REVOLUTIONIZING

Digital Video

The Digital Revolution Rages On, But It's No Longer About Still Cameras

By Dan Reid

The start of the digital still camera revolution several years ago brought with it many questions and reservations about the new, emerging technology. "How will my photography benefit from digital capture?" "Is the image quality comparable to that of 35mm film?" Time has been the true test. New models of digital still cameras have been continually introduced, each bringing evolutionary improvements that have helped solidify and validate their place in photography. We now are entering an era of similar upheaval with the progression of digital video (DV). The ease of use and picture quality of new digital video cameras rival some professional analog video cameras today. We will soon see how new digital video camera technology can and will benefit videographers, photographers, and digital artists alike.

There are four types of consumer analog video. VHS and 8mm tapes record video signals using a single channel of information, while Hi-8mm tapes and S-VHS record two separate channels: chrominance (color) and luminance (grayscale). The luminance portion of the signal is referred to as the "Y" part, which contains all of the detail and picture information. The chrominance contains all of the color information. Because VHS tapes record only a single channel, it's difficult to control the sharpness and color information in the signal.

Digital video tapes record video signals using a very different method. DV tapes are encoded in a component format comprised of three signal channels. Professional videographers prefer to use a component format because it provides much more control over each signal channel throughout the production process. Component broadcast and digital video cameras allow each signal to be carefully monitored and isolated from signal cross-talk, bleeding, and noise—all of which can degrade picture quality.

Another benefit digital video cameras have over analog cameras is their ability to carry out compression and quantization into a digital format at the camera stage. Since analog video records electrical impulses onto a magnetic cassette, there is an inherent problem with generational loss when the tapes are edited or copied. Color and sharpness are altered, and it's difficult to reproduce the shape and intensity of the electrical impulses without distortions. When copies are made, the electrical impulses become weaker and deformed, due to the characteristics of the player and recorder. Degradation is exacerbated by the continual shuttling of tapes back and forth during editing. Metal oxides that were once the information recorded on the surface of the tape rub off and coat the rollers and capstans of the player, eating away at the tape each time it is played. This is why copies of video tapes look different from the originals.

However, all of these problems are negated by digital video. Because the information recorded on DV tapes is composed of ones and zeros, there can be no deformation of the signal. An exact copy of the ones and zeros is made possible through the digital link of FireWire into the computer.

Currently, videographers must use a video capture card in their computers to digitize analog footage. Digitizing analog video footage with a capture card is essentially the same process used by digital video cameras, except for a few distinct disadvantages.

Analog video is encoded with a numerical system different from that used in computers. An analog video signal records information on a scale that ranges from 16 to 235, while computers encode files in a binary system. RGB files record pixel information on a scale of zero to 256. This means that some interpolation or rounding of numbers may occur if the resulting video file is encoded in an RGB format. This quantization error is further intensified by the typical hardware compressor used in video capture devices, motion JPEG (MJPG). All MJPG files are encoded as 8-bit files. This means only 256 steps are used to determine the ones and zeros of the resulting computer file (2^8=256). This relatively low bit depth explains why it is difficult to obtain color fidelity comparable to that of the original tape. If digitized video files were to be encoded with 10 bits of information, quantization errors could be decreased by the closer steps (2^{10}=1,024), resulting in a threefold decrease in quantization errors.

