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MAKING ART HISTORICAL SOURCES VISIBLE TO COMPUTERS

PICTURES AS PRIMARY SOURCES FOR COMPUTER-BASED ART HISTORY DATA

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In research on automatic processing of Art History data and documents, problems are formulated and solved based on implicit assumptions of what tools are available. The purpose of this paper is to call attention to tools drawn from parts of Computer Science, with which art historians are generally unfamiliar, in order to suggest that the computers which process these data and documents may also view them in several senses that will be explained below. We question the assumption that computers must be blind to the art from which the data and documents derive.

Most of the computer technology to which we will refer is widely available though often expensive. Some of the ideas discussed require further research in both computer science and art history. Whether such research is pursued depends, in part, on whether art historians are interested in using the results. Apprehension of the technology is an obstacle, although, as a general principle, it can be asserted that these new methods make much greater demands upon art historians to do the art history that they do well than the demands to learn new technology.

We can distinguish three kinds of sources for the data on which art history analysis is based.

a. Primary sources include the art works themselves (paintings, sculptures and other artifacts). We also consider pictures of art works as primary sources because they are so much closer to the art than the other two kinds of sources.

b. Secondary sources include analyses (by art historians) of the art works. These may include iconographic interpretations, measurements, descriptive and scientific analyses. Almost all data maintained for art history purposes are of this secondary kind. This is the stuff of libraries.

c. Intermediate sources include interpretive data, supplied by the art historian, in the form of annotated pictures and sketches. The annotations are natural and easy for the computer to process. The sketches are similarly easy for the human to understand. The correspondence between the annotations and the sketches in made available to the computer.

The sensing of primary sources can be fully automated, but only primitive analyses are possible with automated techniques. The intermediate sources enable deeper analyses by the computer which reflect the deeper analyses included in the input annotated sketches. The secondary sources enable all the deep analyses currently possible with processing of verbal sources, but very little of the analysis is automated.

The two parts of computer science to which we refer are a) image processing and pattern recognition and b) computer graphics.* Image processing is most applicable to enhancing features of images (like contrast, color, and size) which facilitate understanding by human viewers. Computer graphics enable the human analyst to "talk back" to the computer, expressing insight in graphic form. Pattern recognition enables the computer to view and, in a very limited sense, understand images automatically.

The possibility of digital recording of images is widely known and exploited. In the fine arts this possibility is exploited in video and optical digital disk recording, which is always intended for subsequent human viewing. Notwithstanding the digital nature of such recording it is important to realize that such images are substantially invisible to the computer in the sense that the computer as a <u>tabula</u> <u>rasa</u> can perceive nothing in such images which it can nevertheless demonstrably sense. An example of such a sensed (scanned) image is figure 1, the Durer Melencolia I (1514) and figure 2, the computer selected detail. Merely to reproduce the original image at the resolution shown in the detail requires the area of 66 standard television screens, a raster of size 4,800 by 3,800 digital picture elements (pixels), the detail showing 96 by 96 such pixels.

The fact that the computer can not, in one sense, perceive

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* Computer image processing and pattern recognition as a field of research goes back to (Kirsch 1). Its current status is summarized in texts like (Pratt 2) and (Rosenfeld 3). Computer graphics goes back to (Sutherland 4). Its current status is represented by the text (Foley and Van Dam 5). Journals reporting current research in image processing and pattern recognition are (IEEE-PAMI 6) and (Computer Vision, Graphics, and

Image Processing 7) and the annual (IEEE-CVPR 8). For computer graphics the appropriate journals are (IEEE Computer Graphics 9) and the annual (ACM-Siggraph 10).

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such images does not preclude its being able to make useful transformations of such images for human viewing. Figure 3 shows such a transformation for illustrative purposes. It exhibits information about the gradient (or edge direction) of the original image. These three examples of computer scanned and transformed images on art materials can be matched many fold by other image processing examples in fields like earth satellite scanning, and medical tomography and microscopy. At least one Nobel prize has been awarded for uses, in medicine, of such image processing technology (Hounsfield 11).

We can cite other uses of image processing more immediately germane to art history. The technique of enhancement of X-ray images of paintings to reveal hidden structures is widely known to conservators. Less well known is the possibility of adding sharpness and edge detail to degraded images. Another possibility is enhancement of photographs to compensate for the limited dynamic density range of photographic materials when used to reproduce art works.

