base his retrieval on properties of images — names of artists or topographical names — which are not his primary interest!

It goes without saying that "harbour activities" could have been used as a keyword to denote the content of some of the images in our imaginary databank. The question here, however, is not whether it is likely or not that the term "harbour activities" is used as a descriptive keyword on the second level. We could just as easily have cited the example of an agronomist interested in the different types of vegetables depicted in still life paintings... The question is whether the second level of describing images, as we have defined it, will be of use when dealing with by definition unpredictable questions of researchers from various disciplines.

The answer is of course: yes and no. Yes, because the factual information can be used to delimit questions concerning the contents of images: landscape, Dutch, 17th century. No, because this type of information does not aim at providing the precise, detailed and consistent descriptions of the contents of the images needed in the kind of pictorial information systems we are discussing here.

From the section above we can draw some conclusions:

- It is impossible to predict all the questions researchers will ask from pictorial information systems. It is only by supplying extended information that we can begin to answer them.
- Factual information can be supplied for large and heterogeneous collections of images, although it must be stressed that this is a complex task in its own right. Of far greater

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[4] Cf. section 2 where we saw that the computer can be used to group images according to formal qualities. Here the issue is not so much whether these questions are traditional, but rather whether these questions lead to historical research (another case of preprocessing).

[5] Cf. R. Stenvert, *Constructing the Past: Computer-Assisted Architectural-Historical Research, etc.* Utrecht, 1991, p. 78: "Only when trying to pose specific content-related questions will the real bottleneck of each information system emerge: the 'depth' — or extent — and the consistency of the secondary [i.e. our 'extended'] information."

complexity, however, is the task of providing extended information of the desired level of detail and consistency.

- The problems involved in maintaining that level will decrease when we choose to describe relatively homogeneous material in relatively small research projects[6]
- It hardly needs to be emphasized that the extended information should be added to the basic information. In pictorial information systems we obviously need both.

Two methodological points remain to be raised:

Interpreting and presenting the source

First of all we should make it unambiguously clear that we are dealing with interpretations on each of the three levels of information we have distinguished.

- Digitized reproductions of objects are not the same as the objects themselves and in this sense they can be said to be interpretations of the objects. Reproducing an object, and certainly its digitization, involves a number of thechnical choices, as can be inferred from section 2. But even when we look at objects themselves, we cannot avoid interpreting them. Any intellectual "appropriation" of an object involves instantaneously "considering it under some verbal description or specification."[7]
- Basic information about objects, naturally, is based upon interpretation. This may seem to be less obvious for information about their size or material than about the artist who made them. It nevertheless holds on both a practical and theoretical level.
- Precise, detailed and consistent descriptions of the contents of images are interpretations of a highly integrated and organized nature.

We moreover assert that the need to embed our interpretations in general historical research, increases as we move from the first level, data, to the third level, extended information. This assertion is consistent with the one that the meaning of an image lies outside the image itself. In other words, the meaning of an image can only be studied by carefully holding it against an appropriate cultural context from the past, a context of which (other) images are an important element.

The third level of information provided by a pictorial information system can thus be characterized as having a high interpretative "density". We create extended information by exercizing "brute force" on material from the past. Therefore we have to take into consideration that some users may feel that the data that lead to a certain interpretation are hidden by the layers of interpretation themselves. We can call this the iceberg phenomenon: a part of the data floats below the surface and remains invisible.

We can illustrate this with an example from our own research. When we were working on a prototype pictorial information system on Dutch 17th century printer's devices — the

[6] This conclusion may serve to put the theoretical and practical efforts into perspective of projects that do indeed try to provide both basic and extended information for heterogeneous collections. The intellectual achievement of documentation institutes, faced with this task, is often underestimated, by organizations that fund them as well as by the scholars that make use of their information.

[7] Cf. Michael Baxandall, *Patterns of Intention. On the Historical Explanation of Pictures.* New Haven/London, 1985.

small logo's with which these craftsmen identified their products — our source consisted of photocopied title pages of books printed in the Netherlands during the 17th century. In this period there was no strict distinction between priuters and booksellers. On the title pages both printer and bookseller are sometimes mentioned. Typically, the device belongs to only one of them. Working with a large amount of material we could often assign the device to either the printer or the bookseller by extrapolating from other occurrences of the same device.

