Digital-camera interfaces lead to ubiquitous deployment

Low-cost digital cameras and evolving interfaces simplify video-capture tasks. Meanwhile, software developers tackle advanced edge- and motion-based algorithms for compelling visual applications.

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After years of hype, 1998 may be just the year that desktop-computer users get widespread access to video-input devices. Prices of low-end cameras have dropped to the magical $100 level, and a variety of ways to interface cameras and computers have emerged. More important, software developers have finally conceived more compelling applications than so-so videoconferencing. For example, new motion- and edge-detection algorithms enable applications ranging from security systems to inspection systems to gesture-recognition-based PC control. Designers considering video input for a new product or for their own use could find the emerging technologies an imminently affordable and technically feasible option. Don't evaluate cameras as a first step, however. You must first consider your application and its requirements in terms of frame rate, resolution, the amount of video you need to capture, as well as real-time requirements. Then, find the best interface or medium that can move that video into a computer.

For years, you could go to a tradeshow, such as Comdex, and hear about dozens of compact videocameras pitched as the next persistently connected peripheral for desktop computers. One or two systems, such as a relatively expensive Silicon Graphics (Mountain View, CA) workstation, actually include a camera as a standard feature. The mass market, however, waiting for either low prices or compelling applications to break a stalemate, has procrastinated in adopting video-input technologies.

Throughout the years of waiting, you've likely heard that videoconferencing would be the breakthrough application for desktop video. Unfortunately, compelling videoconferencing requires a broadband connection between two systems, and many users will still wait years for that connection. Because of the widespread use of the Internet and e-mail, however, the acronym for videoconferencing, VC, suddenly has a new meaning—visual communications. Consumers, it seems, have taken to posting short video clips on the Web or even e-mailing short clips to friends or business associates as attached files. Connectix, the market leader in retail sales of low-cost PC cameras, asserts that more than 50% of its customers use PC cameras for "Net socializing." Such socializing eliminates the high-speed, real-time-transmission requirements that are a roadblock to both videoconferencing and low-cost cameras for PCs.

Net socializing spurs market

Connectix believes that the Net-socializing trend could spur PC manufacturers to include a camera in 10% or more of all systems sold by the '98 end-of-the-year holiday buying season. Despite the success of Net socializing, however, emerging algorithms and applications will hold more allure for many users and open the door for camera use in many embedded systems. For example, Prescient Systems' Gotcha software uses a motion-detection algorithm that you can use in security, remote-data-acquisition, medical, and other systems. Reality Fusion, meanwhile, uses edge-detection techniques with a camera to capture user input through gestures. (See box *"Innovative algorithms spur application development" for details on these algorithms and some sample applications.)*

Of course, any widespread adoption of cameras and video input in desktop or cost-sensitive embedded systems depends on a low-cost way to get video into the computer. Fortunately, camera prices are

@a glance

- DROPPING PRICES MAKE CAMERAS A VIABLE PERIPHERAL FOR EVERY DESKTOP.
- INNOVATIVE ALGORITHMS ALLOW DESIGNERS TO DEPLOY CAMERAS IN MORE APPLICATIONS THAN JUST VIDEOCONFERENCING.
- OMNIPRESENT PARALLEL AND USB INTERFACES ARE ATTRACTIVE AS CAMERA INTERFACES BUT SIGNIFICANTLY RESTRICT IMAGE SIZE AND FRAME RATE.
- FAST PROPRIETARY INTERFACES AND FIREWIRE ALLOW DESIGNERS TO CAPTURE 30-FRAME/SEC VIDEO AT VGA RESOLUTIONS.

dropping, and interfaces and other video media have emerged for just such purposes.

If you've conceived a potential application for video input, first think about how you will get the video into the computer. Certainly, low-cost cameras for applications such as Net socializing require a persistent and low-cost connection to a PC. Other applications, such as video editing, may use an occasional PC connection yet require an untethered camera for video capture. Even applications for tethered cameras may require higher data rates and lower latency than the low-cost interfaces available on every PC. A discussion of the available interfaces may help you decide.

