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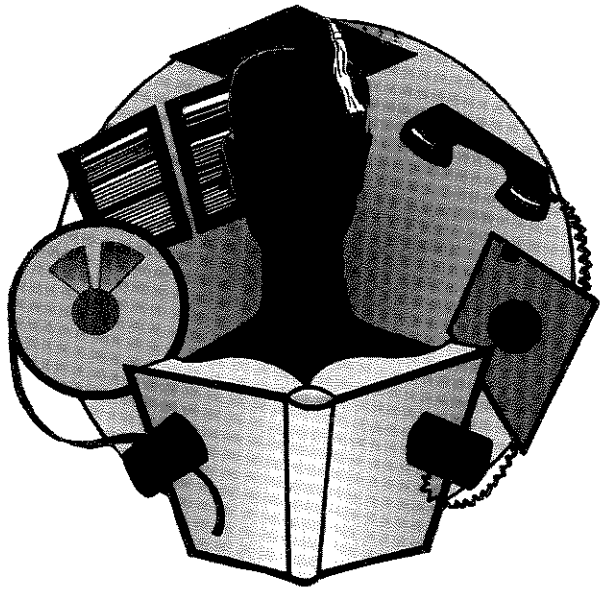
Computer Images for Research, Teaching, and Publication in Art History and Related Disciplines

Charles S. Rhyne



January 1996

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Computer Images for Research, Teaching, and Publication in Art History and Related Disciplines

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January 1996

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The full article will include sections examining the wider availability of digital images, the ways in which digital images will be less or more expensive, and the uses of computer modeling and image modification.

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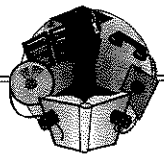
In the conclusion to a recent article on digital images, world expert Michael Ester writes: "No one is asking about, let alone implementing, models of use that are sympathetic with the way professionals work."[1] Without making such an exclusive claim, this article explores such uses for research, teaching, and publication in art history and related disciplines.[2]



The Need for Scholars to Participate

The future of digital imagery has emerged as one of the central concerns of professionals in many fields. International conferences have been held and international commissions organized to examine the role of computer images and to establish standards for their use.[3] Yet these discussions are being carried on predominantly by specialists in computer technology, visual and media resources, and information management. Relatively few scholars have informed themselves sufficiently to contribute to the discussion. . . .

Certainly only a handful of art historians have taken advantage of the profession's unique expertise in the reading and interpretation of images.[4] As a profession, we have a great deal to contribute and a great deal to lose if we remain outside the debate. We cannot assume that the central role visual images play in our work will be fully understood by others or that the characteristics of visual images that matter most in the study of art will be valued by others. We cannot be sure that others will recognize so fully the importance of studying images through a process of free exploration, coming back from time to time to reexplore the same image differently. Others may not understand our need for examining hundreds of tiny details and of relating these to the overall experience of an object. Nor can we assume that others will have worked as fluidly as art historians with the relationships among images, formulating ideas as we browse large numbers of photographs, slides, and reproductions in books, always open to discoveries from unexpected juxtapositions.

Art historians have a critical role to play. Among the diverse disciplines at American colleges and universities, art history is by far the heaviest user of images. . . . In conducting research, art historians browse photographs, slides, reproductions in books, and other images as avidly as statisticians study numbers or literary critics read text. The number of 35mm slides checked out and refiled every day in a major university slide library is astonishing to anyone who has not witnessed such an operation.[5] More importantly, art history presses the demand for image quality more insistently than any other discipline. For the great majority of art historians, who consider the visual experience of the work of art an essential part of its study, no image can fully satisfy. We always wish that we, our students, and our readers were looking instead at the work of art itself. Therefore, no matter how excellent the computer image, we always wish the color were more accurate and the resolution more detailed; not to mention that the size, texture, and opacity of art can rarely be approximated in a computer image.

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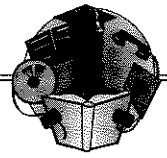
The types of digital images needed for research, publication and teaching in art history should increasingly benefit scholars and students in other disciplines. For more than a decade,

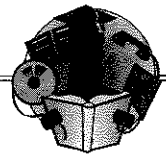
slide librarians have reported that the single most significant change in the operation of their collections has been the number of non-art faculty making regular use of slides. In recent years, other disciplines have drawn on works of art, not merely as illustrations but as subject matter for investigation. As they become more involved in the study of art, professionals in other disciplines are gradually discovering the integral nature of works of art. They are recognizing that whatever aspect of the work especially interests them can easily be misinterpreted if studied apart from other aspects of the art and its overall expressive meaning or without regard for related objects. Thus, the need for large archives of images of works of art and for the most complete, detailed and accurate images possible is increasingly recognized by scholars in many disciplines as a necessity for their research and teaching.

At the same time, other disciplines, especially the sciences, are developing their own uses for digital imagery, which can sometimes be applied to study in the humanities. The overlap has been most significant in conservation laboratories, where materials scientists are often part of the professional staff, and where the detailed, systematic study of objects embraces scientific procedure. . . .