So, in this case, the user of the pictorial information system is confronted with our interpretation, not with the data as we found them on the title pages. When the system was published (on CD-ROM) it became clear, however, that some researchers were interested in aspects of the information that we had filtered out. They would like to know, for example, which printers and/or booksellers had collaborated with whom during this period. The information to answer that question is in our source. We had been aware of that, but we had decided not to make it explicitly available in the information system.

Obviously, processing a source always implies "hiding" aspects of its data by ignoring or filtering them. This holds for any source. No matter how faithfully we reproduce a charter — its integral text together with scanned images of all of its pages — we do not replace the object. We can not avoid to "hide", for instance, certain significant codicological characteristics. We hope to have made it clear above that if a source consists — in whole or in part — of images, simply passing on all of the images to the user, is no remedy. On the contrary, the more images are included, the more pressing the need is to provide pathways to them.

When designing pictorial information systems, one should have a clear view on what information should be presented in what way and how the decisions taken in the process can be made as transparent as possible. We have called this the conceptual issue. It is a difficult issue, because one needs to be aware of how other researchers want to use the material. In some cases that question may evolve into a research project of its own.

The central problem could be defined as: "How does one ensure, given the iceberg phenomenon described above, that one's research is of maximum use to others?"

There is no simple solution to this conceptual problem. In the example cited above we decided to backtrack. We are going over the source once again, surveying all the names of persons appearing on those title pages. These notes will be incorporated in the forthcoming issue of the program as a kind of worksheets. If we have attributed a printer's device to a certain printer, the user can consult the worksheets to see with whom the printer collaborated using that particular printer's device. If we can not attribute the printer's device to one person mentioned on the title page, we will — by default — give all names of persons mentioned.

It might very well be, however, that researchers are not so much interested in cooperation between printers and booksellers, but want to know how these printers and booksellers have called themselves, what they have said about their shopsigns and the name of their shop, how they have described their locations and addresses, etc. In short: as soon as we have solved the retrieval based on question N, question N+1 will be posed.

Anyone describing large amounts of visual material of the past, concentrating on sources that combine texts and images, will have to analyse that source carefully and think carefully how to present the described material. One could imagine that steps are taken to gather data that perhaps will not be presented in the pictorial information system itself, but still can be of use to the researcher posing a N+1 question. Data could then be made available in an alternative way, for example in plain ASCII[8].

The status of a description: the Münchhausen paradox.

The second, even more important issue is the following: what is the status of the iconographical descriptions of images? Are they historical explanations? This is an extremely important issue, because to make precise, detailed and consistent descriptions, we rely on controlled vocabularies, authority lists and thesauri. These tools have to be available, in whole or part, before the researcher has described the images. How can this be? How can the researcher — to put it sharply — have the terminology available to interpret an image before he knows what it means?

The difficulty lies in the exact meaning of the word interpretation. Interpretation in a traditional art historical sense does in fact seem to be defined as the equivalent of historical explanation. This can of course only be the case if the researcher holds the epistemological view that images contain historical information as well as the keys to decipher this information.

If, instead, we assert that the keys to decipher the historical information of images of the past lie outside the images, then the status of interpretations on our third level should be seen as contemporary, but informed — i.e. based on already processed material — descriptions of images. By applying descriptors to images of the past, we not so much explain the image as an element of the past (that is what should be studied), but preprocess the image in order to get an object that can be studied as an element of the past in the first place. The status of our interpretative descriptions is thus by definition tentative and temporary. By collecting as many of them as possible, however, they can gradually begin to pull each other out of the quicksand.

This idea of pre-processing images to get an object for historical research, resulting in labelling descriptions of images as contemporary statements, seems to be valid also for the image manipulation techniques mentioned in section 2. In section 3.3 we will have a look at some of the techniques used for pre-processing images with the help of texts.

