Image Processing And Analysis With Microcomputers

By: **Steven J. Hageman**

Abstract

Recent advances in microcomputer technology have created many tools for image processing and analysis that are useful for paleontologic studies. Although the Journal of Paleontology is not the appropriate forum for reviews of products from the rapidly changing field of computer technologies, a brief introduction to techniques presently available for image processing and analysis, and their potential applications to the field, may be of value to paleontologists.

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IMAGE PROCESSING AND ANALYSIS WITH MICROCOMPUTERS

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RECENT ADVANCES in microcomputer technology have created many tools for image processing and analysis that are useful for paleontologic studies. Although the *Journal of Paleontology* is not the appropriate forum for reviews of products from the rapidly changing field of computer technologies, a brief introduction to techniques presently available for image processing and analysis, and their potential applications to the field, may be of value to paleontologists.

VIDEO DIGITIZATION

Relatively elaborate computer systems have been used for some years by paleontologists to digitize morphometric data (see Raup and Stanley, 1978, figs. 2–4); and, more recently, relatively inexpensive and efficient microcomputer digitization systems have become available (Lazarus, 1986). Data usually are collected by placing a photograph, drawing, or camera lucida image on a digitizer tablet and plotting key morphologic points, which are then stored in the computer.

With the use of a video camera, an image can be digitized and stored directly in the computer. Graphics software allow the image to be edited and measurements taken and stored in the computer. Equipment for this process has been available for several years, but at a cost of $10,000 to $25,000. Several turn-key video digitizer packages are now available for microcomputer systems for about $500 beyond the cost of the basic computer. An incomplete list of available systems includes: Magic Digitizer (New Image Technology), MacVision (Koala), products from Mentauris Corporation and Comtrex Ltd. for Macintosh computers, Idetix image processor (Micron Technology Inc.), Professional Image Board (ATronics International Inc.), DT2853 Frame Grabber (Data Translation) for IBM/IBM compatibles, and Digi-View (NewTek) for Amiga systems. Magazines dedicated to specific computer systems are a good source for information on available systems. Local user groups may also be helpful.

Setting up a video digitizing work station entails simply plugging in connection cables between a video camera, camera power source, digitizer (internal board on some systems), and a microcomputer with display screen. Software required to display and manipulate the images is included in most digitizer packages. The work station shown in Figure 1 was set up and digitizing images in less than an hour, although practice was required to obtain optimal image quality.

Various computer systems employ different methods for displaying images on viewing screens. Resolution of images on display screens is a function of the density of picture elements (pixels) on the screen, the number of available shades of gray (0–264) in two-tone systems, or the number of available colors in various color systems. In general, systems with on/off pixel display provide the greatest resolution for imaging objects with high contrast because of their greater pixel density. Systems with a large number of shades of gray (different light intensity levels for each pixel) provide the greatest resolution for imaging three-dimensional objects with surface textures, but have fewer pixels/square inch. Color displays generally have the lowest resolution, but will surely improve with future technological advances. Accessories such as larger screen and graphics microchips can be added to most systems to increase the display size and/or resolution, but at considerable cost. Video digitizers vary in how completely they take advantage of the maximum resolution of display screens, a feature that should be considered when purchasing a digitizer. Future advances in inexpensive computer display systems and digitizers will increase the resolution of images obtainable with a video camera, the quality of which presently limits their usefulness.

Camera quality also limits the resolution of images. Color video cameras designed for home VCR units have high resolution, scanning 300 lines/inch, and may also be used for black and white imaging. However, they require relatively high light levels and may not be appropriate for some applications. Black and white observation cameras used in security monitor systems are less expensive and require less light, but generally have lower resolution (70 lines/inch). Image quality can be improved on some cameras by replacing the original lenses with an adaptor and 35 mm camera lenses. Most video cameras do not have internal power supplies. Color video cameras can be powered by a VCR unit, with a cord connected from the output of the VCR to the input of the digitizer. The advantage of this system is that images can be stored on video tape and later input into the digitizer. Observation cameras may require a separate external power supply.

For all video digitizing systems, adequate lighting of objects is an important factor in obtaining quality digitized images. Images of macrofossils can be obtained with a quality camera and macrolens. A video camera can also be mounted on a light microscope to digitize thin sections or microfossils.

An advantage of this process is that images are actually stored on magnetic discs and can be placed in data bases specifically designed to accommodate them. Images can be stored with information in text form, which can be sorted and recalled for later use. This enables paleontologic collections to be catalogued with digitized images included and also has educational applications such as for laboratory exercises for which original specimens may not be available. Additionally, images of entire faunal collections can be distributed on computer disks to other workers wtih compatible systems. A digitizer is not required for viewing.

