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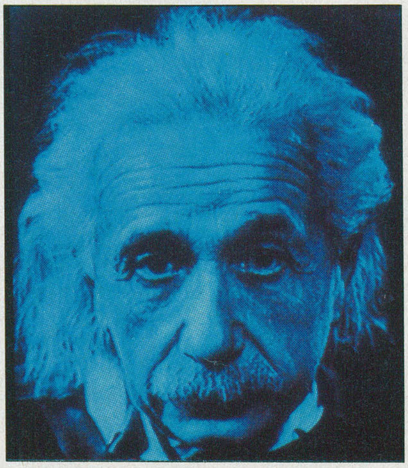
MICRO SOFTWARE FOR PERSONAL INVESTING

MICROCOMPUTER BASED VIDEO PROCESSING

VIDEO PROCESSING

Sophisticated tools for capturing and manipulating video images are reaching the microcomputer market

BY LOUISE MELTON



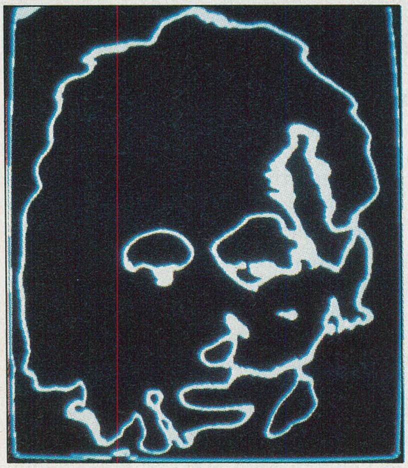
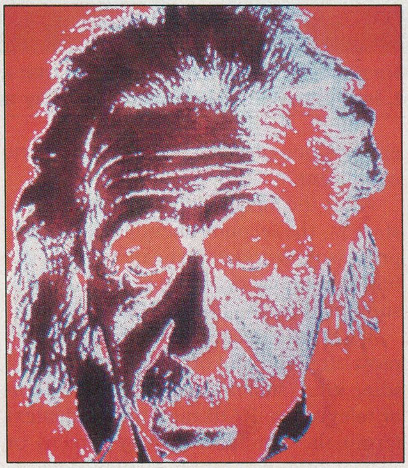
THE human eye is a remarkable instrument. It can perceive faint movements in a dimly lit room or follow the slant of sails in blazing sunlight. But, remarkable as it is, it does have limitations. Through time, humans have devised instruments to overcome some of the eye's shortcomings—we can see inside cells with microscopes and distant galaxies through telescopes. Other limitations have been overcome by modern technologies, from radar to television. Computers are only the latest addition to this arsenal.

For more than 15 years, scientists have been using video processing for everything from enhancing and analyzing television images of Saturn's rings to counting missile silos on grainy aerial photographs. But until now video processing has been the exclusive property of NASA, well-funded university research labs and the Defense Department—those capable of paying $100,000 and more for hardware. Because of the high cost of equipment (primarily mainframe computer systems and massive storage devices) video processing applications have had to be major projects to justify the cost.

Just in the last year, video processing products ranging in price from $495 to $25,000 have been introduced. While they can't duplicate the $100,000 systems, they are still powerful and exciting. And they're just the beginning.

Today, thanks to these dramatic reductions in price, due mainly to advances in microcomputer design, signal processing and dense storage technology, video processing is exploding into virtually every area. Medical imaging, robotics, graphic design and security are the earliest beneficiaries of the new lower costs. Office automation, communications, and commercial and retail applications are following fast.

Like a lot of new technology, low-cost video processing systems are coming from new companies that are getting new products to market quickly. Cromemco, Inc., the California-based microcomputer manufacturer started in 1975 by Harry Garland and Roger Melen of Stanford University, is the oldest and largest company producing small video processing hardware and software systems.


ABOVE PHOTOS COURTESY IMAGING TECHNOLOGY INC.

The other three low cost systems developers are less than three years old.

Vice President Richard Govatski of Memotech Corp. points out that the term "low-cost" is strictly relative. He says that people who already own a fully expanded Memotech 8-bit MTX personal computer, "can add video processing for under $7000. But you have to keep in mind the total system cost is around $18,000. It's possible to do some limited image processing for under $10,000—but not much under. It's still not a toy for the hobbyist or for general purpose computing. For the near future, microprocessor-based video processing is going to be used primarily in dedicated applications."