One use in presentation of three dimensional information is shown in figures 4-7. A stereo-photographic pair of images is scanned and the true three dimensional model is generated in the computer. From the single pair of images, an unlimited number of views from other orientations than those of the cameras can be generated and displayed by the computer. Two such views are shown in figures 6 and 7.

All these examples are drawn from a technology almost three decades old, image processing. Concurrent with the onset of this technology was the development of research interest in programming the computer-as-<u>tabula-rasa</u> to recognize patterns autonomously. Early instances of such pattern recognition technology are optical character recognition machines. Research in the field was substantially accelerated by the introduction in 1964 of so called syntactical methods of pattern recognition (Kirsch 12). The new paradigm introduced here, was the possibility of using the same tools as are used to characterize the structure of language (grammars and their parsers) to characterize images. A grammar is a particularly powerful way to express theory of structure. It makes commitments both with respect to analysis and synthesis and thus demands great insight on the part of the person (not computer) who constructs the grammar. The computer is useful as a tool to help test the validity of the grammar and to exhibit the consequences of theoretical insights expressed in the grammar.

It is not surprising, then, that most of two decades of effort in picture syntax were devoted to the development of tools and only few to their use. Tool development is summarized in (Rosenfeld 13) (Fu 14) and (Kaneff 15). An example of one of the few uses of these tools is (Watt's 16) diachronic study of written alphabets.

A dramatic change took place in 1981 with the publication (Koning and Eisenburg 17) of a grammar for the architectural designs of Frank LLoyd Wright, using the shape grammar tools of (Stiny 18). Here was the first example of a grammatical theory of a major class of works of artistic importance. It is a straightforward task, using a computer, to produce new Wright designs from this grammar for testing it as a theory. Similarly, the grammar can be used to analyze existing designs to elucidate their constructional history and to relate them one to another.

The pattern recognition field must thus be viewed as on the threshold of important uses in the analysis of art works. Supporting this view are already demonstrated uses of pattern recognition. Most of such uses are current subjects of research and improvement.

We may illustrate how such automatic pattern recognition works by an example. Figure 8 is a photomicrograph of some linear objects which might be marks or strokes on some medium (they actually are paper fibers). This image is the result of scanning and display with the kind of image processing technology mentioned above. We may next write schematization programs for the computer which produce the outline drawing of figure 9. We consider this image as a schematization because of the considerable information reduction achieved in going from the image of figure 8 to that of figure 9. This schematization still contains significant information about the original "strokes." For example, it can be used to study how stroke width varies. In figure 10 are shown a set of vectors (that is, lines drawn from the central axis of the strokes to the nearest edges) which give the local stroke width. We may, if we wish, synthesize a new image automatically by further schematization which replaces each stroke by one of constant width which is the average of the many widths along the stroke, as shown in figure 11. A final schematization is the result of the pattern recognition algorithm which produces the highly abstract version of the original strokes, shown in figure 12.

The pattern recognition process thus proceeds from directly sensed data about images, to successively more abstract surrogates, until ultimately the most abstract object may be assigned its own surrogate - its name. Along with the name the procedure assigns a structural analysis of how that name was determined - perhaps by a grammar.

Most of the thousand pattern recognition papers published each year treat the problem of recognizing natural objects or human artifacts in natural environments. Examples occur in medicine, in military recognition, and in industrial inspection. Relatively untouched are the problems of automatic pattern recognition of art objects. We must thus conclude that this is still an area in need of research interest. This research is likely to lead to such uses of oomputers in art history as producing schematizations, making dimensional measurements, comparing different treatments of the same subject, and plastic analysis - all automatically.

Making primary sources visible to computers can thus be seen to provide two different kinds of benefit to art historical analysis. Where image processing techniques are used, the enhancement of the data leads to deeper subsequent analysis by manual means. Where pattern recognition techniques are used, at present only rudimentary analysis is possible but it is largely automated and hence applicable to the large volume sources of primary data such as occur in photo archives.

Fortunately it is not necessary to choose between these extremes since a compromise option is available, the use of intermediate sources. It is possible to maintain some of the properties of primary sources in computer analysis of art history data, by describing the sources, in a semi-automated way, with computer graphics technology using graphic tablets, automated displays, and automated processing. The manual operations are those which require that the primary sources be sketched, traced, or diagrammed on a special tablet with a stylus that the art historian uses. This circumvents the need for automated pattern recognition by involving the art historian's perceptual, cognitive and intellectual resources in producing the graphic portrayal of an art work. Subsequent processing is entirely automatic.