Frame grabbers disappear

Traditionally, the first choice for capturing video centered on analog cameras that output either NTSC or PAL composite video and connected to a video-capture or frame-grabber card in a computer. Some systems integrated the circuitry necessary to display the analog image, but any manipulation of the image required A/D conversion in the frame grabber. Two characteristics made the analog approach popular. First, the lack of A/D circuitry in the camera minimized the camera's cost. Second, no low-cost and

INNOVATIVE ALGORITHMS SPUR APPLICATION DEVELOPMENT

SPELLBINDING—THAT'S THE ONLY WORD TO DESCRIBE THE CAPABILITIES OF SOME EMERGING VIDEO ALGORITHMS THAT WORK WITH LOW-COST VIDEOCAMERAS. IMAGINE PLAYING A COMPUTER GAME, SUCH AS SIMULATED BASKETBALL, BY USING YOUR OWN HANDS IN FREE SPACE, RATHER THAN A GAME PAD OR JOYSTICK, AS AN INPUT DEVICE. OR SET A CAMERA WITH A C-MOUNT LENS ON A MICROSCOPE, AND HAVE A MOTION-DETECTION ALGORITHM RECORD SHORT VIDEO CLIPS OVER DAYS OR WEEKS ANYTIME BACTERIA MOVES. THESE ALGORITHMS PROMISE TO ALLOW DESIGNERS TO DEPLOY VIDEO-CAPTURE CAPABILITIES IN UNTOLD EMBEDDED APPLICATIONS, AND END USERS CAN USE THE SAME ALGORITHMS FOR ENTERTAINMENT AND HOUSEHOLD PURPOSES.

FOR $44.95, PRESCIENT SYSTEMS OFFERS ITS GOTCHA PACKAGE, WHICH USES A MOTION-SENSING ALGORITHM TO ENABLE APPLICATIONS FROM SECURITY SYSTEMS TO BOTANY OR BIOLOGY EXPERIMENTS. THE SOFTWARE ALLOWS YOU TO SET PARAMETERS THAT TRIGGER A CAMERA AND COMPUTER TO ACTION. FOR EXAMPLE, YOU CAN PROGRAM HOW MUCH MOTION IS NECESSARY FOR A CAMERA TO START CAPTURING A VIDEO CLIP AND HOW LONG THE CLIP SHOULD BE. YOU CAN EVEN MASK PORTIONS OF THE VIDEO FRAME AND ALLOW MOTION IN THOSE AREAS, WHILE MOTION IN UNMASKED AREAS SPURS THE SYSTEM TO ACTION. THE SOFTWARE CAN ALSO INSTIGATE OTHER ACTIVITIES. FOR EXAMPLE, IN A SECURITY SYSTEM THAT DETECTS MOTION, GOTCHA COULD DIAL UP A REMOTE COMPUTER AND TRANSMIT A VIDEO FRAME SHOWING THE INTRUDER IN ACTION. Figure A SHOWS GOTCHA CATCHING A NOTEBOOK-COMPUTER THIEF.

IT'S TOUGH TO DESCRIBE ALL THAT YOU CAN ACCOMPLISH WITH GOTCHA. GO TO PRESCIENT SYSTEMS' WEB SITE, AND YOU CAN VIEW VIDEO SEQUENCES THAT SHOWCASE THE CAPABILITIES BETTER THAN WORDS OR PRINT MEDIA CAN DESCRIBE. EXAMPLES OF GOTCHA'S CAPABILITIES INCLUDE A 5-MINUTE SEQUENCE OF A FLOWER BLOOMING, WHICH THE PACKAGE CAPTURED OVER TWO DAYS. LOOK FOR GOTCHA BUNDLED WITH SOME CAMERAS. EVEN THE COMPUTER-VIRUS EXPERTS, MCAFEE (SANTA CLARA, CA), BUNDLE GOTCHA SO THAT YOU CAN PROTECT THE OUTSIDE OF YOUR COMPUTER ALONG WITH THE INSIDE. GOTCHA WORKS WITH ANY CAMERA THAT CAN PRODUCE A VIDEO FOR WINDOWS STREAM.