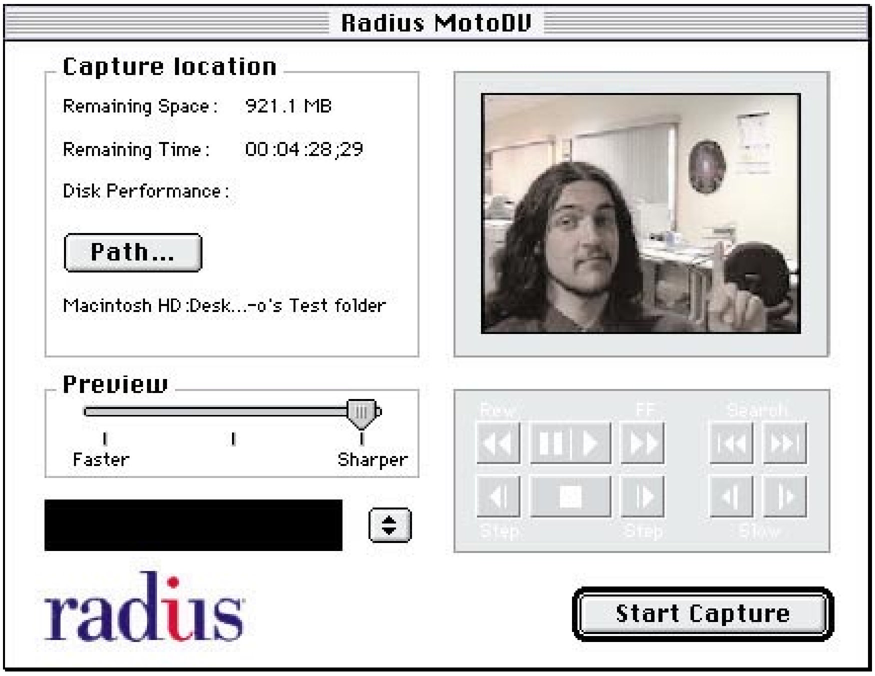
Video images can also degrade through the reverse process, outputting from digital to tape. When outputting back to analog tape, the binary number system must be translated back into the conventional numerical system of video. This effectively doubles the potential for errors to occur in the editing process. Digital video cameras don't have this problem, because there is never a conversion to analog during the editing process. It is only necessary to convert to analog once, if you want to make VHS copies.

Some video professionals jumped on the digital video camera bandwagon early on, before FireWire was introduced. These individuals assumed they had a cleaner, noise- and artifact-free, edited tape. What they did not realize was that there were errors and signal degradation imposed by their non-linear editing systems. They were recording in a digital component format, outputting to a two-channel analog signal from the camera, and then redigitizing the information. Remember, our digital video tapes record three pristine channels of information. Early in the acquisition process, information was thrown away. The analog signal was then converted back into digital format by the video capture card in the computer. More information was lost, and more errors introduced. Once edited, the final piece was output back onto analog tape. A total of three signal conversions were performed! Today, FireWire circumvents the problems inherent in analog video capture devices.

FireWire

FireWire is the umbilical cord between the digital video camera and computer. FireWire was invented to transfer large amounts data quickly over long cable lengths, with up to 60 devices attached at one time. To videographers, FireWire is an answer to their prayers, because of its ability to transfer video's tidal wave of data in a manageable way. Digital video is the first of many products to take advantage of FireWire.

Each video clip contains several small pictures commonly referred to as frames. The number of frames per second (fps) determines how fluid the motion appears. A typical one-second clip contains 30 small pictures (more precisely, 29.97 fps for U.S. broadcast). When you ask your video capture card to digitize one second of video, you are essentially saying, "Make me 30 small pictures for this one-second clip." So, in the blip of a second, 30 pictures are extracted from the videotape. This puts a tremendous demand on your digitizing device,



The author (above) uses Radius MotoDV capture utility to bring DV footage into his computer.

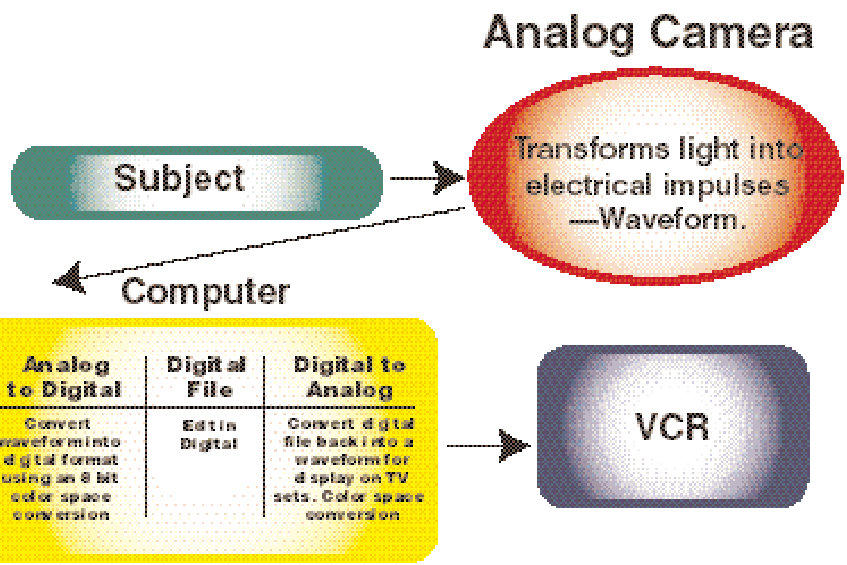
hard disk, and CPU, as they try to keep up with the data flow.

