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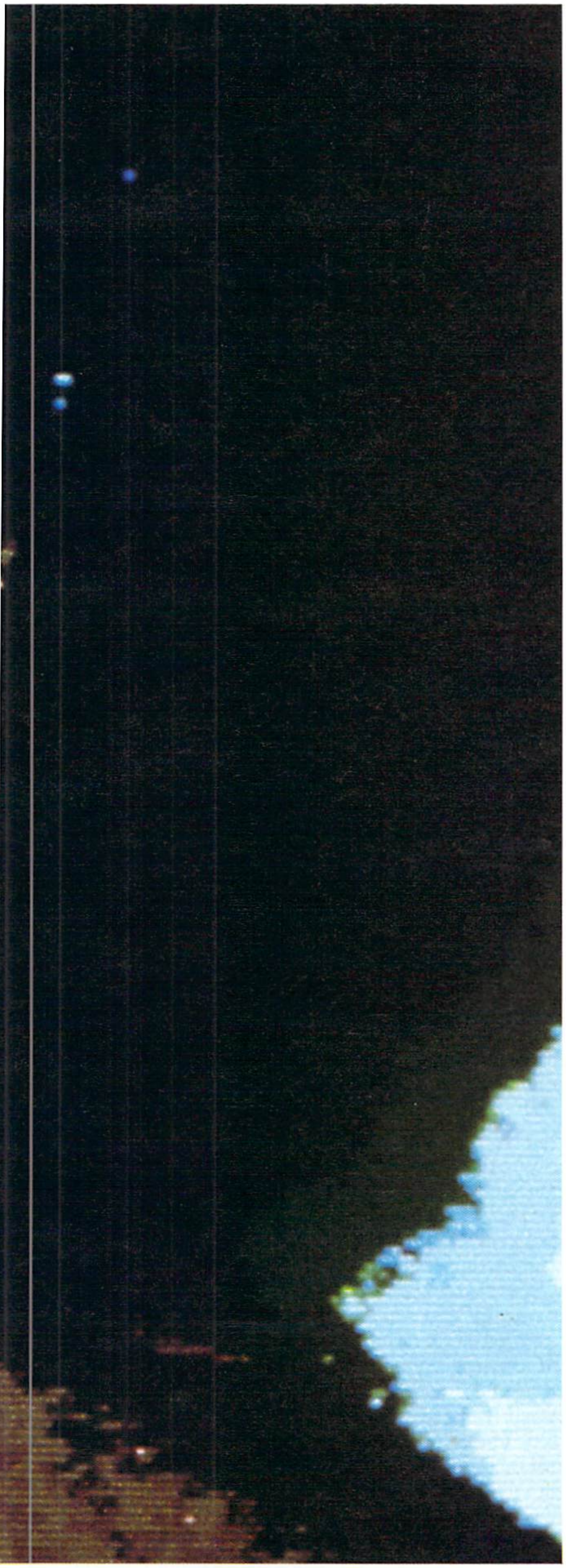
Illustrations by A-Squared Systems



Digital Imagery

By Matthew Leeds

Digital image processing is a rapidly growing field with virtually unlimited applications. The Amiga and a digitizer will bring this new technology within the reach of businesses, art studios, schools and even homes.

You see digitized images all around you today. Most of the time, you don't even recognize them as such. Many of the photographs in newspapers are delivered by news agencies over a telephone line using a digitizing scanner, and then reconstituted on the receiving end. If you've purchased a television in the last year, you might have a digital set. These technologically advanced entertainment centers offer digital stereo sound, the ability to zoom an image on the screen and split-screen options, allowing you to watch two programs at the same time. Digital image recognition is used in manufacturing, process control, astronomy, medical X-ray analysis and cartography.

Until a few years ago, digital image processing was very expensive. Equipment started at $30,000. In fact, there were no systems available for personal computers until manufacturers were able to utilize new technologies to allow medium-resolution systems at moderate prices. Low-end systems now start at $250, and good high-end systems are below $10,000.

These falling prices can be attributed partly to the increased use of graphics in business. Executives are using more computer-generated and/or computer-enhanced images in their presentations, and they are looking for cost-effective means of producing them. Many are still going to professional computer graphics suppliers, but larger companies have started bringing their production in-house. This has several benefits: faster turn around times, more control over the finished image, security of sensitive data and better cost controls.

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Digitally-created images are being seen more and more. Several recent science fiction movies have used digitally-created imagery: *Dune, 2010, Blade Runner* and *The Last Starfighter.* Television commercials are also using digital images to sell products. The premier example of this was the commercial for the Canned Food Information Council that ran during the 1985 Super Bowl. It featured a computer-generated female robot moving and speaking with human-like smoothness. Other examples include the opening to a PBS special on Vietnam and most automobile ads.