The discussion below deals with fenestrate bryozoans, but applies equally to most rocks and fossils studied and measured in thin sections.

APPLICATION OF VIDEO DIGITIZATION TO FENESTRATE BRYOZOAN TAXONOMY

A severely limiting factor in bryozoan research has been the time-consuming preparation of photographs necessary for collection of morphometric data. With a video digitizing system an image can be digitized in a matter of minutes and the process of character measurement greatly expedited with the computer. The increased speed with which specimens can be processed allows relatively rapid compilation of much larger data bases which may then be applied to other areas of paleontologic interest.

Figure 2 shows an initial image of a longitudinal section of a fenestrate bryozoan created with the digitizing package "Magic"

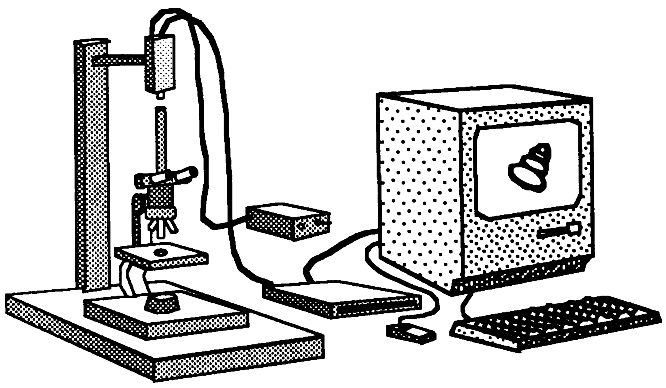

FIGURE 1—Hardware used for digitization of images includes a binocular microscope with a photo-tube, video camera with external power source, mounted on a stand connected to a digitizer which is connected to a Macintosh Plus computer.

FIGURE 3—The same image as Figure 2 after matrix, cement, and background "noise" have been deleted with a bit mapped graphics program.

and a Macintosh Plus computer. Brightness, contrast, and shading pattern options in Magic software allow for control of image quality. Digitized figures shown here were printed with a laser printer, but comparable prints can be obtained with a quality dot matrix printer. The quality of original images on the computer display screen is considerably better.

The resolution of images obtainable with inexpensive video digitizing systems presently available is somewhat limited, resulting in loss of surface details. However, the system is ideal for zooecial shape analysis. Three-dimensional zooecial reconstruction, using longitudinal, transverse, and tangential sections, is the principal characteristic used in fenestrate bryozoan taxonomy (McKinney, 1980; Snyder, 1984) and is required for generic and specific identification.

Digitized images can be saved and pasted into a bit mapped graphics program such as MacPaint. Regions of cement, matrix, and other background "noise" can be deleted as shown in Figure 3. Images can also be enhanced by zooming in on specific areas and filling in regions, although caution must be used so as not to alter zooecial shape. Images can be transferred into object-oriented drafting programs such as MacDraft. Further editing of the image is not possible in object-oriented graphics programs, but figures can be traced over the image for an idealized reconstruction. A most useful feature of graphics programs such as MacDraft is their ability to determine line lengths, angle measurements, and areas. After a scale has been developed using a standard micrometer slide, units can be converted and the data stored directly in a desk top accessory for transfer to a data base. Fortunately, maximum image resolution is obtained at higher magnifications so that measurement error attributed to the system is virtually eliminated (i.e., ± 2 microns on an image magnified $\times 150$ on the display screen). The limiting factor of measurement accuracy is the original resolution of the image, which is dictated by peel quality and preservation of the specimen. Measurement accuracy is greater than the error which results from sections cut even slightly oblique to the idealized orthogonal coordinates of the zooecium.

With the aid of graphics software, images can be edited and integrated with text, numerical data, or drafted figures. For example, thin sections can be mapped and areas of interest highlighted and labeled as shown in Figure 4. Applications for video digitized images are virtually limitless in the field of paleontology.