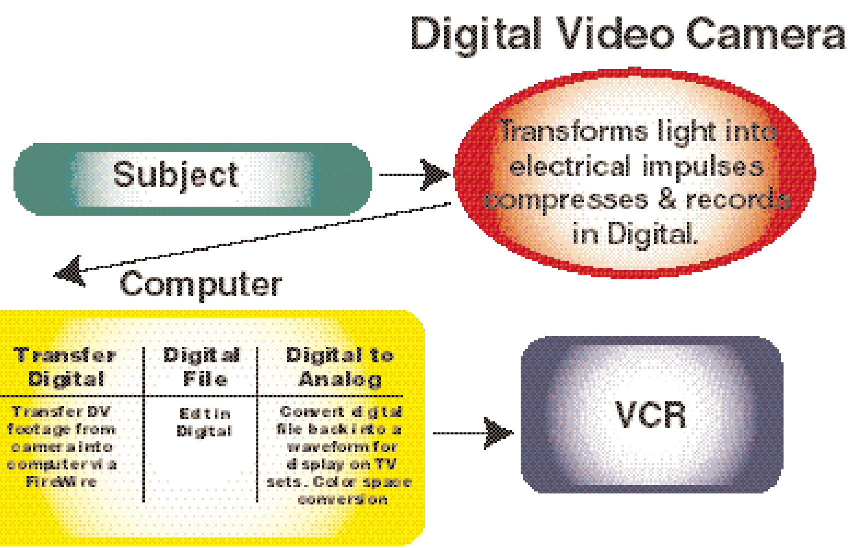
In the past, it was necessary to find a video capture card that had mild compression to minimize the artifacts prevalent in the digitization process. As data compression rates became lower, larger files resulted. Expensive hard disks and SCSI cards were necessary to allow this torrent of data to pass uninhibited to and from the hard drive. Videographers had to invest in numerous expensive hard drives to keep up with the video data and storage space requirements. They digitized their component (three-signal) video with a mild 2:1 or 3:1 compression ratio. This resulted in a file size of about 300K per frame. This doesn't sound like much, until you start doing the math.

Remember, each second of video contains 30 frames. If you multiply 30 frames by 300K per frame, you get 9MB. That's 9MB per second! If you want to capture a minute of video, you now have a 540MB file for that one minute of video (9MB x 60 seconds = 540MB). Broadcast professionals can easily go through gigabytes of disk space just to create a short project.

Digital video cameras record data at a fixed rate of 3.55MB per second. This data rate is comparable to the compression used for S-VHS and Hi-8mm formats. Though the data rates and compression may be the same, the image clarity with DV cameras is far superior.

Digital video cameras can resolve more detail than consumer video formats. (Resolution is determined by how many scan lines are visibly displayed. Standard VHS and 8mm tapes have a horizontal resolution of 240 scan lines, while S-VHS and Hi-8 have resolutions of 400-450 lines. DV cameras record with 525 lines of resolution, about a 25 percent increase over S-VHS and Hi-8. Remember that resolution and detail reside in the luminance or Y portion of the signal. By separating the signals, resolution is preserved throughout the editing process.





Digital Video vs. Pro

But how does DV compare to the professional gear used in broadcast? The industry standard is Beta SP, a component format with a robust color space of 4:2:2. A 4:2:2 color space means the luminance signal is sampled twice as much as the color information. Beta SP format is commonly referred to as YUV color space. A YUV color space translates into luminance (Y), color under (U), and color over (V). The two samples from color under and color over together equal the luminance portion of the signal. The color under and color over components are derived by red minus luminance (R-Y) and blue minus luminance (B-Y). This data compression scheme was derived in the 1950s, when broadcasters needed to continue broadcast of black-and-white signals and also, without changing the signal, incorporate color into the transmission. Black-and-white television sets are still able to receive these signals, since the luminance is separate from the color, while a color television's receiver is able to decode the color information in the same signal.