The Technology of Video

However, there is a difference between images created by a computer and those created with a video camera. The process of converting images created with a video camera or other video source to something a computer can utilize is called digitizing. To understand why we need to convert from a video source, we first need to understand the underlying technology of video.

All video used in the United States conforms to a set of standards called RS-170 NTSC. There are other standards used elsewhere in the world (e.g., PAL and SECAM), but we will confine our discussion to NTSC.

Just about all computers today use a video display called a cathode ray tube, or CRT. Most CRTs use a technology called raster scan to produce an image. All CRTs contain at least one electron gun, used to "paint" the image on the inside of the glass face of the CRT. Monochrome displays use only one gun, and color displays use three. The electron beam is directed by the display controller in the computer.

Imagine yourself holding a can of spray paint, and standing in front of a blank wall. Starting in the upper-left corner, you begin to paint a straight line towards the right. To make the paint thicker and the image brighter, you press harder on the nozzle. When you get to the edge of the wall, stop pressing the nozzle and move your arm back to the left side of the wall. Start painting just below the line where you started. Keep painting until you have painted $262\frac{1}{2}$ lines. This is one field of the display. Now go back to the top. There's a gap between each line. Fill in each gap, one at a time. This is the second field of the display, and it completes one frame. Don't forget you have to complete each field in $\frac{1}{60}$ of a second. Also, your paint fades in less than $\frac{1}{2}$ a second, so don't stop painting. This is how a monochrome monitor works. For color, get two friends with different colors to help you paint. Try not to tangle your arms.

That is the essence of raster-scan technology. The paint spray is the electron beam, the wall is the inside of the CRT and you are the display controller. The NTSC standard uses $262\frac{1}{2}$ lines in each field. By interlacing two fields, it is possible to create a resolution of 525 lines on the screen. For higher resolution, we require a different technology.

The NTSC signal combines the information for the three colors in a single signal. By separating these into three, and sending them individually, we can increase the resolution significantly. This separated information is called RGB, after the red, green and blue signals that are its components.

All of this information is sent to the CRT in analog form (i.e., as a voltage level that varies depending on the brightness of the image and in sync with the horizontal and vertical scanning pulses). These pulses are sent each time the raster finishes a horizontal or vertical scan, and they tell the electron gun to turn off until it returns to the left edge of the screen and moves down one scan line (for horizontal) or to the top of the screen (for vertical). The screen is composed of phosphors that glow when struck by the electron beam. Each point of light is called a pixel, or picture element. The intensity of the beam controls the brightness of each pixel.

The display controller converts the bit-mapped display of your computer into an analog signal that your TV or monitor can display. However, it cannot convert an analog signal back into a bit map. This is why you need a digitizer (also known as a "frame grabber").

Another name for a digitizer is an analog-to-digital converter, because it converts the analog video signal to a digital signal. The analog signal is a wave with highs and lows. The converter looks at, or samples, the analog signal, and if it is at a high, it sees that as an "on" bit. If it is at a low, it sees that as an "off" bit. Sampling only for high or low will result in only a black-and-white image. For more colors or a gray scale, you need to sample the same pixel several times with a graduated threshold. Each graduated level corresponds to a color or gray scale in the final image. The threshold level should be adjustable through either hardware or software. This sampling goes on at a very fast rate. To sample enough information for a screen with a resolution of 640 × 400 pixels in black and white would require 256,000 samples in $^1/_{60}$ of a second. To store this image would require 32K of RAM. If you wanted to capture a 16-color image, you would need 128K RAM. The bit samples are usually stored in a matrix, with each screen line of the image in one row of the matrix and the sampled bits in the columns.

There are several tradeoffs evident here. To get higher resolution requires a higher sampling rate. This requires more RAM in which to store the information and a system that can display that resolution. The same tradeoff occurs as you add more colors to the image. At a resolution of 640 × 400 pixels, black and white needs 32K RAM, four color needs 64K RAM, and 16 color needs 128K RAM. That's for one image. Imagine trying to digitize and store a one-hour film on disk at 24 frames per second. Think of it. A 16-color movie would require 128K × 24 frames × 60 seconds × 60 minutes. That's over 11 gigabytes of memory!

There are other considerations. Not only does the digital converter need to calculate a brightness level for each pixel, it also must assign a coordinate for each pixel. This information is then passed to the computer. There are limits to how fast the information can be transferred. If the digital converter does not have its own RAM in which to store the memory map, it is usually not possible to convert a video image in one scan. By using successive scans, and sampling different sections of the image in each scan, it is possible to transfer information at a rate the computer can handle. This could result in a smeared image due to changes from scan to scan. Some slow scan systems may take as long as a minute to digitize an image.