We can understand how computer graphic portrayal of pictorial sources may be performed by considering an example, (Loran's 19) stylistic analysis of Cezanne's compositions which was done prior to computers. He used diagrams to express his analyses. We may perform analogous analyses by using computer graphics as the diagram medium. Figure 13 shows a drawing which has been made on a graphic tablet using one of Loran's diagrams. Although the diagram is sketched very much as it would be with an ordinary drawing instrument, in this case the computer represents the diagram as a sequence of connected straight line segments which are joined at the points marked in figure 13 by small circles. In the diagramming process, using the graphic tablet, the art historian can supply additional information based on his insights. He may be interested in a time sequence of compositional components. These are shown displayed by the computer in figure 14 which reflects the (arbitrary) sequence in which the segments were sketched in this example. The art historian may also experiment with line quality as in figure 15. Or he may further experiment with alternative compositional solutions by causing the computer to move segments about, deleting and adding at his will as in figure 16.

By using computer graphics technology in this manner, a structural analysis of the art work is provided to the computer by a semi-automated process. It is not as automated as it would be with pattern recognition methods but the depth of analysis that can be achieved is much greater. Most important, however, is the fact that an essentially pictorial data base is thus created in machine processable form.

How can such intermediate sources be used for art historical purposes? The most immediate example occurs in iconography. Often, an iconographic analysis is properly attributable to a particular object in an art work. With conventional methods, the analysis must be stored as attributed to the whole work. With the work structurally decomposed for the computer, the analysis can be stored as a property of the particular component of the art work to which it applies. For complex works, iconographic analysis of many components may be separately stored, searched for, and retrieved automatically without "overloading" the data associated with the whole art work. One can imagine the use of taxonomies like the ICONCLASS (Van de Waal 20) system being used to index individual objects in complex art works with no confusion resulting from the occurrence of very many terms in a single work. The depth of allowable indexing and subsequent retrieval on structurally analyzed art works can go far beyond that allowable in conventional data base systems.

Another virtue of using computer graphic intermediate sources of analysis is the ability to create overlays containing supplementary information. For extensively studied works like the Durer of figure 1 it is useful to associate parts of such a study with the components to which they pertain. This is immediately possible with data bases containing structural descriptions of the art works. The overlays are superimposed on the individual components providing detailed information that may be of lesser interest when viewing the whole work. Thus to "read" such an analysis, one "zooms" in and out of the work, retrieving information from the components as appropriate for the detail being viewed.

Other uses suggest themselves. For art works which have been dismembered and stored in separate locations, graphic tracing with dimensional precision can help in associating such dismembered parts of the works.

The arguments presented above are based on the assumption, shared by (Ohlgren 21), that crude images are better approximations to images than are words. Heretofore, the automatic processing of art history data and documents has largely been based on the assumption that only verbal information can be processed by computers. Since this latter assumption is demonstrably false, one is naturally led to inquire into ways that computers can process the primary and intermediate forms of image data more closely allied to art objects than are the secondary sources of purely verbal descriptions.

Much of art history research has developed about a verbal paradigm even before the onset of computers. Naturally, the first uses of computers in art history have been to accelerate such verbal analyses. But times and technology change and so should the way we look at old problems and how we choose new ones. A beginning of such change has been sketched here.

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Fig. 1 Albrecht Durer, Melencolia I, 1514, Engraving, 240 x 187 mm.

Fig. 2 Computer scanned and reproduced detail with a scanning resolution of 50 micrometers.

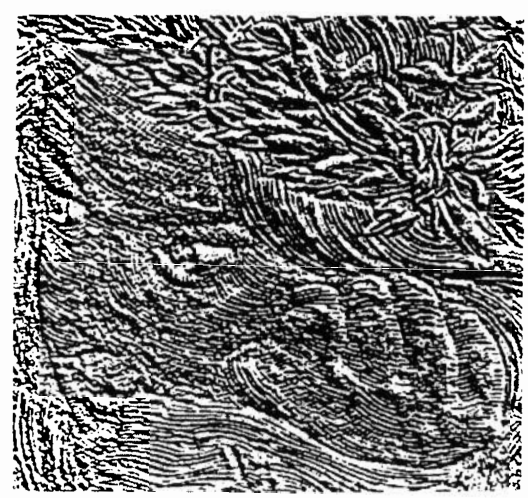

Fig. 3 Computer enhanced detail of Fig. 1 showing edge direction information.