Summarizing

From an epistemological point of view we emphasized the distance between us, the researchers, and the elements from the past we study, the images. We denied the idea that images contained historical meaning as well as the keys to deciper this meaning. Furthermore we argued that in order to study the meaning of images we have to describe them first. We stated that these descriptions do not constitute historical explanations of

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[8] The largest amount of data is by definition available at the time of data entry, i.e. in the production environment. The design of the query environment usually implies filtering data. For instance: divergencies in the spelling of proper names in the source, may be "corrected". Designing the production environment means taking decisions about what data will be entered. Moreover, in this environment the data either are in plain ASCII files or they can easily be downloaded into such files. Whether they can indeed be made available in this form, will depend to a large extent on the researchers' willingness to exchange data in this way...

the meaning of these images, but are an activity we labelled as pre-processing. We did not discuss the various ways or methods of pre-processing images using different (art) theories. The main idea simply is that the (art) historian clearly indicates which parts or elements of an image make it possible to study the image as an historical phenomenon. Whether the (art) historian works with iconographic contents or formal aspects of images or with a combination of the two is not the main issue here.

As we have seen in section 2, the computer offers us a lot of tools to manipulate images. But even with these tools, research of both the formal and the iconographic apect of images will need text to enable others to use the results of this research. In the following sections we will highlight two aspects of adding texts to images:

- The actual process of linking various types of information to images. Emphasis will be on the production phase.
- Techniques and tools to help us control the consistency of the information we link to images. Special attention will be paid to iconographical descriptions.

3.2. Creating Access to Images: An Iterative Process

Wordprocessors and editors

Many projects focus on individual images. They collect, or already have information about each of the images. The simplest way, then, to structure the information, is to create one record for every image, in which basic and extended information are combined. The different elements of the information may be identified by tags or labels.

A file that is thus structured, can be quite easily generated with an ASCII editor or wordprocessor. Such a structured text file then combines features of a text and a database file. It is read sequentially, and although it can not make use of records and fields itself, it can be converted into a genuine database file, if the text is properly marked and one has a DBMS that is able to import ASCII files. Evidently, as long as the file is kept as a text file, all the editing and search facilities of one's editor are available. Data entry can be done simply with a wordprocessor.

This rather low level approach has some benefits over directly preparing or making records with the help of a DBMS. First of all one can start a project without the high initial costs of a DBMS. Editors or word processors are relatively cheap, if not already available within institutions. Furthermore preparing data with the help of an editor gives one time to experiment with the data, begin to think about ways to structure them and about the environment needed to process the data further. So, ideally speaking, the result would be a better choice of DBMS because of a better insight in the data the DBMS has to manage.

This strategy also has some drawbacks. First of all, as the number of records grows, it will become harder to check the quality and consistency of the descriptions with the help of an editor. The critical file size that can still be managed depends of course on the specifications of one's editor. Especially important are its speed and its search facilities. These are by definition string matching facilities, but they can be more or less sophisticated. Some are restricted to exact matching (think of the search possibilities of wordprocessors), others support the use of wild cards and regular expressions.

Secondly, it is difficult to work with a data model that encompasses multiple files, when the tool you use is an editor. Because a text file is read linearly, one tends to keep information physically close together. The iconographical description typically follows information on maker, present location, provenance, description, etc.; and all are clustered around e.g. the inventory number that uniquely identifies the image. The drawback is clear: this causes redundancy. To give one example: with the name of a painter, some biographical data are often included, like date and place of birth and death. Information like that is not unique to one image. Yet, in a single text file, the only way to link it to the unique element — the image — is to repeat it each time it is applicable. A solution might be to create a second text file where information about artists is collected. A number identifying every single artist could then be used in the first file. Clearly, this strategy can not be maintained very long with complex data.

A third drawback is that using a (single) text file is difficult if one works in a team. When a group of iconographers describes images, the use of a database management system is a necessity to enforce uniformity and consistency of the information.

Coming up with the right solution for a particular project will be based on trial and error, or as it is often called: one will be engaged in an iterative process. In order to think of a data model, one has to have data. In order to acquire data, one has to have a vague idea of a data model. The important thing is to acknowledge that one must be able to proceed by trial and error, that is to change software or manipulate the data during certain phases of a project. It needs no further explanation that correcting errors or changing course is easier if the different data elements are properly identified and tagged.