For many applications, you may want to use the computer as a source of graphics to combine with video. Although it is possible to digitize a frame, add your graphics to the image and then record it back to tape, this has many limitations. It will only work with still images, the resolution may be lowered, and it will be difficult to combine graphics with preexisting videotape. The simple answer to this problem is to overlay the computer-generated image on to the video image in real-time. This requires hardware that has gen-locking capability.

Video signals require complex timing and synchronizing. Horizontal drive, vertical drive, burst flag, subcarrier, color frame ID pulse and blanking are some of the signals. Every video source has its own generator for these signals, and to combine two video sources, the timing must be "locked" together. If the two sources are not "in sync," you could have one source trying to start a raster scan at the top of the screen while the other is already halfway down. With two signals trying for control of the electron beam, the display controller would develop schizophrenia. This locking is usually accomplished by using a sync or gen-lock generator. You must also have a gen-lock input on your video equipment.

With the proper software and a gen-locked digitizer, you can perform dissolves, wipes, overlays, blackouts, fades and a variety of other special effects. Using several video decks, it would be possible to create a computer-controlled video-editing system.

Digitizing Systems

Over the last 18 months, several manufacturers have released digitizing hardware for a variety of machines. All of these systems include some software, and a few offer high-level applications packages. The most interesting discovery I made after looking at all these systems was that prices are falling dramatically at the same time that capability is expanding.

There are several systems available for the Commodore 64. The Digi-Cam from Cardco is a combined black-and-white video camera and digitizer. Software is included to enhance or print the image and transmit it over a modem. Computereyes from Digital Vision is a hardware/software package with three scanning modes. (There is also a version of Computereyes for the Apple II family.) The MicronEye from Micron Technology uses an OpticRAM camera and an interface board. Software is included to save and display black-and-white or gray-scale images and print them with Epson/Gemini printers.

Koala Technologies has a product for the Macintosh called Macvision. This is a hardware/software system that attaches to any video source and creates a gray-scale image in five seconds. The ThunderScan from Thunderware is an unusual device that attaches to the Macintosh printer. It replaces the ribbon and uses the printer to slowly advance a document or artwork through the platen as it scans the image.

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The most sophisticated applications for microcomputers are currently running on IBM PCs. Imaging Technology offers a full line of image-processing hardware and software. Their PC Vision Frame Grabber offers 256-level gray-scale, or 16 million pseudocolors. It also has full gen-locking capability to a variety of video sources. Chorus Data Systems also has a professional-level system for image digitizing, called the PC-Eye

Video Capture Board. It has resolution up to 640 × 512 in black and white, and it is supported by several applications packages.

For those systems that do not have gen-locking capability, there are several manufacturers offering stand-alone devices for overlaying computer-generated graphics and video. Valiant I.M.C. markets the Telecomp 1000. This mixes any two NTSC video sources and outputs a single signal in NTSC video, or RF-modulated for display on a television set.

An Amiga Digitizer

A digitizer for the Amiga has been developed by an Oakland, California company called A-Squared. (Andy Warhol used this digitizer to "paint" Deborah Harry's portrait at the Amiga's debut at Lincoln Center.) It plugs into the expansion bus and has an optional external power supply. You could plug in more than one digitizer and do dissolves, wipes and other effects from one source to the other. Input from any composite video source—camera, computer, laser-disk player or VCR is acceptable. There is also an RGB input.

The addition of visual images can make the difference between just another report and a complete presentation.

The digitizer is capable of storing an image with eight levels of gray, in 320 × 200 resolution. There are plans to allow for the capture of a 32-color image, and there's also talk of software to allow for 640 × 400 in 16 colors. A-Squared plans to release a series of programmer's tools to ease the creation of applications software. These will include drivers for the hardware, overlay and false-color routines, moving windows, graphics overlays and full file structure information. There will also be routines for capturing a set of images over time.

The design of the Amiga digitizer is unique. It contains no on-board RAM, and yet it can digitize in real-time. This is in part due to the speed of the Amiga's microprocessor, which runs at exactly twice the frequency of standard video signals. Since the bit map is stored in RAM in the Amiga, it is possible to capture more than one image at a time. In fact, you are limited only by the amount of RAM and the size of the image you are grabbing. It is possible to store about one second of real-time images and view them in sequence. It is also possible to capture images using a time-lapse technique.