Govatski predicts that the proliferation of microprocessor-based video processing applications will depend on the third-party applications-software, developers of the same group that played a big part in the proliferation of business and graphics software.

Ron Massa, an electrical engineer and national sales manager at Imaging Technology in Woburn, MA, agrees. He feels that applications software will be written by third-party OEMs (original equipment manufacturers) who have expertise in specific industrial and scientific areas.

More software is probably being written for Imaging Technology systems than for all the other major players put together. Imaging Technology has the most versatile and impressive array of products and capabilities—including the recently introduced $3000 PC Vision system for the IBM PC. The company's video processors are purchased in volume by systems integrators for use primarily with Digital Equipment Corporation's 16- and 32-bit systems. The company is also developing low-cost VLSI versions of its high-end systems.

Chorus Data Systems in Merrimack, NH, produces PC-Eye, a $495 hardware/software package that users can hook up to their IBM PCs. While other companies concentrate on board-level products and video processing systems software, Chorus Data Systems packages consumer products, and has agreements with retail distributors.

Pictures Are Data

Computer image processing springs largely from the space program. NASA and the Jet Propulsion Laboratory in Pasadena, CA, used video cameras, computers and communications equipment on board spacecraft to send pictures back from our neighbors in the solar system. Starting in the early 1960s with the Ranger 7 through the more recent Pioneer and Voyager probes, scientists have developed increasingly sophisticated image processing techniques.

Enhancing an image makes it easier for a human being (or a machine) to see more detail. Except in the graphic arts, enhancement rarely has an aesthetic purpose—the idea is not to make images prettier, rather more useful. Enhancement can be as simple as adjusting contrast or as complex as modifying image elements to reduce noise or geometric distortion. For example, averaging is a technique routinely used to clean up pictures from space. The image processor compares multiple frames of an image of, say, the Martian desert, eliminating

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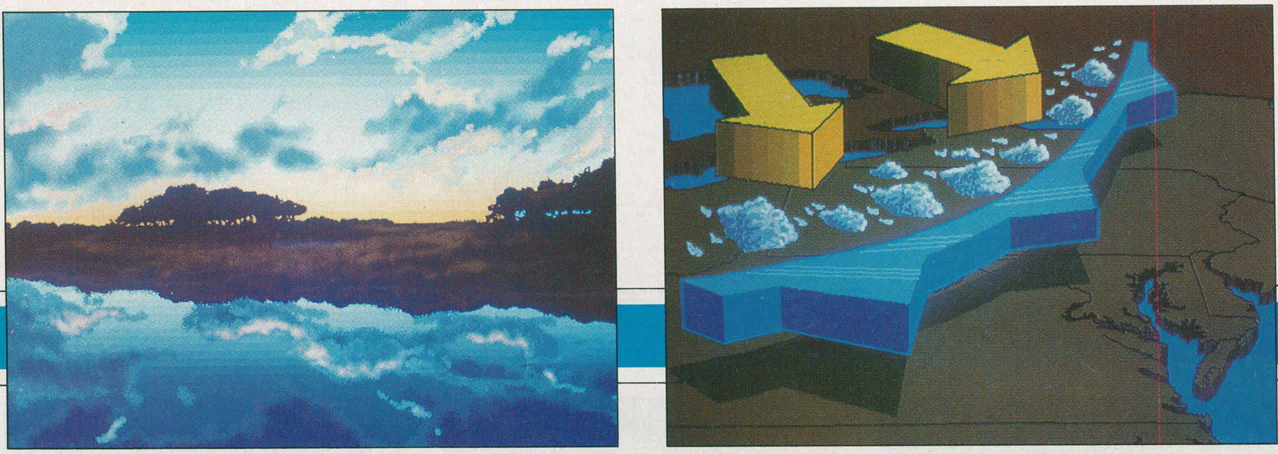


Illustration by Scott Harris, left, demonstrates airbrush and shades generator. Airplane map, right, has arrows and clouds added by artist Ron Clowney.

those that have extraneous, false information, such as that caused by radio interference from a solar flare.

Extraction and *analytical opinions* enable users to measure objects, recognize patterns, and output image data in numerical or graphic formats.

