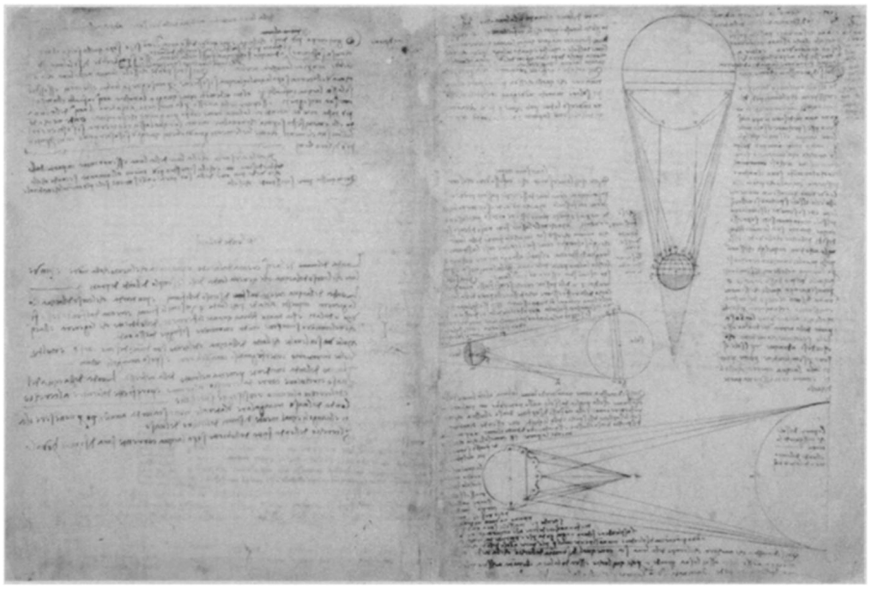
Paint by Digit

Several museums are experimenting with digital image processing to highlight slow deterioration or hidden details in artworks



Seth Joel/The Armand Hammer Foundation

This sheet, from a Leonardo da Vinci treatise, may be slowly eroding. Conservators at the Los Angeles County Museum of Art are studying methods that would reveal such subtle changes.

By IVARS PETERSON

The fragile, yellowed pages are more than 400 years old. The writing and drawings are Leonardo da Vinci's. Suspended from silk tabs within the space between two thin Plexiglas sheets, the pages of Leonardo's treatise on water and astronomy are now on public display.

The sealed pages appear to be protected, but conservators at the Los Angeles County Museum of Art are worried. Within each sealed plastic envelope, tiny breezes swirl around the manuscript pages in response to outside temperature and humidity changes. In subtle ways, the pages warp, buckle and rub against the Plexiglas. Could the manuscript surfaces slowly be rubbing away?

The answer may lie in space-age technology, in digital image processing originally developed to bring out details in pictures taken by space probes. Museum conservators and scientists from the nearby Jet Propulsion Laboratory are in the middle of a study of the usefulness of this technique for detecting very slow, destructive changes that occur in paper as a result of responses to the environment. This project is one of several examples of the recent use of image processing in art analysis. These applications include studies of artists' techniques, the monitoring of the slow fading of colors, and the separation of superimposed images in X-ray photographs of oil paintings.

The first step in processing an image is to break it up into picture elements or "pixels." An instrument scans a black-and-white photograph and assigns a brightness level to each pixel. On a scale from zero to 255, zero represents black and 255 is white, and all the other numbers represent shades of gray. In contrast, the human eye can differentiate only about 40 levels of gray. The digitization process turns a picture into a sequence of numbers that can be fed into a computer and stored or manipulated. A typical image, 1,024 pixels across and 1,024 pixels down, comprises more than 1 million individual numbers.

Computer programs alter an image's features by manipulating these numbers according to complicated mathematical formulas. These programs were developed at the Jet Propulsion Laboratory during the last 20 years for deep-space photographic missions. Preliminary processing steps include "contrast enhancement of pictures to optimize their appearance to the eye and to take advantage of the full range of gray levels," says David Glackin, a JPL astronomer who has participated in several art analysis projects. Other programs can correct gray-level differences when two separate images are being matched, or can simplify complicated pictures by subtracting distracting features. Then the new numbers can be converted back into a picture on a video screen or printer.