Rapidly Changing Technology and Cost/ Long-Term Scholarly Objectives

Important as the capability and cost of available computer technology is at the time decisions must be made, these are short-term decisions about what should be seen as the means to various scholarly and educational ends. In my view they have had too controlling an effect on the direction digital image projects have taken. It seems likely that some computer equipment currently being purchased by American colleges and universities will sit underused when it is discovered that the imagined use would be impractical or educationally counterproductive, or worse yet will be pressed into service despite the educational consequences. More subversively, perhaps, projects which do have serious intellectual purpose take form too unthinkingly within the parameters of available technology. Too often we allow ourselves to be captive, even in our thinking, to technology and budgets, as if they were in the nature of things rather than evolving conditions that we might influence. Whereas new, improved computer products appear constantly and are rapidly upgraded, research and teaching goals evolve slowly, based on successful approaches currently in use. It is not a natural fit. The challenge is to be open to the dramatic new possibilities of digital imagery without being misled by unrestrained enthusiasm for the new technology. This requires above all that we have a firm grounding in our disciplines and a long-term view of what we hope to accomplish in our research, teaching and in the broader dissemination of information and ideas.



Potential Values of Computer Images

What types of digital images would be of most value for research, teaching, and dissemination in art history and related disciplines? This is the central question addressed in this article. A brief answer might be "whatever types would provide the most significant advantages over types of images currently in use," that is, photographs, slides, and reproductions in books and magazines. As we shall see, there are ways in which digital images are distinctly inferior to traditional types of images; but there are also ways in

which, if properly developed, digital imagery offers the potential for research, teaching and dissemination at a level currently almost unimaginable. . . .

Very few of these improved images would be of types now unfamiliar to us; but so many new images could be available, to so many more people, so accessibly, at so little cost, and with a quality and detail of reproduction allowing personal, detailed exploration and manipulation now rarely possible, that the study of art would be transformed. Images would take their rightful place as essential evidence in all of the humanities, and the visual arts would become a more central aspect of our common culture.

Because the potential advantages of digital imagery are interdependent, it is somewhat artificial to discuss them individually, but it will help to identify the several ways in which computer imagery must be developed if these potential advantages are to be realized. This interdependence, the varying uses to which images are put, differing views of what is of value in the world of art, and the impossibility of predicting future developments, make it unreasonable to suggest more than the most hypothetical order of importance for the potential advantages here discussed. At most, the order below serves only to call attention to the almost inverse relationship between the types of computer images and uses receiving the most commercial and journalistic attention and those that may have the most long-term potential for contributing to our understanding of the world's art.

Immense Number of New Images

Because books and magazines are filled with images of so many different works of art, it is not generally realized that most of the world's art has never been photographed, let alone digitized. One sees images of the same paintings, drawings, sculptures, architecture, and other works of art over and over again, and the most famous of these are, of course, the works that are appearing first on commercial compact disks, usually CD-ROMs.[6] Even the largest photo archives for art history research are highly selective, largely dependent on suppliers, and unable to keep pace with the modern discovery and restoration of older art, much less the creation of new. Museum collections, the most accessible and professionally supervised repositories of art, have rarely been completely photographed and in most cases only on black-white film. Untold numbers of unphotographed objects reside in museum storage and in print and drawing rooms. Only occasional manuscripts housed in vast storehouses such as the Vatican Library have been photographed.

Within the world of architecture, only the most famous buildings have been photographed at all comprehensively; this is even more true with vernacular architecture and industrial archaeology. Likewise with sculpture, only the masterpieces of world art have been photographed from a sufficient number of angles to support detailed study, many photographs of sculpture are not in color, and less famous sculpture and tribal objects are photographed inadequately or not at all.

In class, intelligent students regularly ask questions that cannot be answered on the basis of available slides or reproductions. For students and scholars wishing to study a work of art in depth, the lack of adequate slides and reproductions in books, even of photographs in photo archives, quickly becomes apparent. Of course, for such study one must travel to see the object firsthand, but one cannot return to Berlin or Bombay every time one has a new question about a work of art. Unless one has photographed a work of art thoroughly while on site, there will almost always be major unanswered questions. Moreover, some museums deny photographic rights even to scholars, and it is not possible to take paintings off the wall, much less out of their frames, or to remove sculptures from their cases, except in rare circumstances. Being on site does not make it possible to see a building in its partially ruined condition before it was reconstructed or to erect scaffolding to examine upper sections of the present facade. In all of these ways, one is dependent on photographs, in most cases nonexistent.

Within the world of scholarship, studies of art are increasingly based on everyday images, costume and material culture, on tribal art housed in museums of natural history or ceremonial objects in use, on temporary outdoor sculpture, on famous works of art in previous conditions or as previously displayed, on all the paintings exhibited at landmark exhibitions, and on utilitarian structures, vernacular architecture, and urban districts. Most of these have not been adequately recorded.

The appearance of digital imagery has coincided with a recognition of the need for images of these disparate and previously undervalued forms of art, for adequate details of traditional art, and for images of art as it has changed and is changing physically over time. Most influentially, the digital revolution has coincided with an increased demand for public access. As a result, a number of major public museums have undertaken digital image projects aimed at photographing or rephotographing nearly their entire collections and making them available through digital imagery.[7] . . .