Textbase programs

There are software products around that make it possible to process the data with the help of a word processor or editor and overcome the problems mentioned in the first two drawbacks. These programs, "askSam", "Idealist", "ZyIndex" to name just a few, allow the user very easy import and export of ASCII files. They can, in various degrees, handle data structures such as fields and records, which they combine with — sometimes very elaborate — text search facilities. They can act as a valuable and more or less inexpensive link between editor files and a production database, in particular because they let us sort and check the contents of our files, i.e. do a form of data control.

The link will prove to be truly inexpensive when the use of such a program gives the user an opportunity to formulate functional requirements for the production database to be used to handle the data. To give some examples: proper handling of alpha numerical data, variable field length, repeating fields, c-module to link programs in object format written in C, etc.

Hypertext

It is very difficult to give an exact definition of the popular term "hypertext". Its meaning depends entirely on the context in which it is used. Yet, the very fact that it is often referred to as the ultimate retrieval tool provokes some comments here.

"Hypertext" can refer to the original idea of Ted Nelson's Xanadu project about a digitally available universe of information. In some other cases "hypertext" denotes applications that consist of the generalization of text-only documents in which images, moving images and sound may appear whenever and wherever it seems appropriate (Lucky [1989]). And sometimes the word "hypertext" merely denotes the technique of a network of relations pointing to each other.

At present, the word is most often used in the second and third sense: hypertext applications (or multimedia documents) and the hypertext technique (e.g. interactive help systems of computer programs).

Of course the hypertext technique is part of a hypertext application. Concerning this technique a distinction is made between:

- objective links: for example a link from a table of contents to a particular area of a document; and
- subjective links: editorial links that consist of cross references between relevant material or of comments on material.

Although objective or more or less formal links will form the backbone of a hypertext application, the subjective or editorial links make an application attractive.

Three remarks should be made about the hypertext technique and hypertext applications:

1) Hypertext is a sound and valuable information management technique.
2) To this date the best hypertext applications are found in the areas of interactive help systems, document management systems and teaching systems. The benefits of hypertext applications in these areas are clear: they allow the user to follow his own routes through the material according to his particular interests (subjective linearity).
3) There are some drawbacks:
    a) If the so-called subjective links add value to a hypertext application, then these applications need a considerable amount of links not to be trivial and these links have to be provided by informed staff. In short: building hypertext applications is a time consuming and costly affair.
    b) It is one thing to give users of hypertext applications the possibility of the path of subjective linearity, but then one must also provide them with the possibilities of backtracking (where did I come from?) and overview (where in hyperspace am I?).

Production databases

A database or a database management system — DBMS as it is often called — is used to manage information (data). This information needs to be represented in a well structured form: the database. A database consists of files, files consist of records, records consist of data elements or fields as they are often called, fields consist of entries. Traditionally three types of DBMS's are distinguished: the relational model, the hierarchical model and the network model. With all the literature on DBMS's around, we will not describe these models here. What is important, though, is that the complexity of the data (the complexity of information in the (art) historical disciplines is not of the same order as the information of, let's say a dentist) incorporated in the database often requires creative solutions, read: hybrid systems, like a database with a thesaurus attached to it or a database that is a combination of the relational and the hierarchical model.

3.3. Aspects of Vocabulary Control

In various ways basic information and descriptive text can be added to images to create retrieval possibilities. Scholars generally agree about the need to use controlled vocabularies in the area of basic information. There is less consensus in the area of iconographic description. Moreover, a tendency can be detected to consider some of the methods of creating iconographic information — e.g. systematic classification and describing images in free text — to be mutually exclusive. We will argue that they are not. They can in many cases be used as complementary techniques.

Control mechanisms and tools

Wordprocessors offer us nearly unlimited freedom to input information in any form. And although database management systems generally make sure that we obey certain formal rules — no text in a numeric field — they do not restrain our freedom concerning the contents of the entries. The ease with which computers allow us to sort and search large quantities of data, however, have made us acutely aware of the necessity to control that freedom. The advantages of selecting a preferred variant name for a particular artist, city or object are evident, even if there can be cause for disagreement on what that particular preferred variant should be. In general, the importance of vocabulary control can hardly be exaggerated.[9]

Input control can be done in several ways. Here we don't have to discuss them, but it is useful to mention two principles. The first is to build one's own list of preferred terms while inputting the data. The list, which grows as one progresses, can then be used to check new entries and to copy accepted ones. The second one is to build on an existing source of terminology. The existence of these alternative principles does not force us to make an absolute choice between creating an authority list or conforming to one. Quite often we find a mixture of both: a particular standard is chosen and then diverged from whenever it is judged necessary.