Fig. 4 Left member of stereo photo pair of sculpture with texture superimposed.

Fig. 5 Right member of stereo photo pair of sculpture with texture superimposed.

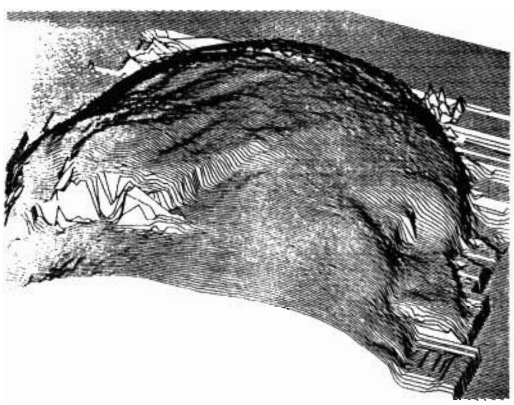

Fig. 6 Computer generated view from beneath sculpture of Fig 4-5.

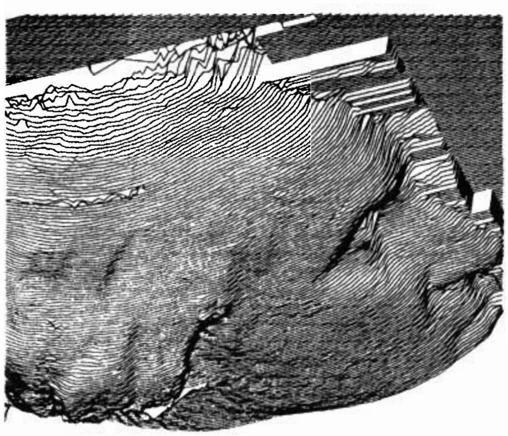

Fig. 7 Computer generated view from above sculpture of Fig 4-5.

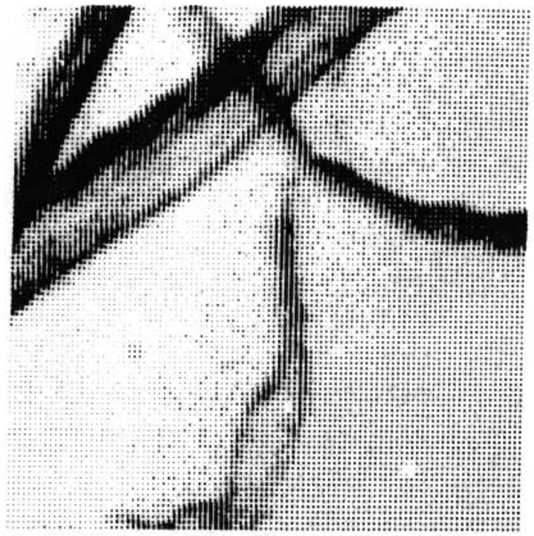

Fig. 8 Computer display of linear objects.

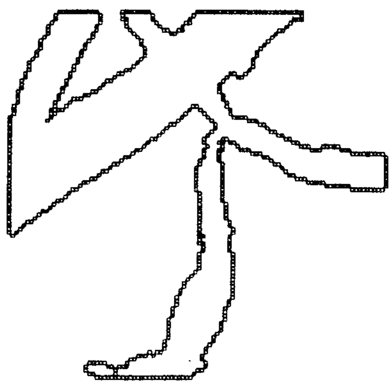

Fig. 9 Computer generated outline of Fig. 8.

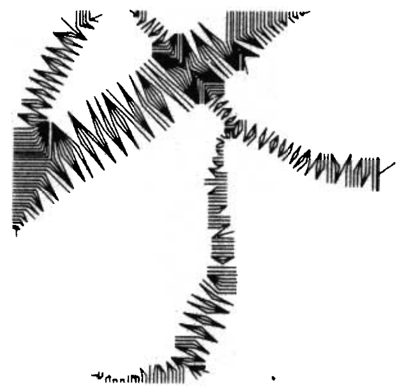

Fig. 10 Computer generated thickness vectors along strokes.