The DV format records in a component color space of 4:1:1, so the color information is sampled half as much as Beta SP. This makes DV inappropriate for broadcast applications. Tapes that are of true "broadcast quality" have a color fidelity that can hold up through the rigors of transmission.

Other factors influence broadcast quality. Most DV camera users will not be broadcasting their videos through a television station; rather, the tapes will be viewed directly on computer screens or television monitors. All consumer DV cameras record in the 4:1:1 color space, including Sony's DVCam and Panasonic's DVC-Pro. Both the Sony and Panasonic use more robust DV tapes, but lack the color fidelity necessary to hold up in broadcast. However, many TV stations have switched to these DV formats.

The only true 4:2:2 DV cameras currently produced are JVC's Digital-S, Sony's Betacam SX, and Panasonic's forthcoming DVC-Pro 50. The JVC system has a standard VHS/S-VHS shell, making it backward compatible with analog formats. Since DV chips record only 4:1:1, JVC uses two of them to obtain a 4:2:2 color space. The tape size of these professional formats can withstand the rigors of editing. Consumer DV tapes are quite small and could break if care is not taken in handling and shuttling.

Is DV for You?

Now that you know the process and mechanics behind digital video, how is DV going to benefit you in producing Web and multimedia productions? We know that the signal is cleaner coming into the computer because of the component format and acquisition through FireWire. We will also assume that your audience will be viewing the final product on a computer monitor. We can surmise then that video compression down to computer distribution platforms should be very easy.

Digital video cameras are the solution for multimedia artists who want to incorporate video into their productions. With digital video, it will no longer be expensive, confusing, or frustrating to integrate video into multimedia productions. Acquiring digital video footage is as simple transferring files from a Jaz disk to an internal drive.

The superior image quality lessens the artifacts introduced with recompression to a Web or CD-ROM production. Because the video is encoded in a digital format at the camera stage, there is no intermediate color space change or compression needed. The only compression necessary after acquisition into the computer is for the final delivery platform. This single compression eliminates the numerous compressions and color space conversions necessary with traditional analog video—all of which introduce noise or artifacts into the video signal. Because digital video cameras alleviate noise and artifacts, they do not put such a heavy demand on the compressor to faithfully reproduce these idiosyncrasies at the final output resolution.

On the whole, digital video cameras possess similar traits. All of the cameras reviewed here have a remote control for operating the camera at a distance. This feature is particularly useful for scientific and surveillance videography. Most include a photo mode that allows a still image to be recorded on tape for five to six seconds. Interestingly, the photo mode does not record a higher resolution image. All of these cameras employ some form of image stabilization system, whether electrical or optical. These stabilization systems work by monitoring subfrequency vibrations and shifting the image to counteract these "jitters." Digital zoom is common to all of the cameras. This form of zooming uses interpolation, much like resizing in Photoshop, to obtain a magnified view of the recorded image. Overall, I did not like the digital zoom function because of the image pixelization.

Panasonic PV-DV710

This palm-sized camera packs a lot of features into a relatively small unit. A bright, robust screen allows the videographer to shoot without having one eye glued to the viewfinder, though a viewfinder is also provided. I enjoyed the freedom of the LCD screen. The electronic viewfinder has provisions for adjusting the brightness and saturation of the screen. Although these adjustments are very basic, it was surprising to see the absence of these controls on other cameras.

The camera fits quite comfortably in your hand, with the index finger falling naturally onto the zoom control. The thumb can then easily turn the camera on and off and control recording functions. The Panasonic has manual exposure and focus controls, but they are inaccessible unless you retract the viewfinder from its base. Like most DV cameras, the PV-DV710 offers a photo mode. In this mode, a still image with audio can be recorded on the tape for five seconds. Unfortunately, the camera's audio capabilities leave a lot to be desired. There is no provision for a headphone jack except with the analog output adapter, which attaches to the bottom of the camera. Though not heavy nor bulky, the adapter was obviously an afterthought.