Controlled vocabularies may of course include non-preferred terms too, and cross-refer them for the preferred ones. Elaborate systems cross-link terms that are semantically related. These relationships may also include hierarchical ones. Eventually vocabulary systems can become real thesauri.

Of course, vocabulary control did not start with computerization. It has always been an important element of documentation. The computer, however, possesses unprecedented facilities to stimulate or even enforce uniformity of the data entered. Some standard software packages support the creation and maintenance of authority files. A few authority files have recently been published in an electronic form, some of them as part of a larger system, some of them as independent instruments.[10] Ideally you consult these and copy from them, without leaving your own application, e.g. your DBMS.

[9] In the field of art history important work is being done by various institutions. To name a few: the *Witt Library* (Courtauld Institute, London), the *Bildarchiv Foto Marburg* (Marburg a/d Lahn), the *Inventaire Général* (Paris), the *Index of Christian Art* (Princeton), the *Getty Art History Information Program* (AHIP, Santa Monica) and the *Istituto Centrale per il Catalogo e la Documentazione* (Rome).

[10] AHIP, for example, has published its Union Lists of Artists' Names and the Art and Ar-

Status of authorities

Controlled vocabularies, dictionaries, and thesauri offer us names and terms which we use in creating basic and extended information about images, i.e. in creating a subject for historical study. We are aware of the fact that these authorities themselves are based on research and thus not really "pre-fabricated" at all. The terms they propose will be accepted until they are falsified and everyone who uses them is — or should be — aware of their provisional nature. In a sense, every time "pre-fabricated" terms are used to make a new image accessible, they are tested against new data.

3.3.1. The Vocabulary of Iconography

We now turn to the problems we encounter when we create and try to control the systematic and detailed iconographic access to images. In analyzing these problems we shall concentrate on two closely related questions:

- How can we maximize the consistency of our descriptions?
- How can we optimize the retrieval of iconographic information?

Focussing on these questions implies that our interest is of a practical rather than a philosophical nature.

Consistency

Art historians are seldom trained in the systematic description of large amounts of images. In general they focus on the individual image. Yet, the idea that it is not only useful but also possible to produce large quantities of iconographic information has gained more and more acceptance. To some extent this is due to the acquaintance many scholars have recently made with the personal computer. These machines process, store, retrieve and index text with great ease. Because of that, the creation of iconographic indices has become a much lighter task. We may even escape making one if we have an electronic version of the descriptions at our disposal. The very ease with which text can be manipulated and retrieved, however, tends to blur some fundamental issues.

Undoubtedly, one of the most important of those issues is consistency. It is essential to the quality of the information in iconographic descriptions that:

- a single level of detail is maintained
- a detail mentioned once, is mentioned every time it is observed afterwards
- the same visual phenomenon is described with the same term every time it is observed.

If the descriptions fail to meet the first two conditions, the information is unreliable by definition, and can not be made consistent without going back to the source. If the terminology varies while the visual elements described do not change, or the same term is used to describe different visual elements, creating consistency can become extremely complex, because links have to be established between the different terms.

The importance of consistency — and the difficulty of enforcing it — increases dramatically if:

- the iconographic descriptions in a single project are made by a team of scholars

chitecture Thesaurus. Authority files are available with the HIDA/MIDAS DBMS, developed by Bildarchiv Foto Marburg and StarText GMBH.

- the iconographic information that is gathered, or rather created, has to be made accessible to others.

Control procedure

To determine whether we have remained faithful to a once chosen level of detail and to see whether a particular detail has been mentioned every time it occurs, we have but one option. After describing a certain number of images, we have to go over the material a second time, and check if every occurrence of a particular phenomenon has been noticed. It is only by creating a complete index of our descriptors and systematically going back from this index to the images that we can estimate just how consistent our descriptions are.