Experts evaluate each processing step. James R. Druzik, a paper conservation expert at the Los Angeles County Museum of Art, is one of those who sets the goals and determines the significance of each stage in the process. Druzik illustrates: "We would look at the results and say, 'Yes, that does show more about what we think is there, but can you do a linear stretch or can you display the kind of information over there a little bit better?' " Often, a project can take months of "rather intensive tinkering" before the correct combination of contrast and spatial filters provides an image that is acceptable, says Glackin.

In the case of the Leonardo treatise, now called the *Codex Hammer,* the investigators are interested in detecting changes in the paper's surface texture that could signal deterioration. "It occurred to us that one way to study this would be to do an initial documentation of the *Codex,* then to digitize those images and put them into the computer banks at the Jet Propulsion Laboratory," says William R. Leisher, head of conservation at the L.A. County Museum of Art, "then periodically go back to the documents, photograph them, digitize them and compare the various images."

To test the idea, museum personnel encapsulated some 18th century paper and for about five months put it through the most extreme changes in environment possible. Each day, two experimental sheets went through a temperature range of about 60°F and rapid humidity fluctuations. Using a light source that skimmed the surface to reveal better any surface hills and valleys, the researchers photographed these sheets before and after the experiment. "We're talking about very minute changes, changes that normally you would not detect just on a casual or even more-than-casual examination," says Leisher. "Preliminary tests show that [image processing] will probably work

well. If there are any changes, they will show up."

Glackin and his JPL colleagues are now entering the pictures into the computer. "We're going through, first, contrast enhancement and, second, some spatial filtering, which selectively cuts out or enhances features of a certain size," says Glackin. On top of that, Glackin plans to use a "fast Fourier transform" technique, which provides a plot of the frequency of occurrence of features of different sizes. Because surface features are altered over time, these plots can highlight subtle changes.

Glackin and Druzik have previous experience in studying surface texture. Earlier, they examined two different copies of a bronze sculpture by Edgar Degas. "Whenever we begin to look at the surface of three-dimensional objects, we quickly become aware that there is more detail than the human eye and brain can comprehend easily," says Druzik. "But you can digitize that information and can find similarities and distinctions, correlations and so forth." Using photographs of the Degas figure, they were able to show numerically that the earlier copy had sharper detail. Although the study revealed nothing new about the Degas sculpture, the potential of the method "to correlate vast sums of minutiae with little effort has great value," says Druzik.

The Leonardo project introduces another innovation to art image analysis. As a second source of data, JPL personnel will use a new electronic, digital camera being developed for the Galileo mission to Jupiter. "The nice thing about the CCD [charge-coupled device] camera is that the images come out in digital form," says Glackin. "You don't have to go through the intermediate step of taking pictures and digitizing those to get them in a computer. That results in some degradation."

Leisher says, "Since we've started this project, some other institutions have gotten interested in it." One is the National Archives in Washington, D.C., which is considering a contract with the Jet Propulsion Laboratory on the use of image processing to monitor the stability of preserved documents, in particular the Constitution and the Declaration of Independence.

Another project involving image processing links the Detroit Institute of Arts, the Metropolitan Museum of Art in New York and the computer science department of Wayne State University in Detroit. Maryan W. Ainsworth, an art historian at the Metropolitan Museum, is interested in drawings that lie beneath 15th and 16th century paintings from the Netherlands. These drawings were done in charcoal on a white background. Infrared light penetrates the upper layers and is absorbed by black lines and reflected by the white ground. Thus, an infrared reflectogram produces an image of the drawing.

"What the computer linkup will do for us is simply to clear up the image," says Ainsworth. "We can see the image, but... because of the thickness of paint layers on top or because of the crackle pattern in the paint layers, we can't see that particular drawing as clearly as we might." Computer programs are being developed to subtract the unwanted portions of the image.

The group at the Los Angeles County Museum of Art has already demonstrated the possibility of removing distracting patterns and separating images. They worked with a 17th century painting called *The Crucifixion*. X-ray photographs showed that an entirely different painting existed underneath, but its details were hidden. One of the first image processing tasks was to remove the grain pattern of the wood on which the work was painted. Then, by "subtracting" the information in a low-energy X-ray photograph, which showed only the top layer, from the original X-ray image, the researchers eventually produced a clear image of the hidden painting.