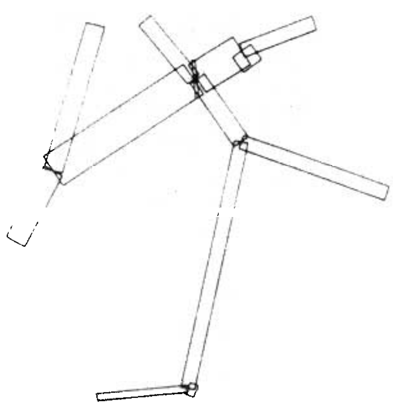

Fig. 11 Computer synthesized image with constant stroke width.

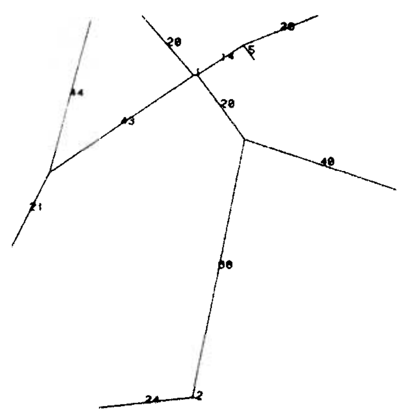

Fig. 12 Computer abstracted image from Fig. 8.

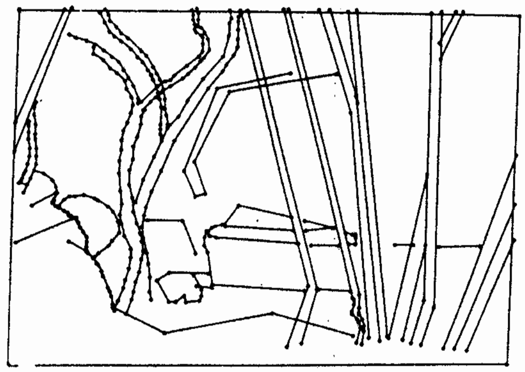

Fig. 13 Graphic tablet drawing of Loran's diagram showing tracing points.

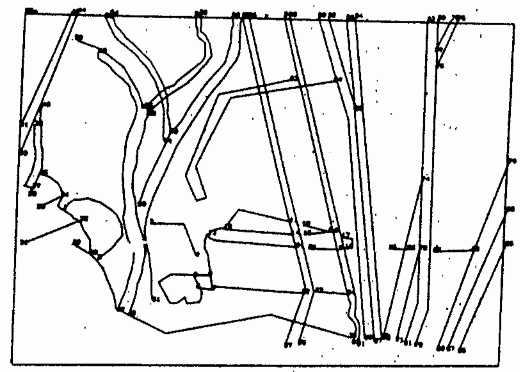

Fig. 14 Time sequence of drawing of components of Fig. 13.

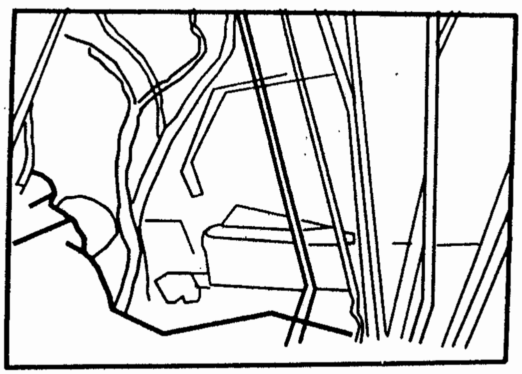

Fig. 15 Computer generated line qualities.

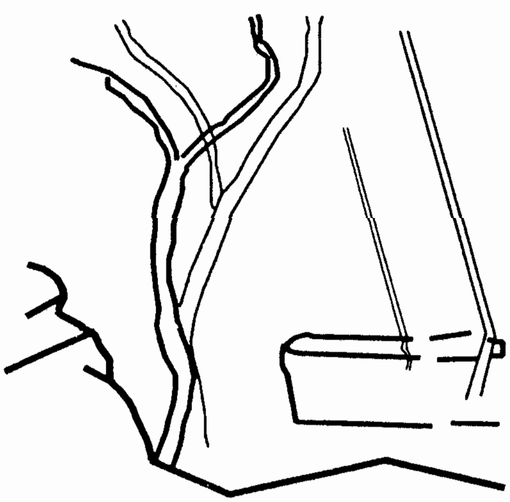

Fig. 16 Computer-aided edited version of Fig. 13.