The marriage of video and computers maximizes the strengths and minimizes the limitations of each. Video signals are analog—messy, complicated, ungovernable waves of information. Computers take in digital signals—precise, quantitative, mathematical. Convert analog signals into digital signals and you've domesticated them. The first of the four major functions that define video processing therefore is *digitizing.* Video images are made up of dots of light arranged in a grid. Image components include the relative brightness of each dot—called a *pixel* or picture element—and its *xy* coordinate position on the grid. Digitizers are essentially A-to-D converters that take their input from television cameras, electron microscopes, radar, infrared detectors, or X-ray devices and translate the brightness and position of each pixel into a numeric equivalent.

After the image is digitized, it must be stored—the second function of an image processor. Storage can be in an on-board buffer memory or in the storage devices supported by the host CPU.

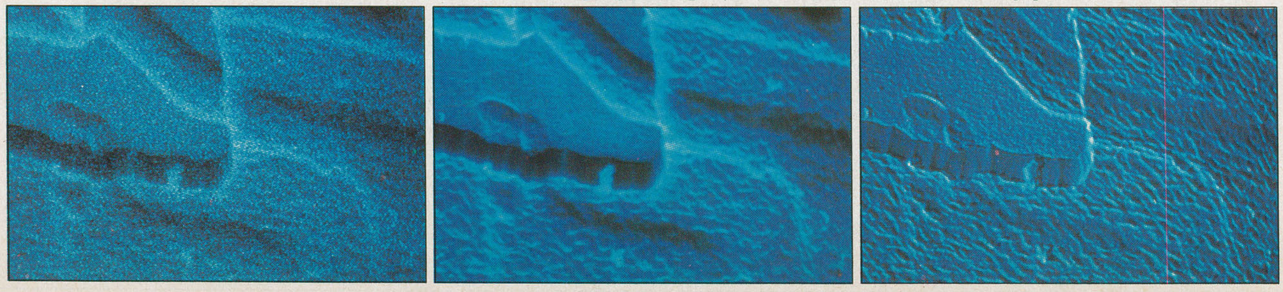
Third, the image must be output. We most often think of output as a display of some kind, such as monochrome or color televisions, RGB monitors, videotext terminals, computer display screens or special high-resolution display devices. Extracted data may also be output as histograms, scatter plots or other graphic representations.

The fourth function of an image processor is, of course, the actual processing, which may be performed by internal processors or, via an interface, with host computer. Most often, ROM on a dedicated board holds the logic that performs operations such as subtracting one image from another, or shifting brightness levels throughout an image by a predetermined factor, or retaining only those pixels within a certain range of intensity.

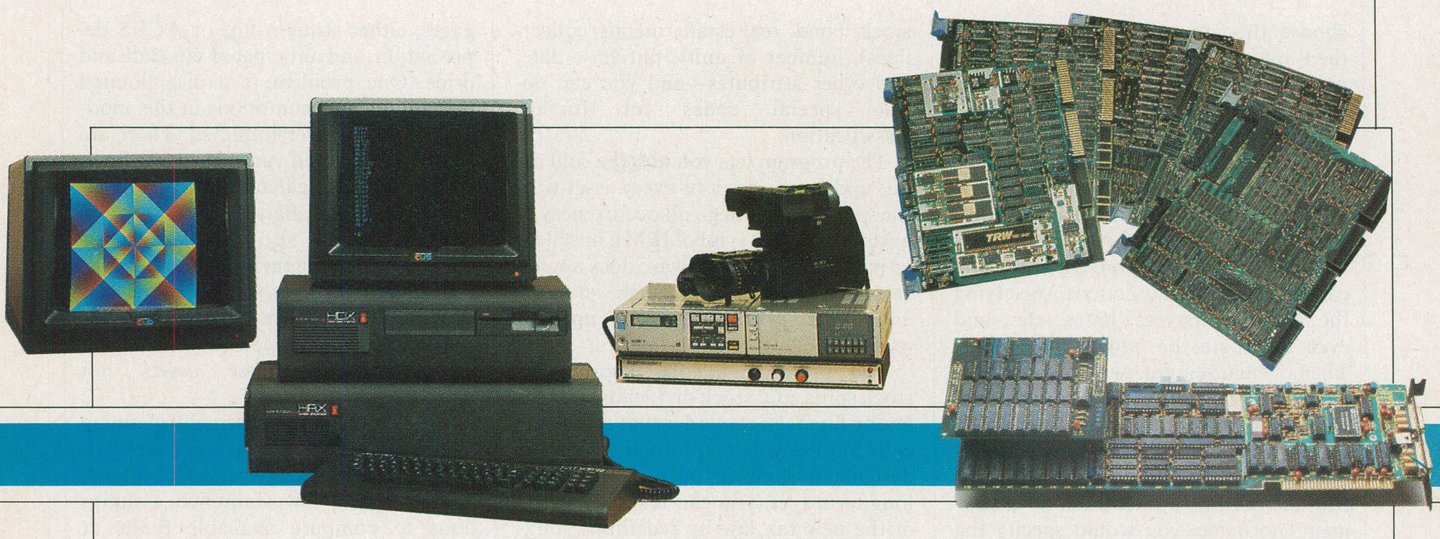
How detailed the image is, and how much information the computer can therefore garner from it, depends on *resolution.* The higher the number of pixels on the grid, the clearer the image input and output. The application determines the resolution necessary—and the cost of the system. Higher resolution takes more memory and more processing power and time. At the top end of image processing systems are what Imaging Technology's Massa calls "the real exotic Landsat stuff, 4000 by 4000 resolution, a million bucks each." Systems capable of producing images of 1024 × 1024 pixels are common in scientific applications. At the low end are 256 × 256 resolution systems adequate for, say, simple edge detection devices used in robotic vision.