REALITY FUSION OFFERS AN ALGORITHM THAT USES A CAMERA TO PERFORM EDGE, SHAPE, AND COLOR DETECTION. A $29.95 DEMO PACKAGE—VARIETYPACK—SHOWCASES THE TECHNOLOGY IN COMPUTER-ENTERTAINMENT APPLICATIONS, SUCH AS THE AFOREMENTIONED BASKETBALL GAME. THE CAPABILITIES EXIST, HOWEVER, TO COMPLETELY CONTROL A PC WITH GESTURES AND BODY MOVEMENT. YOU CAN ALSO USE THE ALGORITHM TO ISOLATE OBJECTS, CAPTURE OBJECTS, AND USE THE COMPUTER TO PLACE OBJECTS IN ANOTHER SCENE. THE ENTERTAINMENT ANGLE FOR THE TECHNOLOGY IS CLEAR, BUT EMBEDDED DESIGNERS COULD USE THE ALGORITHM IN HANDS-FREE MEDICAL, SIMULATION, AND OTHER APPLICATIONS.

THE REALITY FUSION ALGORITHM IS EXTREMELY COMPUTE-INTENSIVE AND, IN FACT, HAD TO BE HAND-CODED IN ASSEMBLY LANGUAGE. THE ALGORITHM REQUIRES A CAMERA THAT PROVIDES 15-FRAME/SEC VIDEO AT A MINIMUM AND WORKS BEST WITH A 30-FRAME/SEC STREAM. THE COMPANY IS CURRENTLY WORKING WITH PARTNERS TO CUSTOMIZE AND EMBED THE TECHNOLOGY IN OTHER APPLICATIONS. IN THE SECOND HALF OF THIS YEAR, REALITY FUSION PLANS TO SHIP A SOFTWARE-DEVELOPMENT KIT THAT ALLOWS WIDESPREAD ACCESS TO THE ALGORITHM.

EVEN IF YOU DON'T CURRENTLY USE A CAMERA WITH YOUR COMPUTER, GO TO THE PRESCIENT SYSTEMS AND REALITY FUSION WEB SITES, AND PLAY WITH THE DEMOS. THESE ALGORITHMS WILL SURELY SPUR THOUGHTS OF INNOVATIVE APPLICATIONS. MOREOVER, BOTH COMPANIES ALLOW YOU TO DOWNLOAD TRIAL VERSIONS OF THEIR SOFTWARE FOR FREE.

FIGURE A

A sequence of captured-video frames shows the capabilities of Prescient Systems' Gotcha in office-security applications.

convenient interfaces existed to connect a digital camera.

You can still buy video-capture cards for low-resolution video applications, but the market is disappearing fast. For example, Winnov sells the Videum AV capture card for $199, and that board has been bundled with analog cameras sold by some large vendors, such as Philips (Sunnyvale, CA) and Sony. At VGA resolutions (640×480 pixels) and lower, the camera market is transitioning toward digital cameras that combine the image-sense element, such as a CCD, with A/D and video-manipulation electronics. At the low end, manufacturers have moved to digital cameras so that the user won't have to open a PC and install a capture card. Moreover, you can sometimes more easily move a digital camera from system to system than you can an analog camera. Placing more intelligence in the camera head, however, can offer technical advantages as well. For example, Silicon Vision has used a digital camera and interface to develop an application-programming interface (API) that allows software developers to control the fine details of camera operation, such as color saturation and exposure.