Whatever our analysis of the relationship between descriptors and visual phenomena will tell us about the consistency of our selection of details, it will surely reveal that we have used different words to describe the same visual phenomenon. Reversely, it will also show that we have described different visual elements with the same word. Different words we use for the same element may be synonyms or they may represent different levels of abstraction. In both cases we need to eliminate the divergencies or cross-link our terms.

Uniformity

It can be argued that by enhancing the uniformity of our terminology, we do injustice to the features that are unique to each individual image. To some extent this is both true and inevitable, because it is impossible — even theoretically — to completely verbalize the contents of an image. In our case, moreover, it is exactly what we want. Our aim is not to replace the image by a description or to try to evoke it in the user's mind, but to provide it with textual keys by which it can be retrieved. We do have an interest in identifying similarities and divergencies, but we do not want our choice of words to complicate things for us.

There is not much beyond discipline and common sense with which to minimize variations and omissions in the selection of the visual elements we want to describe, although we can seriously improve our chances by a systematic approach[11]. At the same time, it is crucial to limit the variation in our terminology. If we do not make an effort on this point, it will become almost impossible to use the index of our descriptors as an instrument to check our descriptions against the images. Even worse, others will hardly be able to retrieve information from our descriptions.

Optimizing the uniformity of our terminology can be done at different times during the process and different strategies may be used. We do not intend to exhaustively survey all aspects involved. Instead we shall take a shortcut by analyzing the features of two hypothetical types of description, located at both ends of a theoretical scale that indicates degrees of organization.

It is not very difficult to imagine what is to be found on the end of this scale where the ambition to be consistent is minimal or absent. There we encounter free form prose descriptions that closely follow the variety of the images. No prescriptions other than

[11] A heterogeneous collection may be broken up in more homogeneous parts; the order in which the images' elements are described may be strictly regulated, etc. ...

the syntax of the language they are written in, regulate their structure. No controlled vocabulary regulates their terminology. No index gives access to the individual descriptors. No cross-links are established between broader, narrower, and related terms. In agreement with this low level of the organization of their contents, these hypothetical descriptions are stored as part of a sequential text file, together with the basic information.

A collection of such descriptions would bear a close resemblance to the typical arthistorical exhibition or oeuvre catalogue. We would have a hard time defending that they aim to provide extended information as defined above: detailed, systematic, and consistent.

It is more complex to define what we would find on the other end of the scale. It would certainly not be sufficient to simply invert the elements of the definition we just gave. The absence of a feature, such as vocabulary control, does not need to be further qualified. Its presence does. So, let us have a look at the features we have just mentioned and try to picture them as constituent elements of extended information.

Free text

First we have to ask whether we can use free text as a vehicle for extended information? Is this not a 'contradictio in terminis'? In other words: "Is there a place for free text descriptions at the 'highly organized end' of our scale?" We think there is, but only on certain conditions. Some of these conditions concern the contents of the texts, others have to do with our retrieval instruments.

The retrieval of information from a text file, as we have said before, is based on string matching. A string is given as a query argument and the file is sequentially scanned for the occurrence of this string. This is a slow process. But more importantly, trying to find relevant information in this way is like trying to find the light switch in one of the rooms of a pitch-dark house. If we are very lucky, we may light up one room, but we still have no idea what is in the rest of the house. This holds, irrespective of the sophistication of the tools with which we can define our question, such as wild cards, proximity searches, and regular expressions.

For free text to be of any use as a vehicle of systematic information, it must be made more transparent by means of an alphabetic keyword index of its descriptors. To be useful, an index should not mix different kinds of information. For example, it should not mix the names of painters, former owners, techniques, and iconographic descriptors. In other words: to create meaningful indices, the information has to be broken up into its constituent data elements and put in separate records and fields (Cf. section 3.2).

Two other conditions have to be fulfilled, if free text is to function as a vehicle of extended information. The descriptors have to be submitted to vocabulary control and they ought to be cross-linked.