Another factor that contributes to cost is the range of gray scale the system accommodates. Gray scale is determined by the number of bits used to represent a pixel's brightness. One bit is sufficient to tell the computer that a pixel is black or white. Six bits—sufficient for most current applications—provide 64

Below left is noisy image of a silicon wafer generated by a scanning electron microscope. At center, noise is eliminated by image averaging; at right, texture is accentuated by phase contrast.



TOP PHOTOS COURTESY OF LIVELINE IV COLORGRAPHICS SYSTEMS INC.



**At left, Memotech's HRX image-processing computer in a typical configuration.
At right, Imaging Technology's series of plug-compatible modules.**

different levels of gray. Until recently only very sophisticated systems in the $100,000 range offered more—8 bits and 128 gray levels. VLSI-based 8-bit systems that will sell for a quarter of that cost are now being developed.

What about color? Like very high resolution and broad gray scales, color is not necessary in the great majority of applications. In fact, 90% of image processing is done in black and white. As Imaging Technology's Massa says, "Color looks nice, but the computer can care less, and it just makes the system very expensive. It's gray level that the computers are looking for in processing data—and you actually get better resolution with black and white."

In applications where direct input of conventional video signals is not necessary, color can be handled by using three boards to process red, green, and blue separately. For special applications, the user can assign color definitions to only those pixels that are of a certain intensity. The technique is called *pseudo-color*. This process can be used to create the illusion of true color or simply to highlight certain areas of interest on an image. Pseudo-color is particularly useful in infrared image analysis—displaying wear in friction-stressed machinery or demonstrating how poorly insulated houses shed heat during cold winter nights.

Capability Determines Cost

Video processing is characterized by a wide range of system costs and capabilities. Special equipment, such as frame grabbers, flash digitizers, slow scan video acquisition systems and true, full-function video processors all use the same basic technology. The real difference is how much of the image the system can acquire and how fast. The clerk in the variety store who puts your kid's video image on a T-shirt or kitchen towel is using a very low resolution, non-real-time image acquisition and digitizing system.

Flash digitizer chips convert an entire frame of video information from analog to digital in real time—that is, at video speed, $1/30$ s. Frame grabbers such as Imaging Technology's and PC Vision products and Memotech's HRX add-on are combinations of flash digitizer chips and buffering boards so that the video speed input doesn't overcome the processor's RAM.

Adding arithmetic logic units and resident lookup tables to a frame grabber allows for video processing. If processing is done by the host CPU, it is limited to the CPU's processing speed and has to be done off-line.

Imaging Technology's high-end board systems use the host CPU only for power, system initialization and user interface. All image processing is done on very high speed ALU boards. Data is transferred at 10 MHz over a unique video bus.