Capture cards will remain popular at higher resolutions for several reasons. For starters, higher resolution imaging elements generate orders-of-magnitude faster digital-video streams, and few digital interfaces can handle the requirements. Moreover, a capture card in a computer allows an algorithm to immediately sort out a specific region of pixels of interest. Therefore, high-end inspection and image-processing applications will continue to use capture cards. Watch for the Mar 2, 1998 issue of EDN *for a report on image-capture boards by Senior Technical Editor Dan Strassberg.*

USB and parallel interfaces

In late 1994, Connectix started the trend toward low-cost digital cameras with its QuickCam, which aimed at persistent connection to a PC. The company correctly anticipated that many end users didn't want to open PCs and add a capture card, and the company knew it must deliver an outboard digital camera at low cost. The original QuickCam sold for $100 and could capture only gray-scale images, yet it was a breakthrough product. The camera used the parallel port for the PC connection, and every PC had a parallel port. Today, the latest product, QuickCam VC, still comes with a parallel-port interface or an optional USB interface yet can capture 24-bit color images.

Today, it appears that USB and the parallel port offer the only options through which a user can connect a camera without additional hardware and without opening the system. USB and parallel ports, however, impose significant limits on the size of the image you can capture and on the frame rate of the captured video. The interfaces are simply too slow for some applications.

You may find several flavors of parallel ports on PCs and even some older systems that are limited to unidirectional transfers. Most recent systems, however, include bidirectional ports, and the newest systems support ports that operate in one or two advanced modes—ECP (extended-capabilities port) and EPP (enhanced parallel port). ECPs support data-transfer rates faster than 4.7 Mbps, with some implementations reaching approximately 6 Mbps. USB, meanwhile, offers a theoretical-peak data rate of 12 Mbps, but tests by EDN *editors reveal that users will likely experience sustained rates around 6 Mbps (*references ` *and* ´*). Moreover, additional devices on the bus can further degrade performance. The point-to-point parallel port will probably offer slightly faster transfers in most cases, but USB offers the advantage of connecting multiple peripherals and avoids the parallel port where users regularly connect printers.*

Interface limits image size

To decide if USB or a parallel interface suits your application, consider the video performance of some typical cameras. These devices generally have imaging elements that can capture around 352×288-pixel Common Intermediate Format (CIF) images, because the cameras target videoconferencing as a key application. (See box *"Video formats" for information on video-format standards.) All of the cameras also support smaller images, such as QCIF (Quarter CIF) or QSIF (Quarter Standard Image Format).*

Even a CIF video stream far exceeds the capabilities of USB or the parallel port, especially if you try to capture 30 frames/sec. Camera vendors typically allow you to vary image size, frame rate, and color depth to meet a given application requirement. For example, USB or the parallel port can handle an SIF image with 8-bit color at 10 frames/sec. Only cameras that perform video compression in the camera head can transfer 30-frame/sec images to a host.

You can already see a shake-out in the

VIDEO FORMATS

STANDARDS BODIES IN THE UNITED STATES AND EUROPE DEFINE BOTH SIGNALING AND PICTURE FORMATS FOR USE WITH MOTION VIDEO. THESE STANDARDS AND FORMATS USE TYPICAL TECHNO JARGON, AND WITHOUT SOME BASIC UNDERSTANDING OF THE TERMINOLOGY, YOU CAN QUICKLY BECOME LOST READING DATA SHEETS FOR DEVICES SUCH AS CAMERAS. FOR EXAMPLE, THE TERM NTSC (NATIONAL TELEVISION SYSTEM COMMITTEE) REFERS TO A COMPOSITE COLOR VIDEO SIGNAL IN THE UNITED STATES, AND PAL (PHASE-ALTERNATION LINE) REFERS TO A SIMILAR EUROPEAN STANDARD.