A closely related and more obvious potential advantage of digital imagery is the wider public availability of the massive numbers of already existing images. But it may eventually be in the seemingly prosaic provision of an immense number of new, higher quality images, not entirely dependent on but stimulated by the new technology, that digital imagery makes its most significant contribution. . . .

Greater Quality and Fidelity

No potential of digital imagery is more unrecognized and undervalued than fidelity to the appearance of the original works of art, yet none carries more promise for transforming the study of art. Why is fidelity so crucial? It is a matter of historical accuracy and responsibility to evidence, at base perhaps a matter of ethics. If we claim to be recording an important object created by another human being, let the image look as nearly as possible like that object and not some aberrant version. If we wish students to experience the visual character of an object, to explore for themselves how the forms, colors, and textures interpret the subject depicted, let them experience an image of the object that is as accurate as possible. And if we wish to convey to others our understanding of these complex cultural artifacts, let those who hear and read our words have the opportunity to form their own judgments as we have, based, if not on first-hand experience of the original, at least on the most accurate possible images. The history of art is too often the history of slides and reproductions. Let us at least do what we can to make the one approximate the other.

With each jump in quality, new uses become possible. Most of the images of art available on CD-ROMs, on institutional file servers, and over the internet are adequate only for identification. They tell us what objects are available at a given museum, which objects were included in the lectures for a class, and they provide illustrations for accompanying texts. . . . These delivery mechanisms are making possible a revolution in public access to images. However, in terms of quality, most serve only as substitutes for run-of-the mill reproductions in books and are not even as informative as the photographs and slides they often replace. Even in terms of identification, one would not want to rely on these images to distinguish between a work of art and a copy of it.

With images of somewhat higher quality, color becomes more reliable and one can begin to see details with some clarity. When displayed on a large video monitor or projected, such images seem to serve adequately for discussion in grade or high school classes where student participation and ease and speed of manipulation might be valued more highly than fidelity to object.[8] Museums that have made available CD-ROMs with digital images of their collections, even when produced only at this moderate level of quality, have contributed to the public interest in art. Images of this moderate quality might be acceptable also on CD-ROMs that discuss social history or other subjects that do not encourage response to the visual qualities of art. In all of these cases, however, the unity and overall impact of a work of art is being

sacrificed for a simple reading of surface information, and the opportunity for the viewer to discover an inspiring work of art is compromised. . . .

What has been overlooked in most discussions of digital imagery is the immense potential of high quality images. Because these are currently expensive to produce, require an amount of memory available only to well-funded projects, would overload the internet if distributed in significant numbers, and because owners of these works of art and transparencies fear the commercial exploitation of their property, . . . too few of us have even experienced high quality digital images of art; and I have read nothing that explains how research, teaching, and the dissemination of information and ideas would be transformed if high quality images were available.

Quite the contrary, moderate degrees of detail and color fidelity are being proposed as international standards and recommended by even the finest producers of CD-ROMs,[9] partly for the practical reasons mentioned previously, but also because the immense potential of high quality images has yet to be recognized. Because carefully conducted studies show that, when looking at digital images on computer monitors, human beings cannot distinguish between images with high resolutions and those with moderate resolutions,[10] the conclusion is easily reached that extremely high resolutions are unnecessary, useful only for printing high-quality commercial advertisements and glossy annual reports to stockholders. . . . This conclusion is reinforced by the fact that computer monitors currently available cannot display the full amount of detail and color fidelity recorded in extremely high quality digital images; thus an extremely high resolution digital record appears no better on the computer monitor than a record with moderate resolution.

But this is true only when looking at the full digital image. As soon as one zooms in to enlarge details, the moderate quality image pixelates, whereas the high quality image allows one to move in and examine details with clarity. With images recorded at extremely high resolution one can zoom in amazingly far to examine the construction of an arch, the way a painter has varied brush strokes to convey different surfaces and materials, and to read inscriptions and the text on medieval manuscripts.[11] The relevance of studies demonstrating the limits of human perception largely disappears once one recognizes the capacity of computer imagery to approximate the normal process by which people move back and forth between viewing the overall work of art and exploring it in detail. The limits of human perception are largely irrelevant also for machine analysis of images, so essential if we are to develop image-searching comparable to text-searching, surely one of the most useful functions of computers.

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If there is a central pedagogical point to be made regarding the use of digital imagery, it is that the best teaching, like the best research, requires free exploration. One does not examine art just to answer prescribed questions. . . . We cannot foresee what we as scholars will discover or what a student will find of interest. What are the figures in the background doing? How is the woman's hair braided? What is holding up the sculpture? How is the reflection in the mirror painted? What is on top of the building? What is the expression on that person's face? What does the inscription say? To answer such questions we need very high resolution images and the ability to zoom in to examine details. Moreover, we need to be able to do this in a manner approximating as closely as possible the way in which we, quite naturally, examine works of art. We need to be able to move in smoothly, not jump from the overall image to a close up, then another. We need to be able to scroll from side to side smoothly at whatever speed we choose. . . .