Keywords

The most obvious alternative to prose descriptions is a string of keywords. Both solutions have their advantages and disadvantages. A string of keywords, for example, is not subjected to the syntax of natural language. Thus, we can convey additional information by the way we arrange them. For instance, the order in which we put the descriptors may be used to distinguish between a whole and its parts. A query for words in a particular order or within a particular distance from each other, may then be more relevant. A prose description, on the other hand, is a more flexible instrument, e.g. to supply information about how visual elements are distributed over the surface of a picture.

Vocabulary control

A controlled vocabulary can be a feature of the free text descriptions that we would admit to the high end of our scale. In that case it would be a custom-made term list, based upon our previous descriptions and created simultaneous with them. The terms from such a list will in turn be used to build new descriptions. It can also originate as a list of our preferred keywords, which we may have put in a separate keyword field, instead of or in addition to the free text descriptions. Finally, we can borrow our descriptors from an external source of terminology[12]

Context and cross references

With 'church' we may mean a building which can house a Christian congregation and is 'physical' enough to park a bicycle against. It also refers to an abstraction: an 'organized Christian society'. A table can be made of oak; it therefore is a wooden table. We may have seen a castle in a landscape painting; you may see a fortress...

Language is our inescapable medium of (scholarly) communication; at the same time it is a potentially unlimited source of confusion. While creating, consulting or copying from a controlled vocabulary we come across many linguistic complications, such as homonymity and synonymity. And, what is more, we have to guide users through these complications.

When we employ a vocabulary — whether of our own making or a 'foreign' one — we need to know the exact meaning of the words it contains. If our term list is no more than an alphabetically arranged, 'flat' list of the keywords we allow as descriptors, no light is shed on their meaning. We would feel uncomfortable when borrowing terms from such a list. Meaning can of course be explained through definitions, like in a dictionary. The semantics of the terms in a vocabulary can also be clarified by organizing them into hierarchies. In that way the meaning of a term is explained by the term(s) that surround it hierarchically. 'Table' could then be subordinated to 'furniture', 'oak' to 'wood', 'wood' in its turn to 'plant materials', etc. Using the terms from a vocabulary that is thus organized, we would always know exactly what is intended.

Like the word 'church' (a building as well as an institution), the word 'oak' should appear (at least) twice in a hierarchically organized vocabulary of iconography: once as a material for e.g. furniture, a second time as the tree itself, e.g. as part of a landscape. As a matter of fact, all homonyms should appear as often as their different meanings are relevant to the purpose of iconographic description. Furthermore, when preference is given to 'fortress' over its synonym 'castle' — the building, not the 'rook' (not the bird...) of chess — this must be made clear to users of the vocabulary, who may try to find 'fortress' by asking for 'castle'.

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[12] Note: Examples of such sources include: the subject headings of both the *Princeton Index of Christian Art and the Library of Congress*, and the *Art and Architectural Thesaurus*. The ICONCLASS System, and François Garnier's *Thesaurus Iconographique* are tools specifically designed to facilitate the creation of iconographic descriptions.

Finally, to function properly as a hierarchy of iconographic descriptors, our controlled vocabulary must accomodate concepts of such different levels of complexity and abstraction as 'table' and 'The Annunciation to the Virgin'.

Images are a subject for study potentially as rich as the 'representable' world; maybe even richer, since they can also be a testimony about the visible world of the past. Building a hierarchically organized controlled vocabulary — including cross references — for a field as rich as that, is an intimidating challenge.

Systematic classification

So far, we have failed to mention one important expedient to meet this challenge: the systematic classification. The essence of a systematic classification scheme is that its ordering principle is not alphabetical but, indeed, systematic. This means that its descriptors are arranged in hierarchically subdivided classes. Each descriptor is accompanied by an (alpha)numeric code or notation which assigns it its place in its class, by which its context and semantics are clarified. The concepts, defined of course in natural language, and the codes form inseparable units. Access to them is provided by keywords.

Features characteric of a systematic classification include:

- its descriptors are absolutely unambiguous, since every code is by definition unique, although the actual words used in it may occur many times in the vocabulary
- a descriptor can consist of a single word, but it can also consist of a detailed definition of complex — in our case iconographic — subjects
- because its hierarchical arrangement is dealt with by the codes, there is no need to arrange the keywords that give access to the descriptors, into hierarchies
- because of its (alpha)numeric encoding, a systematic classification can not be as freely extended as a vocabulary that exists of language only. A very high degree of control must be exercised during its construction.