WITHIN THE NTSC AND PAL STANDARDS, YOU CAN FIND SEVERAL PICTURE FORMATS, INCLUDING:

- SIF (STANDARD IMAGE FORMAT)—A 320×240- (NTSC) OR 384×288- (PAL) PIXEL IMAGE.
- QSIF (QUARTER STANDARD IMAGE FORMAT)—A 160×120- (NTSC) OR 192×144- (PAL) PIXEL IMAGE.
- CIF (COMMON INTERMEDIATE FORMAT)—A 352×288-PIXEL FORMAT SPECIFIED AT 29.97 FRAMES/SEC FOR VIDEOCONFERENCING APPLICATIONS.
- QCIF (QUARTER COMMON INTERMEDIATE FORMAT)—A 176×144-PIXEL FORMAT SPECIFIED AT

USB-camera market over these limits. Kodak, for example, was the first company to market with its $200 DXV 300 USB camera, which included a 640×480-pixel CCD and 24-bit support. Unfortunately, the camera can't perform compression, so it's practically limited to still-image capture. Intel also sells a USB camera without compression capabilities.

USB proponents argue that the achievable data rates perfectly suit the target market, and they have a valid point. Dial-up videoconferencing systems can't transmit video streams that are any faster than the ones these cameras produce, so a camera sold to the videoconferencing market needs no further capabilities. Unfortunately, users and certainly embedded-system designers might find many more uses for faster, low-cost cameras. Therefore, vendors that have added image-compression capabilities will probably find much greater market success.

Compression boosts frame rate

Xirlink's $199 USB camera offers a proprietary 18-to-1 video-compression scheme that allows 30-frame/sec video capture, despite the interface's limitations.

Consider a few USB/parallel-port cameras and their capabilities. Connectix has a proprietary Videc compression algorithm that delivers 4-to-1 compression with no loss in image fidelity and 16-to-1 compression in a lossy mode. The compression yields CIF images at rates faster than 15 frames/sec. The company also asserts that it achieves sustained 10-Mbps USB rates by eschewing the USB isochronous transfer mode in favor of bulk transfers. Connectix offers the $99 QuickCam VC at retail and sells to OEMs.

Xirlink offers an even more powerful compression engine with its $199 Video Phone USB camera. The company's Vice compression engine can perform lossless compression at ratios as high as 18 to 1, depending on the content. The company asserts that it achieves 7.5-Mbps USB rates, allowing the camera to handle 30-frame/sec video in both SIF and CIF modes.

VLSI Vision, meanwhile, harnesses compression techniques and has a camera with a revolutionary CMOS image sensor that promises to further reduce camera costs (see Reference .. *for more information on CMOS image sensors). The company's Vision family uses a lossy compression technique to deliver maximum 8-to-1 ratios. At a 5-to-1 ratio, the camera delivers QCIF video at 20 frames/sec and CIF video at 15 frames/sec. The CMOS imager allows VLSI Vision to integrate additional functions*

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VIDEO CAPTURE

on the same IC with the imager and produce a true one-chip camera. Moreover, the CMOS imager reduces power consumption and works from a 5V supply. VLSI Vision asserts that it can deliver cameras to OEMs in large volume at prices less than $50. The company offers a USB version, a parallel-port version, and a camera with both interfaces. Two well-received retail cameras from Vivitar (Newbury Park, CA) and Creative Labs (Milpitas, CA) use VLSI Vision's OEM camera and sell it for $139 with a software bundle.

Increasing data rate

Although these USB and parallel-port cameras offer the simplest way to capture video, you may find you need faster frame rates or larger images, especially in real-world applications. Surprisingly, it doesn't cost a lot more to buy a better camera, and designers working on complex applications certainly shouldn't hesitate to use a product requiring an add-in card. An analog camera and a capture card offer one option, but you can also buy digital cameras with faster interfaces.

Several companies have digital cameras that use proprietary interfaces to supply full-color, 30-frame/sec video. For example, Silicon Vision offers two types of cameras and ISA, PCI, and PC Card interfaces that OEMs can mix and match. In fact, the company provides OEMs with a turnkey camera and board or sells the building blocks, such as ASICs and the internal parts of the camera. Therefore, OEMs can build a Silicon Vision camera into another product.