More demanding of course is the need for images of three-dimensional objects, sculpture and architecture. Here, in addition to the types of exploration desirable for studying paintings and other relatively flat objects, we should like to be able to move around three dimensional objects and, for architecture, also within its spaces. As with paintings, we should like to be

able to do this at our own pace (not viewing a film), following our own patch and looking in whatever direction we wish. And we should like to be able to move up close to examine details of whatever catches our attention. Although still at a primitive stage of development, these types of visualization already exist and need only to be developed in ways that will allow us to explore sculpture and architecture as freely, in as much detail, and with as much fidelity to the original objects as possible. . . .

This article deals almost exclusively with images of works of art and other objects as they are seen in the real world. These include images made from drawings or prints of maps, charts, and other types of diagrams. But there are also maps, charts, diagrams, etc. that are created in the computer. Here there is no real-life object against which to test the fidelity of the image, and one judges the image rather by its fidelity to the concept one is attempting to diagram, as well as by its clarity and, often of great importance, the ease with which the diagrams can be manipulated to test complex alternatives. For example, biologists regularly use digital imagery of the real world, usually microscopic, whereas chemists almost always work with models of structures created in the computer, which can then be manipulated in complex ways. Although art historians and other humanists predominantly use images of the real world, including ground plans and elevations of architecture taken from real-life drawings or prints, we are learning to make use of the programs so heavily used by architects for creating three-dimensional drawings within the computer, which can then be manipulated (computer aided design or CAD).

In the process of producing computer images, the weakest link in the chain determines the quality of what we see. It is true that certain corrections can be made to a slide or transparency that is underexposed or in other ways misrepresents the work of art depicted. For the most part, however, any inadequacies in the conditions under which a work of art was photographed, any inadequacies in the camera lens, in the grain or color fidelity of the film, in the angle or exposure of the slide or transparency, in the development of the film, in the scanning of the image, in its manipulation within the computer, in its archival storage, in its compression for any particular use, or in its display on a computer monitor or projection on a screen will show themselves in the image we see. It is essential, therefore, if we care about the fidelity of the final image, that we attend to each step in the process.

In terms of quality, the most important part of the process remains that which precedes use of the computer, the remarkable ability of film to record detail with extraordinary precision and accuracy. (The remarkable exception of direct digital capture in conservation laboratories is discussed at the end of this section.) Even the highest resolution computer imagery based on film cannot capture this remarkable detail. Somehow this still surprises people, although it should be obvious that a copy can be no more accurate than the original against which its accuracy is being judged. It is easy enough to confirm this. Have a high quality, original 35mm slide of a detailed painting digitized at extremely high resolution by the finest professional lab. Then view this digitized image on a very high quality computer monitor, zooming in to enlarge details of a face or pattern in the floor. If we then examine these same details in the 35mm slide itself with a standard 8x lupe, we will find that we can see the details a little more precisely in the slide. Lines are a bit sharper; the distinctions between one form and another are a bit clearer; colors are a bit more distinct. Preserved on those remarkable pieces of film, the images only 35mm in length (less than 1 ½ inches), are the most amazingly accurate, detailed records of the world's art, made possible by the miracle of photography. Moreover, we have more confidence in the reliability of the slide for recording the appearance of the work of art, because it has not gone through an additional process of duplication.

The quality of the original slide or transparency depends to a great extent on the ability of the photographer. Likewise, the scanning of the slide into a digitized format is not simply a mechanical operation but depends on the skill and understanding of the person carrying out the process, and even a perfectly digitized image can be distorted through inept manipulation. In everything to do with computers, there is a naive trust in technology. For example, it is reg-

ularly said that, unlike duplicating a slide or transparency, copying a digital record produces an exact replica, even to the tenth or hundredth generation. Conceptually, this may be true, but even this is vulnerable to deterioration of material, machine malfunction, or human error.

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I have been using the terms quality and fidelity almost interchangeably. But of course what one means by quality varies according to what one values in an image. If one is attempting to sell posters illustrating a work of art, quality may lie in the image's beauty or commercial appeal. But when one is conducting historical research or discussing a work of art in class, we would always prefer to be looking at the work of art itself (assuming one is really studying the art rather than something else). Hence, as historical documents, images of art are valued to the extent that they approximate what one would see if looking at the work of art.[12]

Such a standard is exceedingly complex. Not only can the image never match the appearance of the original work of art, but there are a variety of ways in which this is true, and in each of these ways there will be different degrees in which an image will approximate the appearance of the object it depicts. Moreover, what constitutes the appearance of the original is variable, and human perception is not a static process. It is clear that there are immense differences between our viewing of an original work of art and our viewing of its digital image on a computer monitor. Nevertheless, while recognizing these differences, fidelity to the appearance of the original work of art remains the overall standard we attempt to approximate, and taking these photographs under selective or controlled conditions which we record can help us more nearly to achieve this.

Because cameras commercially available for direct digital capture are designed for speed and ease of use and therefore produce very low resolution images, it is easy to suppose that direct capture is inherently inferior to images digitized from high quality transparencies. Especially where one begins with a 4 x 5 inch, or even better an 8 x 10 inch original color transparency, which is then digitized by a top quality professional lab at very high resolution, the digital image can be remarkably true to the work of art it represents. But zooming in to examine details, one eventually discovers that the brushstrokes with which an eye is painted or the knife marks with which a nose is carved are less clear than if one is looking at the work of art itself. Amazingly, in the very highest quality direct digital capture in conservation laboratories, one can see these brush strokes and knife marks not only as sharply as in the original object but as if looking through a magnifying glass. This process is normally used for technical studies, not the normal viewing of works of art, and so is discussed only briefly here. It requires complex, extremely expensive, custom designed equipment, available in only a few conservation laboratories in the world—and on space shuttles.