Video processing can therefore be added to a real-time, multitasking, interactive system without the enormous CPU overhead usually associated with the process.

In many applications, acquiring the entire image may not be necessary. Video sampling systems trade real-time, full-image acquisition for lower memory

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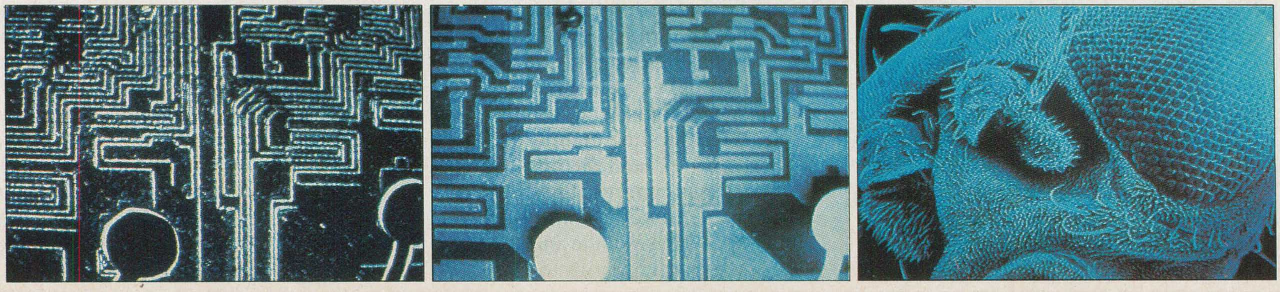
Photo at left, made on an optical microscope, shows edge enhancement of original image of a silicon wafer shown at center. At far right is a high-pass filtered image of a fruit fly.



BOTTOM ROW OF PHOTOS COURTESY IMAGING TECHNOLOGY INC.

Video Processing

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requirements and cost. In a personnel database that includes photos with employee records, for example, real-time image acquisition would be expensive and pointless. Chorus Data PC-Eye is, according to Chorus' co-founder Bruce Monk, "intended for things which can be frozen in time—still pictures. It captures only every tenth frame and something like 50 lines of information per frame in 1/3 second, whereas a true frame grabber would get all 512 lines of video." The digitized image is fed directly into the host CPU's main memory or graphics adapter card for processing. PC-Eye can also use an IBM PC's display screen rather than an additional video monitor in most applications.

Cromemco's SDD (Super Dazzler Digitizer) also doesn't use flash digitizer chips. Unlike the PC-Eye image acquisition system, which samples on a fixed basis, the SDD does image processing as the image is being captured. It takes the system 2 or 3 s to acquire a frame because it only takes in information as it needs it for specific operations.

Operations Algorithms Critical

The capabilities of a video-processing product are largely a matter of trade-offs based on price/performance. The real heart of any system is its software. As Imaging Technology's Massa says, "Anybody can stuff components on a board. But where are the equations? That's the real soup that makes the whole thing work. That's proprietary stuff. Top secret. That's what makes it a difficult technology to copy. It took years to write those equations." At Imaging Technology the operations algorithms were written largely by Rashid Beg, vice president of engineering. Beg founded the company with fellow Canadian Robert Wang in 1982 because, as Massa says, "They knew really powerful image processing could be done with microprocessors and nobody was doing it."

Complex and mathematically elegant operations algorithms like Beg's are responsible for the excitement video processing is causing at trade shows and among systems integrators. Components are what a system is. Algorithms dictate what the system *does.*

There are basically four types of video processing operations. *Pixel point processing* enables the user to address and manipulate pixels independently in order to do enhancements and change contrasts. *Pixel group processing* involves manipulating the spatial relationships between pixels. *Frame processing* deals with an entire image and may include both pixel point and pixel group processing. *Geometric operations* allow the user to enlarge and reduce images or rotate and position them on a screen.

First Step by Robotics

Microprocessor-based vision systems are found in industrial robots and automated inspection systems. Historically, they were the initial step that led to the development of the powerful processing software we have today.