Silicon Vision calls its camera iCam, its nine-pin interface CamPort, and its host-interface IC CamHost. The camera uses a 512×492-pixel CCD imager and supports 16 million colors. The company specifies no data rate for its interface but guarantees that the interface can handle a 16-million-color, 512×492-pixel stream at 30 frames/sec. The PC Card version of Silicon Vision's interface uses the zoomed-video standard to attain the high rate.

In addition to a fast video rate, Silicon Vision has pioneered software control for its cameras (φigure `). The company has published an API that allows programmers complete control of the camera. Embedded designers should also note that Silicon Vision offers a camera body with a C-mount lens in addition to a plastic-encased camera typical of the PC market. The removable lens on the C-mount camera allows you to adapt it for fields of vision ranging from microscopic to several miles. The company asserts that OEMs can produce a complete camera kit using its technology and sell the kit for less than $300. Indeed, some of Silicon Vision's OEMs showed products at Comdex Fall '97 that will retail for less than $200.

Professional rates

Even some companies that squarely target videoconferencing realize the need for speed. Winnov, for example, sells cameras to the corporate-videoconferencing market and has also announced digital cameras to complement its capture cards. The company's new VideumCam comes in both desktop and notebook versions and sports a 3.5-Mbyte/sec interface called Media-Plug. The camera sells for $299 with an interface card, includes a 320×240-pixel CCD imager, and handles SIF and CIF video at 30 frames/sec. The company also offers a MediaPlug ASIC that OEMs can integrate directly into their systems.

VLSI Vision has also made provisions for faster data rates in its CMOS-sensor-based Vision cameras, although the company does not directly offer a turnkey product. The company is shipping a version of the camera—Vision QS—that supports 30-frame/sec SIF and CIF video via a proprietary nine-pin interface. VLSI Vision has partnered with Rockwell Semiconductor to support the camera as an option to a 56-kbps modem. The bundle uses the DSP in the Rockwell modem chip to handle image manipulation, making the camera head even cheaper. Several of Rockwell's modem customers plan to sell the modem/camera bundle for less than $300. VLSI Vision, meanwhile, offers the ASICs necessary for other OEMs to use the Vision QS camera and may offer turnkey PCI or PC Card interfaces.

What Silicon Vision, Winnov, VLSI Vision, and other companies are waiting for is ubiquitous deployment of the IEEE-1394, or Firewire, interface. Firewire supports data rates from 100 to 400 Mbps and can handle uncompressed video even as the image size grows. Unfortunately, you won't find 1394 as a motherboard feature until at least late this year. Meanwhile, companies such as Silicon Vision and Winnov can sell their own proprietary interface cards for less than they can a 1394 host adapter. Still, all of these companies believe that 1394 is the future of desktop-camera interfaces.

In fact, you can already buy 1394 cameras from several sources. Moreover, Adaptec offers several host adapters that start at around $300 and include models with multiple 1394 ports and a model with both 1394 and SCSI channels. Sony led the way in 1394 cameras with its CCM-DS250. The company labeled the product a communication camera, but it can serve a variety of applications. The camera can capture VGA images and