OPTICAL SCANNERS

Scanners that digitize two-dimensional media are now available for microcomputers. Prices range from $200 for scanners that attach to computer printers and scan pages as they are passed through by the platen to $2,000 for high resolution scanners that resemble photocopiers. With a scanner, photographs

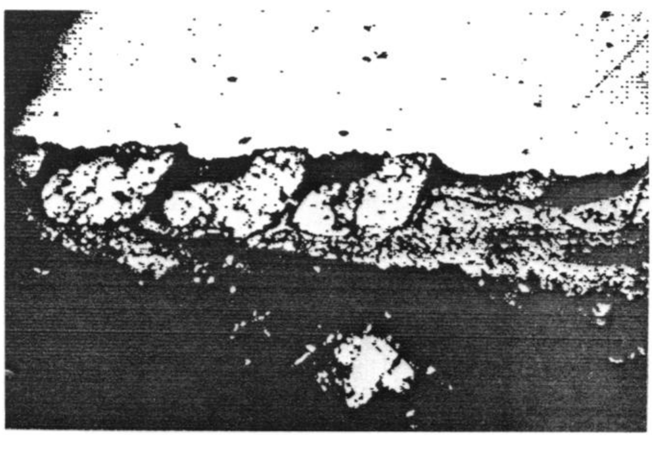

FIGURE 2—Initial digitized image of a longitudinal section of a fenestrate bryozoan, $\times 81$ reduced from $\times 162$ on 9-inch computer screen.

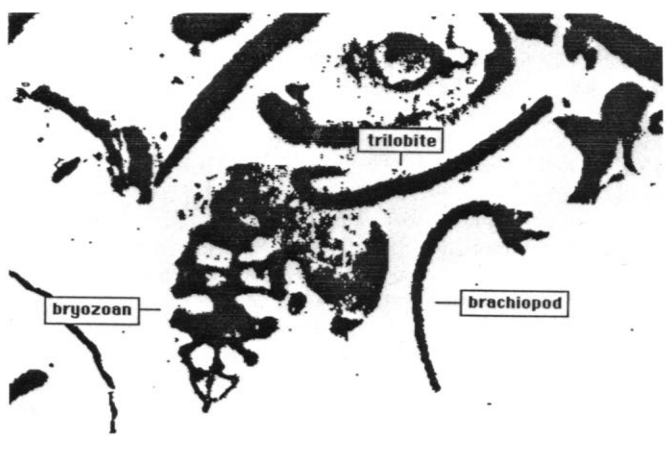

FIGURE 4—Digitized image of a limestone thin section with areas of interest highlighted.

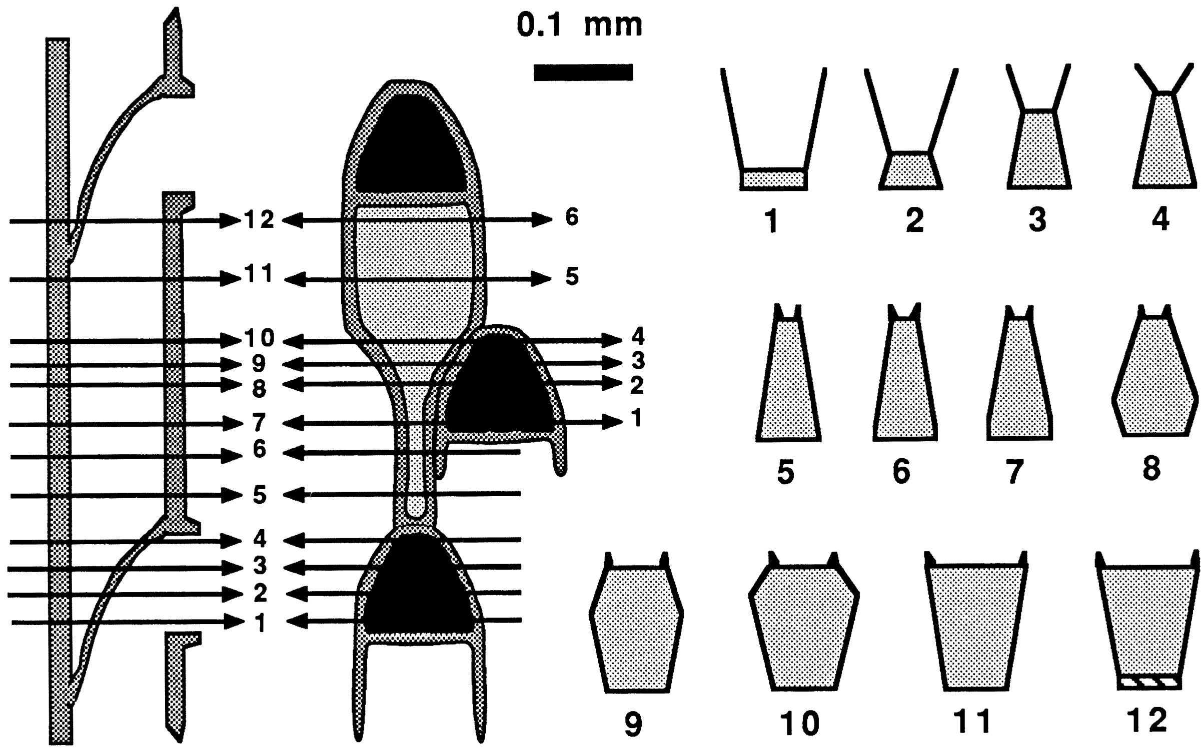

FIGURE 5—Reconstructions of *Worthenopora spatulata* (Mississippian ptilodictyian) in longitudinal, tangential, and serial transverse sections, drafted with MacDraft graphics program on a Macintosh Plus microcomputer.