But we should note that digital images of works of art with spectacular accuracy and detail are already possible. Methods of direct capture have been developed in three conservation laboratories, each method emphasizing a different aspect of fidelity. One approach emphasizes the recording of surface characteristics in such detail that one can compare two different digital images of a hairline crack in a paint surface to see if it has widened even minutely.[13] A second emphasizes the recording of color so carefully calibrated that one can detect infinitesimal color change over time.[14] The third emphasizes recording of three-dimensionality so that even slight changes in three-dimensionality are noted.[15] Although these procedures have been developed for technical study beyond the range of normal human vision and therefore have highly specialized uses, it is not unreasonable to hope for vastly improved digital imagery for normal viewing that has profited from these laboratory developments. The standard to which we should aspire for digital images of works of art is one that would allow us to zoom in on the computer screen to see details of works of art at life size with as nearly as

possible the same amount of detail visible as one could see if viewing the original object under museum conditions.

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Easier and Faster Access

In comparing the ease and speed of access to digital images with access to slides or illustrations in books, it is important to think in practical terms about the various uses to which images of art are put in a typical class. Images are browsed in large numbers by faculty and teaching assistants in preparation for classes. Images selected are then studied in detail. Some are assigned for student study in preparation for class. During lectures, student reports and class discussion, images are usually projected, but occasionally viewed on video or computer monitors, and in small seminars sometimes in books. Images are reviewed after classes and in preparation for exams. During research for class reports and papers, students browse images in large numbers, studying key images in detail and reproducing those discussed in their research papers.

These images are drawn from a number of sources. Students have typically been limited largely to reproductions in books and magazines or to photographs posted for specific classes. At some institutions, lecture slides are made available for review and identification after each class. When preparing class reports, students often have some access to institutional slide collections. Faculty and teaching assistants typically make heavy use of institutional slide collections and, where they are available, of photographic archives. Some faculty draw heavily on their personal slide collections.

For which of these uses might digital images provide easier or faster access? For browsing large numbers of slides in preparation for class, it seems clear that being able to call up images on a computer screen could be immensely faster and, especially in the convenience of one's office, immensely more convenient than pulling slides from cabinets in the slide room. However, until all the usable slides in the slide collection are digitized, one would run the risk of missing key images, and even if the images were put on at relatively high resolution one would not be able to study the slides in as much detail as with an 8x lupe, though surely with less eye strain. Moreover, in spite of the much heralded ability to tile many images on a computer screen, if one were examining a sizable number of images, these would become crowded more quickly than on a slide room light table. Under ideal conditions, however, with images of all usable slides available at extremely high resolution and with near-immediate computer response, the ease of accessing the images, enlarging them and zooming in to examine details would far outweigh the current advantages of the traditional slide room. One must add, however, that until reliable and high quality computer projection is available in classrooms, the slides would still have to be pulled and some of those chosen might be checked out or missing.

The potential advantages of assigning computer images instead of reproductions in books for class preparation depends on the availability of specific images and their comparative quality. For class preparation, one needs images of specific works of art and images that record specific types of information about them, and because these are to be studied with some care, one needs the highest quality available. For smaller classes, one would presumably assign whichever images best serve the purposes of the assignment, drawing both on computer and printed images. In large classes, where expensive art books cannot be assigned for study, computer images offer, for the first time, the possibility of assigning high quality color images for student study. This one use of digital imagery could transform the study of art in large introductory classes. It is hard to imagine a more immediate benefit to the study of art history at undergraduate institutions than the acquisition of very high quality digital images of the art studied in large introductory classes, loading them onto institutional servers, and making the images available to students on large, high quality monitors.

The projection of digital images of art for lectures currently offers no educational advantage over slide projection. The technology for projecting digital images with acceptable quality for art history lectures is available only at extreme cost and with a technician available to tune the projector at frequent intervals. Even then, the possibility that projector malfunction might scuttle an entire lecture is enough of a threat to discourage any lecturer, not forced by administrative decree, from giving up the relatively secure, field-tested, use of slide projectors. Eventually, digital projection will be equally reliable and, at that point, will eliminate the time consuming job of pulling and refiling slides.

Discussion classes and seminars are another matter. There are innumerable times when a different work of art, sometimes from a previous meeting of the class, or a different view of the work under discussion would provide exactly the evidence necessary for a question asked or the point under debate. Even where the slide room and classroom are adjoining, the time necessary to locate and pull the crucial slide would cause too severe a break in the discussion so one does without. If the projector were linked to the slide room server, one could project such images almost at a moment's notice. For this reason, if not for lectures, digital projectors will eventually facilitate the serious study of art.