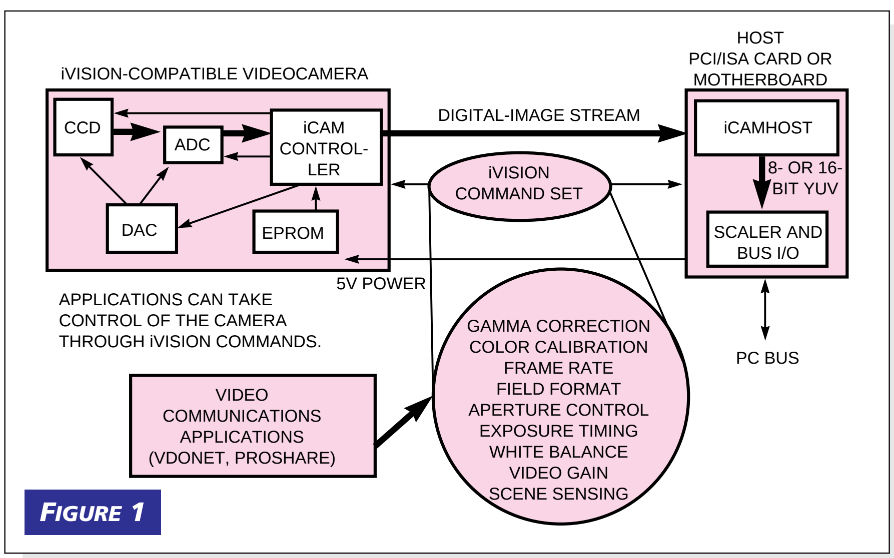

FIGURE 1

A proprietary digital interface allows Silicon Vision to offer software-based control of most aspects of its iCam cameras, which capture 30-frame/sec video.

transfer the video stream at a full 30 frames/sec using 1394. Moreover, the camera includes numerous features, such as powered focus and a 12× zoom lens that you can't find on low-end cameras. The CCM-DS250 sells for $750.

At Comdex Fall '97, Sony introduced a second 1394 camera that suits embedded applications, such as circuit-board inspection and laboratory analysis. The new DFW-V300 features a compact, streamlined body and weighs just 7 oz. Moreover, the camera uses a standard C-mount lens, so it adapts to many applications. Sony plans to ship the camera in February but has yet to price the unit. Expect a price, however, nearer to the CCM-DS250 price than to the price of low-end desktop cameras. Also at Comdex, Panasonic and LG Electronics became the next companies to demonstrate 1394 cameras for communications, industrial, or embedded applications. Unfortunately, both companies showed working models but provided no detailed specs or information on price or availability.

Outboard, real-time MPEG-1 encoders, such as Futuretel's $400 Video Sphinx Pro, have dipped to astonishingly low prices.

You should note another class of cameras that sport 1394 interfaces. Digital camcorders from every major consumer-electronics company include a 1394 interface, and professional and high-end video producers regularly use these cameras for video composition and editing. These untethered cameras offer an optimal way to capture video and later download the clips into a PC, but the cameras start at more than $1000 and can cost as much as $2000 or $3000.

Recently, the cost of moving video from an analog camcorder or VCR to a computer has substantially dropped. For example, Futuretel, Dazzle Multimedia, Avermedia, and Videonics just announced outboard peripherals that connect to a parallel port and perform real-time MPEG-1 compression on an NTSC or PAL video signal. The 200-to-1 compression ratio that MPEG-1 achieves eliminates parallel-port bandwidth issues. A breakthrough in MPEG encoding ICs by C-Cube (Milpitas, CA) has allowed these companies to offer these peripherals for $299 to $399. The Futuretel Video Sphinx Pro costs the most at $399 but offers MPEG audio compression as well as video compression. The other products rely on a sound card to capture audio. Dazzle Multimedia, in addition to its $299 Dazzle outboard encoder, offers a $399 PCI-based encoder card called Snazzi. All of these products have dipped to extraordinarily low prices. Previously, MPEG encoders bottomed out around $1000, with most units costing substantially more.

As you might note, these MPEG encoders revert to the use of analog cameras because generally, users can't afford a camera with an MPEG encoder. You can buy such a device today, however, from Hitachi. The company's MP-EG1A videocamera costs $2400, includes a 6× zoom lens, and encodes a 352×240-pixel video stream. The camera also offers a unique way to move video from camera to computer. You can buy an optional cable connection and add-in card. As standard equipment, however, the camera comes with a 260-Mbyte hard disk in a PC Card package. Capture 20 minutes of full-motion video to the disk, and then you can slide the PC Card out, insert it into a PC Card slot on a computer, and copy the file.

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