For a description of ICONCLASS — a systematic classification system especially designed for iconography — we may refer you to chapter ... of this book. There is no need to go into detail now.

Summarizing: at the end on our scale of organization opposite the 'uncontrolled', free form prose descriptions, we find a number of items on our list of wishes:

- highly controlled free text.
- keywords.
- controlled vocabulary.
- systematic classification.
- hierarchical organization of descriptors.
- cross references.

Some of these items may be regarded as each other's alternative, some are complementary.

Optimizing retrieval

From what has been said above, we can conclude that to optimize the retrieval of iconographic information the following two conditions should be met:

- It must be possible to specify the semantics and the iconographic(!) context of the term that is used as a search argument. This means that we have to be able to distinguish between 'eagle' as a predatory bird, 'eagle' as an animal often used in heraldry, 'eagle' as symbol of St. John, and 'eagle' as an attribute of Jupiter.
- It must be possible to eliminate or at least reduce the risk that information actually present in the information system is withheld from the user, because the term used in a query is not identical with that used in the iconographic description. This might occur if the search term is of an hierarchical level different from that of the descriptor, or if the search argument is a synonym of the descriptor. The problem may be rather straightforward: the descriptor is relatively specific, e.g. 'eagle', while the search argument is more general: 'bird'. It can also be more complicated: 'the symbol of St. John' is used as descriptor, while the search argument is 'eagle'. In the context of iconography this constitutes a synonym[13]

If the retrieval system fails to meet the first condition — i.e. if we can not exclude an 'eagle' we are not interested in — it will retrieve too much. If it fails to meet the second condition — retrieve the 'eagle' we did want but failed to ask for in the right way — it will retrieve too little.

It must be admitted that these two conditions add up to a demand which is too ambitious to answer with even the most sophisticated text retrieval tools. The reason for this is as simple as it is paradoxical and confusing to a computer: when we try to retrieve iconographic information through textual keys, we may explicitly ask for things we do not want; at the same time we may not explicitly ask for things we do want.

4. Conclusions

In this article we have moved across three related areas of interest, all relevant to the subject of Pictorial Information Systems:

- the, often underestimated, intellectual challenge of studying images as elements of the past
- the technical issues involved in studying images with the help of the computer
- the theoretical and practical need to add text to images in order to make them accessible and retrievable.

Iconography is a more or less established art historical method. Techniques to store and manipulate electronic images are readily available. In spite of this, the study of large

[13] A final desideratum for a specifically iconographic retrieval system is built up of two features: (a) Iconographic details should be cross referenced for the broader subject and themes they are part of, e.g. from a particular saint's attribute we should be pointed to the saint's general iconography; (b) Subjects and themes that are related in some way should be cross-linked, e.g. from 'Hercules killing the Nemean lion' to 'Samson killing the lion' These feature can not be called a condition, because it must be seen as belonging to an expert system rather than a retrieval system. In spite of this, both of them are intrinsic to the ICONCLASS System.

amounts of visual material from the past in a systematic way poses some new problems, as we hope to have shown in this article. We have dealt rather extensively with problems of (art) historical method. We have also mentioned a number of practical issues: financing projects, project management, the exchange of information, etc.

A fourth area of interest that may be seen as relevant to our subject — we could refer to it as the area of "pattern recognition" — has been excluded from our discussion. This has been done for various reasons. Firstly, the research on this subject is mainly done in fields like Artificial Intelligence and Military Intelligence (if that is not a contradictio in terminis). In short, not in areas where we can have ready access to the result of the studies that are being done. Secondly, to be honest, major theoretical and practical problems have to be solved before pattern recognition and other, comparable, techniques can be applied to historical imagery in a scientifically meaningful way. At this moment, and on their own, these techniques do not bring us much closer to our aim: the systematic study of images as elements from the past, with the help of the computer.

We can, however, turn the argument around and state that these techniques should be tested within the framework of the systematic study of images from the past. We should not exclude that future developments will turn pattern recognition into a tool with which we can generate meaningful information about images. In dealing with a subject as complex as the imagery of the past, a Pictorial Information System should encompass as many useful tools as possible.

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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