For class review and exam preparation, the convenience of viewing a large number of images with accompanying identifications instead of turning through a shelf of books offers obvious advantages, not to mention the ease of reviewing in one's dorm room or apartment. For text, paperbacks offer the advantage of reading in the bus or under a tree, but high quality reproductions appear in large, expensive books, and must normally be studied in the library. Digitizing the majority of slides in a typical university slide library is such an extended project that current technology will almost certainly be superseded before such projects can be finished. On the other hand, digitizing the images necessary for individual courses is manageable and has immediate use for student review.

For research, and to a lesser extent for class preparation and other study, reproductions in books offer the fundamental advantage of context. Each image of a work of art is surrounded by images of other related works, by diagrams, descriptive text, historical narrative or theoretical argument, and by a bibliography and index. Short of putting all of this on the computer, the importance of digital images for research depends on the availability of images that are different or of higher quality than those in books and slides, on the speed with which images can be put on the internet in contrast to the slow pace of publication, and, for some research, on the ease with which computer images can be manipulated.

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The Permanence of Digitized Information

We have gradually come to realize that the much publicized claim that information stored in digital electronic form is permanent needs major qualification. The digital concept is indeed permanent, based as it is on the absolutely clear and invariable distinction between zero and one. However, all information created by human beings can be saved only in the minds of living humans or as part of some material object, and both of these are subject to change and destruction.

Nevertheless, digital records do have a number of characteristics which, in some ways at least, make them more useful for the permanent recording of images than any previous means. One of these is the remarkable fact that, unlike all previous means of preserving images, digital records do not gradually deteriorate. Even reading a CD-ROM many times does not shorten its life, because the laser used in a CD-ROM drive is very low power and does not harm the disk. If the digital record survives, it remains exactly as originally recorded. This means that, for the first time in human history, we can make reasonably accurate comparisons between the appearance of works of art at different times. This is most unprecedented in the recording of

color. Because color fades in all objects (amazingly fast in watercolors, amazingly slowly in glazed ceramics), all previous comparisons have depended on images that had faded in different degrees. With digital imagery, this is no longer the case.

Equally remarkable is the fact that digital records can be copied over and over again without the gradual image deterioration characteristic of photographic copies. If there is no flaw in the process, the hundredth digital copy is identical to the original. . . .

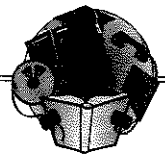
Like very high quality color transparencies, high quality digital imagery offers the possibility of making images of works of art available for some uses in cases where the original works of art are themselves highly impermanent or, as in the case of medieval manuscripts where the pages must be turned, are easily damaged by use.

There is the additional virtue that images can be projected digitally for long periods without damaging the digital record. Although teachers seldom pay attention to this unless it is their own research slides, projection causes fading of color slides, in the case of some color film distressingly quickly.[16] For those who take pride in projecting high quality, original color slides, especially when class discussion turns on the visual appearance of the art, the prospect of being able to leave a high quality image on the screen for ten or fifteen minutes while the artist's account of the work or a later critic's comments are being debated is inviting in the extreme.

Set against these remarkable characteristics are the realities of the material world and human behavior. There are different types of CDs, some produced by several different manufacturers. They vary in the materials out of which they are made, in their methods of construction, and in the quality of both materials and process. Estimates vary widely concerning their usable life spans. In contrast to photographs, slides, and color transparencies, which one can observe gradually fading and thereby decide whether or not to copy and at what point, digital records completely stop working without notice. Moreover, digital images can be viewed only if the necessary equipment and computer programs are available. Unlike slides and transparencies, they cannot be held up to the light and viewed, however imperfectly. And CDs are easily damaged. . . .

Of more concern than the impermanence of the physical objects on which digital images are recorded is the impermanence of the formats in which they are recorded and the systems for reading them. Given the relative infancy of the digital language, the inexorable march of technology, and the now obvious rewards for anyone who invents a dramatically improved format or system, it seems clear that new digital formats will replace those now in use and new systems be developed.

It may even be that some as-yet unimagined form of image recording will replace the digital language. It is unlikely that many institutions will preserve not only their earlier digital records but also the accompanying computer equipment, operating systems, system software, spare parts, and instruction manuals. Therefore, at the very least, digital records will need to be recopied at regular intervals and transposed into new formats as they become available. At each stage there is the possibility that some types of information will be altered or lost. Therefore, it is important that all digital image records be stored in multiple forms, especially in ones that seem likely to allow for transposition to new formats and new systems.[17]



Endnotes

1 Michael Ester, "Digital Images in the Context of Visual Collections and Scholarship," *Visual Resources,* X, 1 (1994), p. 23. In this article, Ester provides the defining formulation for any consideration of the use of digital images for scholarship in the arts. For a previous warning about the complex interface between art historical research and electronic imaging, see Marilyn Schmitt, "Art Historians and the Computer: The Context for Electronic Imaging," *EVA '92: Electronic Imaging and the Visual Arts: Conference Proceedings* (London: National Gallery, 1992). See also Howard Besser and Jennifer Trant, *Introduction to Imaging: Issues in Constructing an Image Database* (Santa Monica, CA: Getty Art History Information Program, 1995); available also on the internet (http://www.ahip.getty.edu/intro_imaging/home.html); and *Visual Resources* (X, 1, 1994), ed. Christine L. Sundt.