The Amiga digitizer works by sampling a video field every $^1/_{60}$ of a second. It then converts the analog signal to a bit map, called a bit plane. It takes three fields to give enough information for an eight-level gray-scale. Each pixel is controlled by three bits, one from each bit plane. This would require $^1/_{20}$ of a second to complete the three scans necessary for an image, but the software retains the existing bit planes and updates each one as the scan is completed, on screen and in real-time. If a bit changes, the gray scale for that pixel changes.

The software included with the digitizer stores information in a file format that is compatible with the Graphicraft paint program from Amiga. This format could become a standard, with all other software developers creating applications using it. It takes 24K to store one digitized screen, so you can fit over 30 on a single disk.

The Amiga digitizer is due out in Oct. '85; the price, though not yet official, will be around $200–$250. Thanks to its open architecture, A-Squared was able to use the Amiga's unique hardware capabilities and produce a product with professional features unheard-of in its price range.

Unlimited Applications

A-Squared is looking at several applications for the Amiga digitizer. One area of interest is the creation of color separations for silk screen, T-shirt and other medium-resolution printers. The systems now in use cost over $20,000.

Thermal studies using an infrared camera are useful diagnostic tools in sports medicine. Injured joints show up hotter than the surrounding tissue. An Amiga, digitizer and thermal camera would bring the cost down to a level that a small clinic could afford.

Other uses for digital image processing are limited only by your imagination and your pocketbook. The addition of visual images to a business report can make the difference between just another report and a complete presentation. Visual databases can be used for inventory-control purposes, allowing an operator to visually match a stock item without knowing its part number. Parts suppliers could offer electronic catalogs of their products, on disk with an integrated ordering application. Updates could be easily added without the cost of reprinting a paper catalog. In fact, they could be sent over the telephone lines via modem.

Real-estate listings could be available on-line and include pictures of the properties. Lot size, floor space, age and condition of each building could be listed, as well as information on current loan costs and comparables. Financial calculations on monthly payments, property taxes, insurance and closing costs could be added to a printout of the property for prospective buyers to study at their leisure.

Security and law enforcement personnel could maintain an image database of faces along with personnel records. Signatures could be added to the file and compared using software. It's hard enough to forge a signature, let alone a face.

Medical records could include X-rays, sonigrams, cell slides or other visual information. In the long run, it might be possible to create a standard for the storing and retrieving of medical data. This would allow for a universal medical Eprom card containing all of an individual's lifetime medical records.

There are other medical applications. Using a variety of image-manipulation functions known as *radiometric operations,* it is possible to enhance the usefulness of an image. Contrast stretching is used when all of the pixel brightness values in an image fall into a small range. By taking the lightest values and redefining them as white and the darkest values as black, and linearly varying the midvalues, it is possible to increase the useable information in an image.

Another function is *density slicing.* By selecting pixel values that fall within a specific range, it is possible to select certain details within an image and highlight them. This process is often aided by the use of *pseudo-color processing*, which involves assigning colors to ranges of pixel values. You've seen this in pictures taken from the LANDSAT satellites.

Some additional techniques include *spatial operations*. Spatial texture, registration procedures, filtering and feature extraction are some of the operations that are used in image processing of CAT scan results, structural X rays, thermal analysis, nondestructive testing, astronomy and geophysics.

There are a tremendous number of other applications: interior design, computer-aided design and manufacture, robot vision, video post production, sports training, graphic arts, computer simulation, motion study, electronic art, animation and hundreds of educational possibilities.

Home uses also come to mind. More and more families are using video cameras instead of Super 8. A digitizer would allow for the creation of either a disk-based picture album or hardcopy still images. With the coming of CD-ROM-based encyclopedias, a digitizer could be used to include diagrams and pictures in school reports and homework assignments. Children could color in digitized images of their favorite Saturday morning cartoon characters. MTV fans could create their own posters of rock stars.

Bright Future

The future of digital image processing is bright. Improvements in image resolution will continue at an accelerated pace as the cost of memory falls. Sophisticated data-compression software may decrease the needed RAM to store an image and allow digitally stored images to approach the resolution of taped images at a cost that businesses can afford.

Linked to a laser printer, image processors will combine many of the functions of the office photocopier, fax machine and graphics workstation. Connected to a video projector, they will replace the 35mm slide projector in business presentations. The addition of optical character recognition capability will create a system that can interactively learn new fonts, read a printed page and convert it to an ASCII file.

As more people purchase digitizers, more software applications will be created by third-party developers. Education, graphic arts, manufacturing and business will all benefit from the use of digital image technology.

As a graphics workstation, the Amiga should be at the forefront of low-cost commercial and consumer applications of image processing. The potential of the Amiga with A-Squared's digitizer in the graphics/video markets should give the Amiga a tremendous boost.

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