According to Massa, "In the early 1970s there was an explosion in robotics and automated assembly systems based on minicomputers and, later, on micros. With that explosion came a great need to develop low-cost image processing as eyes for the robot, to do automatically what people were doing—visual inspection, where high reliability is important. By the late 1970s and early 1980s, image processing really began to take off because of the increasing number of applications—primarily in inspection." Massa cites a 1981 report by International Data Corporation, an independent industry research organization, that forecast a total market for image processing at around $80 million in 1982, increasing to a $550 million annual market by 1987.

"I think that the market has grown considerably more than that because of the use of microprocessors," Massa says. "My guess is that it's as much as a $300-$400 million market currently, and by the end of 1987, it will probably be higher than $600 million."

Automated inspection can be as simple as image subtraction, as when the computer compares an image of an electronics board coming down an assembly line to a stored image of a perfect board. Where it is possible to "step" the inspection line (so that the object under scrutiny pauses under the camera), low-end sampling devices are adequate. Says Massa, "We have some customers who were inspecting only at the end of the line. By doing process inspection so that they could make necessary changes in their equipment as things were going through, they increased their yields from 10 or 20% to 50 or 80%.

More complex inspection systems, such as those developed for automobile assembly plants by Machine Vision International and Synthetic Vision Systems, use combinations of operations to perform a variety of inspection and robot positioning tasks.

Security, simple surveillance and monitoring systems comprise the second major application for low-cost video processing equipment. Bruce Monk of Chorus Data says, "It's practical now to [have a camera that is linked to an image processing system] look at a control panel to read gauges, note combinations of lights on and lights off and then automatically dial a telephone number to set off an alarm if necessary." So in a power plant, a petrochemical factory or a scientific experiment with a lot of instrumentation, you don't have to have an expensive human inspector. And you don't have the cost and hassle of wiring a computer up to all those devices.

According to Memotech's Govatski, the success and spread of security applications will open up more and more archiving applications for video systems. "Within a few years," he says, "we are going to be storing images in computers as routinely as we now store data."

Medical imaging is a third major—and growing—application. Because much of the state-of-the-art medical instrumentation in use today is based on microprocessors, adding video processing digitizer and logic boards and software is taking place very rapidly. Adding video processing to ultrasound scanners and video X-ray systems, for example, allows the physician to select particular frames (or parts of frames) for enhancement and to store them as part of a computerized database along with other pertinent data. Scanning electron microscopy products from Bausch and Lomb and diagnostic eye care systems being developed by Cooper Vision employ Imaging Technology video processing boards.

Graphic arts is also becoming an important market for video products. Dramatic visual effects are generating a lot of excitement in the industry, but it's the cost benefits that are selling systems. Among the huge stack of sales leads Memotech picked up at a recent trade show were greeting card companies, billboard studios, ad agencies, cartographers and print producers of all kinds. "Dummy layouts for artwork and storyboards are very labor intensive and time consuming," Govatski says. "The greeting card companies put out a tremendous amount of material every year. They're very interested in being able to bring up a real-time picture of some scene or photograph, play with it by manipulating the color, combining images, superimposing text and graphics—and then printing out hard copy of the result as a dummy."

Microprocessor-based video systems can provide simple productivity improvements, for example, by allowing the graphic artist to alter in minutes the gray scales in a photograph. The same process formerly had to be done painstakingly in a darkroom using silkscreen masks. Linked with special cameras that produce 35-mm transparencies, video processing is reducing the cost of commercial slide production from $50-$75 a slide to around $5 and improving the quality of the image at the same time.

The broadcast industry is, of course, an old hand at video processing. The vivid and colorful video montages that swoop out at us nightly are the products of video processing. Until the last few years, only the big networks and major-market stations could afford the equipment to do the best video processing and special video effects.

Colorgraphics Systems, Inc., based in Madison, WI, is this country's largest supplier of broadcast graphics systems. Some 80% of all the television stations in the country use Colorgraphics's LiveLine systems to generate weather, news and sports graphics. The basic system is built around Cromemco microcomputers and, at $50,000, is about half the cost of comparable earlier generations of equipment. In April 1983, Colorgraphics introduced the ArtStar video processing hardware and software package as a $7000 add-on. ArtStar uses Cromemco's SDD board. It takes standard NTSC signals and allows the studio graphic artists to capture and manipulate video images not only of people and props, but also of radar patterns from weather information network services. Algorithms developed by Colorgraphics give the artist some 256 colors to play with and emulate the visual effects of airbrush, chalk and other media as well as picture surface textures ranging from hard bristol board to rough canvas.