2 This article is heavily dependent on information and ideas already published by others, on notices, images and discussions posted on the computer internet, and on conversations with experts who have already implemented the use of digital imagery at their institutions, a number of whom have been kind enough to demonstrate their systems for me. . . . I am especially in debt to the editors and authors of two journals that comprehend the field with professional standards: *Computers and the History of Art* and *Visual Resources.* I also thank Christine Sundt, Curator of Slides and Photographs in the Architecture and Allied Arts Library at the University of Oregon; Marianne Colgrove, Associate Director, Computing and Information Services at Reed College; Dr. Linda Mantel, Dean of the Faculty and Professor of Biology; and Martin Ringle, Associate Dean and Director of Computing and Information Services.

3 A list of available reports and specialized studies can be obtained from the Commission on Preservation and Access, 1400 16th St., NW, Suite 740, Washington, DC 20036-2217 (AMathews@cpa.org).

Of special note have been the heroic efforts of the Getty Art History Information Program (AHIP), in collaboration with other institutions, to establish international standards and practices in the visual arts and humanities. Without these it would be impossible to document, store, access, and share the increasing overload of textural and visual information in the modern world. These multifaceted initiatives are described on AHIP's world-wide web site (http://www.ahip.getty.edu/ahip/home.html).

4 Prominent among these has been Marilyn Aronberg Lavin, Art and Archaeology, Princeton University, who also serves as listowner for the Consortium of Art and Architectural Historians listserv (CAAH@pucc.Princeton.EDU).

Archaeologists have been more active in investigating and using digital imagery. See P.M. Dew, et al., "Illuminating Chapters in History: Computer Aided Visualization for Archaeological Reconstruction," *Papers Presented at the World Archaeological Congress WAC2, Barquisimeto, Venezuela, September 1990,* ed. P. Reilly and S. Rahtz, *Science and Archaeology,* no. 32, pp. 20-27. See also P. Reilly & S. Rahtz, eds., *Archaeology and the Information Age: A Global Perspective* (London: Routledge, 1992).

Likewise, conservators and conservation scientists have been quick to investigate potential uses of computer imagery. For the most advanced uses in both archaeology and museum conservation, see the forthcoming proceedings of the international conference, "Imaging the Past: Electronic Imaging and Computer Graphics in Museums and Archaeology," held at the British Museum, 3-5 Nov. 1994. For annual summaries of the most technically advanced digital image projects for the visual arts, see the preliminary conference information and Conference Proceedings of *EVA (Electronic Imaging & the Visual Arts)* , an annual conference, held each year, beginning in 1990, at the National Gallery, London.

5 In her 1994-95 annual report, Christine Sundt reports that the University of Oregon Slide Library circulated an average of over 200 slides per day for the calendar year, nearly 400 slides per day in peak months during the academic year.

6 For information on new art museum CD-ROMs etc., see *ITEM (Image Technology in Museums and art galleries database)* , ed. Isobel Pring, pub. by the International Visual Arts Information Network (IVAIN, ivainjr@gn.apc.org), in association with the International Documentation Committee (CIDOC) of the International Council of Museums (ICOM). For reviews of art CD-ROMs see *Visual Resources: An International Journal of Documentation,* ed. Helene Roberts, sponsored by the Visual Resources Association (VRA), review ed. Elizabeth O'Donnell. An annotated list of CD-ROMs available on art is included in a book scheduled for publication early 1996, *Key Guides to Electronic Resources: Art and Art History,* by Martin Raish (Medford, NJ: Information Today). Raish is Art Bibliographer, Binghamton University Library, Binghamton, NY (mraish@bingvmb.cc.binghamton.edu).

7 The two most extensive programs with which I am familiar are at the Canadian Museum of Civilization, Hull, and at the American Museum of Natural History, New York. At the Canadian Museum of Civilization, the Executive Director, George F. MacDonald, reported in May 1994 that, to date, over 200 master Photo CDs had been produced, holding more than 20,000 images, and that half a million analogue images were about to be digitized ("Dynamics of Culture and Identity, and the Potential of Interactive Technologies to Engage Users of Cultural Institutions," paper prepared for a panel session of the Cultural Technologies Convergence conference, Toronto, 27 May 1994). Also in 1994, William Weinstein, Systems Analyst for Research and Databases at the American Museum of Natural History, reported that the Anthropology Department was "halfway through a twenty-five year plan that includes . . .

computerizing catalogue records, and the creation of an image database of the department's 1.5 million artifacts" ("Designing an Image Database: A Holistic Approach," *Visual Resources*, X, 1 [1994], p. 49).

8 The same digitized image viewed on a video monitor, Kodak Photo CD player, or with an affordable digital projector will always be significantly fuzzier, with much less detail, than the same image viewed on almost any computer monitor. This may not matter for many uses, but fuzzy images are unacceptably limiting when one is attempting to study a work of art.

9 As a standard reference for degrees of resolution, it is helpful to use the five standard resolutions in which images are digitized on the widely used Photo CDs. Described in terms of the total number of pixels (a pixel, or picture element, is one dot) that we can see on the screen when we look at a digitized image, the five standard resolutions are 192x128, 384x256, 768x512, 1536x1024, and 3072x2048. A Pro Photo CD includes one higher resolution, 6144x4098. Kodak plans to make available one even higher resolution in the near future. Of course, where the monitor can display the full resolution of the image, the higher the resolution, the more detail we can see.