and figures can be digitized and transferred to graphics programs where they can be analyzed by methods discussed in the previous section. Presently, images that can be obtained with optical scanners have greater resolution than video digitized images, and higher end products attain 1:1 resolution between scanning digitizers and computer display screens.

GRAPHICS SOFTWARE

Drafting of figures is possible with the extremely versatile graphics software packages that are available for most microcomputer systems. Many programs have preset functions that draw orthogonal, diagonal, and freehand lines, rectangles, polygons, circles, arcs, and ellipses. Drafting is usually accomplished with the use of a mouse, or digitizing tablet. Precise technical figures can be drafted because dimensions of objects can be displayed on the screen over a variable background grid system. With systems that allow for variable line widths, fill patterns, and the incorporation of text with different fonts and sizes, quite complex figures can be drafted with surprising ease. With graphics programs, professional figures can be quickly drafted by those with even the most limited artistic talent (Figure 5).

The ability for workers to precisely draft their own figures can also lead to insights of geometric relationships in and among objects that may be overlooked in original specimens or not possible with rough sketches. Drafted figures can also be modified, so that it is possible to topologically evolve figures of specimens to reflect evolutionary sequences or to show functional movement of certain structures without having to completely redraft each figure from scratch. In fact, some systems allow for animation by displaying separately created story boards in sequence. Many three-dimensional modeling programs are also available for most microcomputers.

Macintosh computers allow for complete integration of graphics, text created in a word processor, and numerical data stored in a data base. IBM is expected to introduce an operating system in 1988 that will allow for true multitasking. Publication ready figures and text can be obtained from laser printers that have recently become available for microcomputers.

SUMMARY

Recent advances in microcomputer technologies have created user friendly systems that prove powerful tools for image processing and analysis in paleontology. One no longer needs to be an electronics specialist or even have knowledge of computer programming to take advantage of these systems. In fact, a skeptical colleague of mine, within one and a half hours after sitting down with a graphics program for the very first time, drafted two figures that he used the following week in a professional talk.

Relatively inexpensive computer systems have made image processing and analysis more accessible. In the future microcomputer imaging techniques will play ever greater roles in paleontologic research, publication, and education.

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APPENDIX

LIST OF EQUIPMENT

Computer and printer
Macintosh Plus with: 1 Mb RAM, 1 800 k disk drive.
Apple Laser Writer with computer interface.

APPENDIX (continued)

Video digitizer
Magic (Macintosh Graphics Input Controller), New Image Technology, Inc.; Magnavox MC-3511 observation camera with external power supply. Computer and camera interfaces.

Software
MacPaint, Apple Computer Inc.
MacDraft version 1.2, Innovative Data Design, Inc.

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A LARGE-DIAMETER CORING DEVICE FOR USE IN SHALLOW WATER AND SOFT SEDIMENTS

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A LARGE-DIAMETER coring device was designed to recover plant litter in fluvial sediments as part of a taphonomic study of plant deposition in a modern river system. The corer was used to retrieve unconsolidated sediments from shallow (< 1.5 m) water, either from a boat or from the riverbank, and was designed to be transportable for use in remote reaches of tropical rivers. The device is operable by a single person, easily repaired, and rugged.

A large diameter core permits a single sample rather than successive samples to be taken in a small area, thus eliminating the possibility that duplicate cores intersect the trace of the first core. Potential macrofossils that are larger than the standard 5–7 cm core barrel may be retrieved without damaging or slicing the potential fossil, while maintaining the stratigraphy of the sediments. In addition, the thinness of the core barrel wall and large diameter of the barrel reduce compression and distortion of sediments, a problem frequently encountered in stiff muds when using narrow diameter P.V.C. pipe corers. Physical limitations, such as loss of sediment cohesion or sheer weight of sediments, ultimately may restrict the diameter and length of coring devices of this design, but these limits were not reached with the coring device described here.

DESCRIPTION OF THE CORER

The suction-corer (Figure 1) consists of the following parts.