The Future

According to Richard Daly, vice president of research and development at Colorgraphics, the merger that is now taking place between advanced computer graphics techniques and video processing will have a profound effect on the broadcasting industry. The production of TV ads using integrated graphics and video processing techniques, he says, is a huge and lucrative marketplace just waiting for low-cost video processing.

Video is even cheaper than film, and images are easier and less costly to manipulate than writing all the software that turns bits into objects with color, depth, texture and motion. According to Daly, "The only thing holding back the widespread use of video processing in the production of television commercials has been the quality of the image. Products coming up from the low end are now solving those problems and creating systems that are compatible with existing studio equipment."

On the basis of these new systems and on its own unique expertise integrating graphics and video, Daly's company is expanding from broadcasting into the graphic arts market. "I foresee this technology being an important part of the processing chain that brings work from the original scene to the final viewer," Daly says. He predicts that an integrated print production system including automated typesetting, video processing, graphics, designer interface and machine output of four-color printing plates will be available within a year.

Bringing together text, graphics and images promises to create new products for office automation. However, as Memotech's Govatski points out, wider use of video processing in the office awaits better hard-copy output devices. "The ink jet printers now entering the market are a real improvement over the older dot matrix technology," he says, "but we're looking for even more improvement."

High-Communications Bandwidth

Bruce Monk at Chorus Data Systems sees a future for video processing in the office, based primarily on communications. "We have to make computers productivity tools," he says. "So we ask, 'How do you make this product closer to the human?' A lot of people are looking at things in voice recognition. That's good. In some applications, that's definitely the way to go. But voice is not the high-communications bandwidth for humans—*vision* is.

"There is a lot of printed material that is not suited to computer entry via keyboard, mouse, or digitizer tablet—a lot of visual information out there that could be telecommunicated."

Chorus Data Systems is working on a telecommunications product tentatively being referred to as Video Mail. Suppose someone in an office in San Francisco wants to send a sketch, a set of plans or a photograph to someone in an office in Philadelphia. "It's not like video teleconferencing," Monk says, "where you want to send moving images in real time. With the proper compression of the image and with the 56K baud lines that are now being offered, you could send images—not as economically as facsimile perhaps—but at quite reasonable rates. And facsimile is limited to text and line art—no gray scale, no color."

Melen at Cromemco thinks that, in the retail or commercial market, video processing will be widely used in catalogs and in point-of-sale systems. "Mitsubishi Rayon in Japan has a Cromemco-based system," he says, "that allows the customer to design a kitchen. You display pictures of kitchens, combine the images with images of faucets, cabinets and other items you wish to include. And when you've put together the design you want, the computer prints out a bill of materials."

More interesting than faucets and kitchen cabinets, however, is the potential video presents as a data capture medium for input to artificial intelligence systems. Melen says, "I think intelligent, interactive imaging expert systems form an important technical direction of the future." He cites existing AI systems like MYCIN, a medical diagnostic system, as candidates for interfacing with video processors. If such a system could "look" at an X-ray, a blood sample or an ECG pattern directly, a great deal of the expense and time involved in routine diagnostics could be saved.

The future for video processing may parallel other electronics technology—systems will grow smaller, more powerful and less expensive, spreading outward into more and more applications.

Given the rapid pace of development, does that mean that we'll have four-color picture phones with zoom and windowing capabilities at home within a few years? No, probably not. But it is likely that most computers with a practical purpose will have vision.

[A good source for information on the more detailed aspects of video processing operations and video processing technology in general is Gregory A. Baxes' Digital Image Processing: A Practical Primer (Prentice-Hall, 1984).] ◇

You Can Get There

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Summing Up

By using the means we've discussed, you can sometimes make what is otherwise incompatible software and hardware work together. The operative term is "sometimes." Sometimes it's almost 100% successful, sometimes barely 10% —and you often won't know until you give it a try. We evaluated a considerable amount of various "interchange" and translator software in preparing this article, and a large portion of it barely worked. The interchange and translator products that appeared to live up to their manufacturers' claims are the ones we included here. We found enough of them to demonstrate that there are ways around most of the theoretical incompatibility problems associated with computers. The farmer was wrong. You really *can* get there from here! ◇