The digital image industry seem to be accepting the middle resolution as its standard. Advertisements for even leading CD-ROMs frequently refer to their images as "high resolution" and "superior quality" when they are only 768x512. An image at this resolution pixelates at the first standard zoom. To be able to examine a digitized image of a work of art in detail, the resolution must be at least 3072x2048. A Pro Photo CD includes the six resolutions listed above. In this article, I refer to the lowest two as "low resolution," to the middle two as "moderate resolution," to the highest on a regular Photo CD as "high resolution," and to the highest on the Pro Photo CD as "extremely high resolution."

10 The classic study was Michael Ester's "Image Quality and Viewer Perception," *Leonardo*, Supplemental Issue 1990, pp. 51-63; republished in *Visual Resources*, VII, 4 (1990-1991), pp. 327-352. Ester rightly points out that "decisions about resolution and dynamic range are inseparable from the intended used of an image" (p. 58). This being the case, conclusions based on viewing the full image lose relevance once we accept the fact that an important intended use is to examine details.

11 Scholars in other fields who discount art historians' need for high resolution digital images often revise their opinion when they are shown that one cannot read the text in digital images of medieval manuscript pages unless there is high resolution. Many beautiful manuscript pages, with illegible text, have been put on the internet. The Vatican and IBM are currently engaged in a joint project to digitize all the manuscripts in the Vatican Library at extremely high resolution.

12 The distinction between "higher quality" and "fidelity" has been made by Michael Ester. Understandably, he writes that "Assessment of image quality is a statement about the image's fidelity to the source reproduction from which it is derived" ("Digital Images in the Context of Visual Collections and Scholarship," *Visual Resources*, 10 [1994], p.16). However, for purposes of art history, we are concerned primarily with fidelity to the appearance of the work of art and would therefore favor correcting the color, etc. of the digital image while viewing the art rather than the image that was digitized. According to this standard, digital images can sometimes be made more "faithful" than the photograph, slide or transparency from which they were digitized.

13 See the publications of the Doerner Institute, Munich.

14 See David Saunders and John Cupitt, "Image Processing at the National Gallery: The VASARI Project," *National Gallery Technical Bulletin*, 14 (1993), pp. 72-85. Forthcoming: David Saunders, John Cupitt, and HelÄnne Chahine, "Longterm Colour Change Measurements: Some Results after Twenty Years," *National Gallery Technical Bulletin*, 17 (1996); HelÄnne Chahine, John Cupitt, Kirk Martinez, and David Saunders, "Investigating and Modeling of Colour Change in Paintings during Conservation Treatment," *Imaging the Past* (London, British Museum, c.1996). A similar facility, with more recent equipment, has now been set up at the Uffizi, Florence. See Vito Cappellini & Team, Florence University; Bruno Brunelli, Sidac, Italy; and Ron Cox, Time & Precision, UK, "The New Vasari Museum Laboratory System at the Uffizi Gallery & Colour Certification of True Colour Images," *EVA'95: Conference Proceedings* (London: National Gallery, forthcoming).

15 See Ian N.M. Wainwright, "Rock Painting and Petroglyph Recording Projects in Canada," *APT Bulletin*, XXII, 1-2 (1990), pp. 56-84; Ian N.M. Wainwright and John M. Taylor, "NRC's Laser Scanner for Recording and Replication," *CCI Newsletter*, No. 6 (Sept. 1990), pp. 6-9; and R. Baribeau, M. Rioux and G. Godin, "Recent Advances in the Use of a Laser Scanner in the Examination of Painting," *Restoration '92, Conservation, Training, Materials and Techniques: Latest Developments*, ed. Victoria Todd (Amsterdam, 1992), pp. 69-73. For further information, contact Ian N.M. Wainwright, Acting Chief, Analytical Research Services, Canadian Conservation Institute, Ottawa (ian_wainwright@pch.gc.ca).

16 Henry Gilmer Wilhelm, *The Permanence and Care of Color Photographs* (Grinnell, Iowa: Preservation Pub. Co., 1993), ch. 1, 6 and 18.

17 See Janice Mohlhenrich, ed., *Preservation of Electronic Formats & Electronic Formats for Preservation* (Fort Atkinson, WI: Highsmith Press, 1993); and Jeff Rothenberg, "Ensuring the Longevity of Digital Documents," *Scientific American* (Jan. 1995), pp. 42-47, though digital storage experts have objected that Rothenberg severely underestimates the physical lifetime of digital magnetic tape.

This report is one of several investigating scholarly involvement in preservation and access. Commission reports on this topic include:

Difficult Choices: How Can Scholars Help Save Endangered Research Resources? Gerald W. George. August 1995, 24pp.

Digital Imaging of Papyri: A Report to the Commission on Preservation and Access. Roger S. Bagnall. August 1995. 8pp.

Preserving the Intellectual Heritage, A Report of The Bellagio Conference held at the Rockefeller Foundation Study and Conference Center, Bellagio, Italy. October 1993, 36pp.

Preserving the Illustrated Text. Report of the Joint Task Force on Text and Image. April 1992, 31pp.

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