Core barrel.—A 61.5-cm-long, 15.5-cm-(6 in.) diameter, 1-mm wall stainless steel stovepipe was used. The thin-walled steel core barrel acts like a knife edge, cutting through sediment of high viscosity or high organic content. A longer core barrel is feasible; the increased weight of a larger volume of wet sediment is the most obvious drawback to a longer device.

Sealing plug.—A cement-pipe sealing plug fits into the top of the core barrel to create a closed cylinder in which suction is formed. The plug consists of two pieces of rigid plastic separated by a 2-inch-thick rubber gasket. A bolt and wing-nut assembly through the center of the plug expands the rubber gasket between the plastic when tightened, thus achieving a tight seal against the pipe wall.

Steel collar.—For greater rigidity at the top of the core barrel, a 4.5-cm-high steel collar with inside diameter of 15.5 cm was spot welded to the outer margin of the core barrel. Two ¾-inch female pipe fittings were welded to opposite sides of the collar to allow attachment of driver handles.

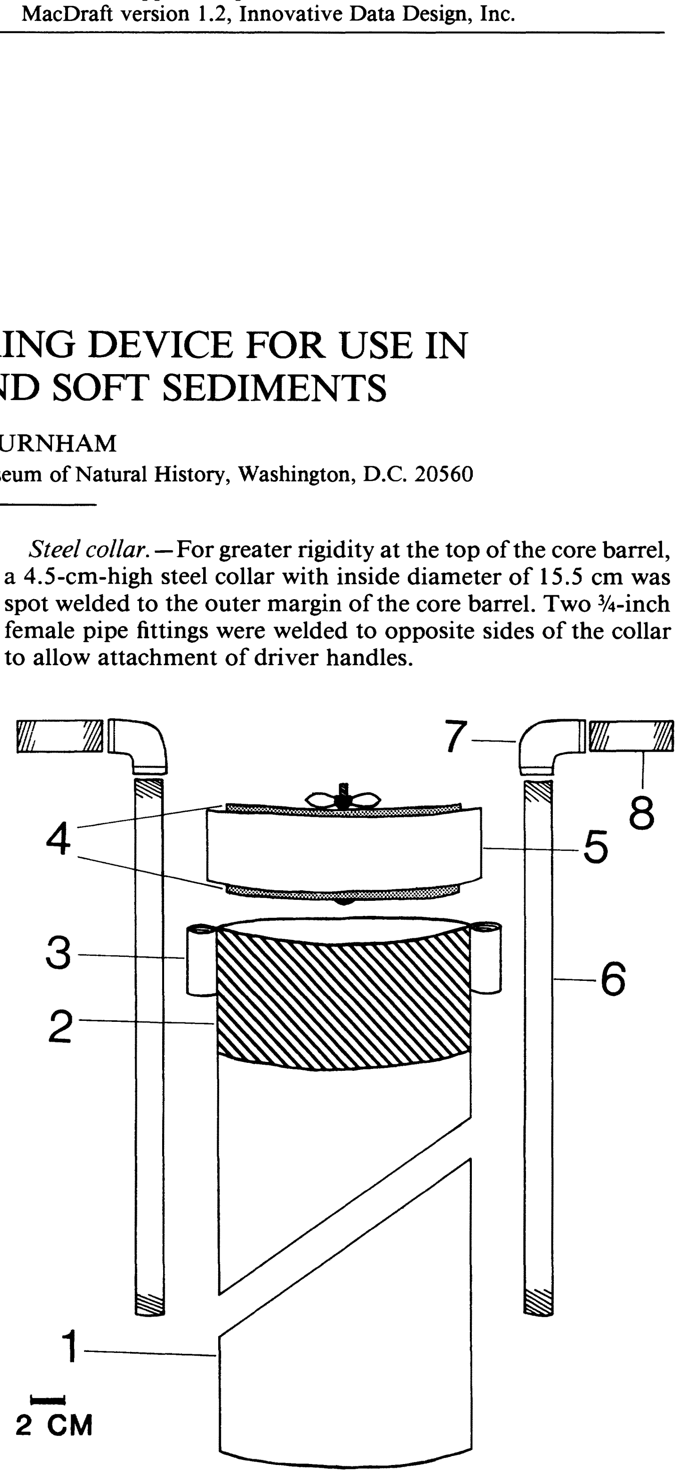

FIGURE 1—Diagram of the corer. 1, core barrel; 2, steel collar; 3, pipe fittings; 4, plastic plates; 5, rubber gasket; 6, vertical handle extensions; 7, elbow fittings; 8, horizontal handles.