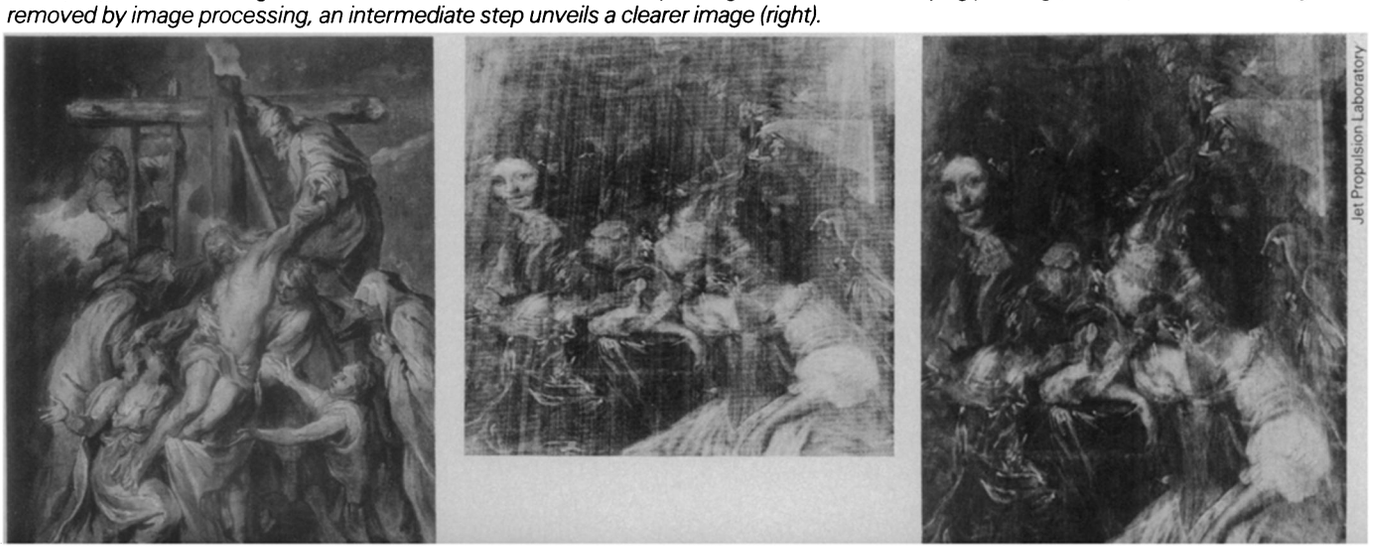
The infrared reflectography group has not yet applied these techniques to images of drawings, but this month they expect to start using computer processing to solve another problem. The infrared camera used to make reflectograms can scan only a small area of a painting at a time. Thus, many photographs have to be spliced together to make up the full picture. Unfortunately, the result looks like a mosaic because gray levels don't match exactly and individual photographs may have slightly different magnifications. Gary W. Carriveau, senior research scientist at the Detroit Institute of Arts, says, "With the computer program we've developed, we've been able to eliminate this distracting mosaic effect."

Despite the expense of image processing, applications to the arts are expanding. Researchers at the National Gallery in London are using image processing as an objective color measurement method to document the fading of paintings. Druzik says, "The biggest value of digital image processing in the future is in monitoring aging with great analytical precision. There's a lot we can do to correct problems if they are found in time, like making a subtle humidity adjustment or deciding whether certain paintings can travel to other museums or countries."

Carriveau speculates that in the future researchers may be able to quantify artists' techniques by looking at brushstrokes or other characteristics. This could be useful in detecting forgeries or in deciding who created a particular painting, he says. His project with Wayne State University is an attempt to keep the cost of computing as low as possible by developing programs for small, inexpensive computers. Carriveau sees the possibility of a national center for computer image processing, to which museum and gallery personnel could go for help in solving art analysis problems.

Digital image processing is new to the arts. The first results have appeared only in the last year. "This is very much an interdisciplinary technique," says Carriveau. "An image-processing expert could spend days, weeks or even months processing a photograph or an image, and unless he's directed as to what to look for, it would be pretty much a waste of time. There has to be a strong interaction between the art expert and the image-processing expert." □

X-ray photography shows a completely different painting beneath The Crucifixion, *a 17th century oil painting by an unknown Flemish artist (left), but the wood grain and elements from* The Crucifixion *painting obscure the underlying painting (center). With the wood grain removed by image processing, an intermediate step unveils a clearer image (right).*



Jet Propulsion Laboratory