More info? Circle 110

Canon Optura

The Optura from Canon Computer Systems has several responsive controls that make it stand out from the rest of the pack. Exposure and focus controls are conveniently located for easy adjustment without removing your eye from the viewfinder. Unlike other cameras, the Optura has a provision to manually set white balance by taking a reading on a white card. Other cameras have set color temperature adjustments or an automatic compensator.

A feature unique to the Optura is the ability to manually select aperture or shutter priority. In these modes, the user can select the aperture or shutter based on image content, and the Optura will automatically compensate, much like a 35mm. In fact, the camera looks and feels much like a 35mm camera. Those accustomed to a 35mm design will feel at home with the Optura, while videographers may find it somewhat awkward. The design is not conducive to extended taping. Adjusting the viewfinder's brightness requires a jeweler's screwdriver, and there is no provision for color adjustment.

The camera has a 14X optical zoom, which is slightly longer than the others listed here. A headphone jack is provided on the camera, but the volume is fixed. Only the internal speaker volume can be adjusted by navigating through menu displays. I had a hard time loading and unloading cassettes in the Optura because the cassette door was difficult to open. And once opened, its delicate components were exposed to the outside elements.

More info? Circle 111

Canon ZR

The greatest asset of the Canon ZR is its compact size. The ZR can easily fit into a shirt or coat pocket. Like other DV cameras, the ZR offers superior audio and video fidelity by transferring audio and video via FireWire. A unique feature of the ZR is its retractable LCD screen. The LCD screen can be positioned for low and high angle shooting. The LCD can be converted to a viewfinder using the external Finder Unit converter. Using this accessory alleviates LCD glare when shooting outside scenes in direct sunlight.

Canon designed this camera horizontally—styling it in the fashion of a point-and-shoot. Most DV cameras are designed vertically, for shoulder mounted shooting. Consumers used to shooting with point-and-shoot cameras will feel comfortable using this camera. Canon has also cleverly engineered a built-in lens cover that slides into place when the camera enters sleep mode. Manual settings are preserved when the camera is turned off.

More info? Circle 112

Sharp VL-DX10U

The Sharp VL-DX10U with its horizontal design looks very different from the other DV cameras listed. It has a rectangular body with a right hand grip. The camera has no viewfinder eye piece, employing only a large LCD display, which can be adjusted for color balance. Brightness, color (saturation), and tint (hue) controls allow flexibility in adjusting the screen to faithfully represent NTSC color space. These adjustments have no effect on the recorded image.

An interesting plastic hood is provided that resembles the old Graflex camera viewing hoods. It is absolutely necessary to shield the LCD display from stray light, but the hood prevents the camera from being mounted to a tripod. The viewing hood attaches to the bottom of the camera with the tripod screw threads. The DV cassette loads into the back of the camera much like a 35mm film cartridge, but the LCD hood prevents quick and easy loading.

Manual white balance is not possible with this camera, nor is manual exposure. There is also no provision for FireWire input and output, only for S-VHS and composite via an external adapter.

Sharp uses an electronic digital image stabilization mode. When it is enabled, the image is magnified, and the shutter speed defaults to $^{1}/_{100}$ second, instead of its normal $^{1}/_{60}$ second. I noticed considerable deterioration in image resolution when image stabilization was enabled. Unfortunately, this camera was designed for handheld shots, so the image stabilization is a necessity.

Some of the functionality of the Sharp camera is automatically controlled. The camera automatically shuts off if left in standby mode for more than five minutes, even when connected to A/C power. This can be extremely frustrating if you are using the remote control to operate the camera. Also, the sensor for the remote is on the back of the camera, rather than the front. The placement of the sensor is contrary to most design principles. An automatic gain feature is available, though if the camera momentarily detects enough light, the gain function is canceled.

The pistol grip slides down vertically to balance the camera better. I found this camera difficult to hold and use. The design is awkward, with many confusing menus to scroll through for simple operation. The autofocus was not as responsive as that on the other cameras I tested, and there was a significant delay in focusing when the camera's lens was zoomed out all the way. The operation of this camera in manual focus mode is almost a necessity, though it is possible using a menu window.

A headphone jack is supplied for monitoring audio. Fortunately, Sharp chose to allow for volume adjustment, not by menu screens, but with the zoom switch when in playback mode. Audio monitoring is not possible when recording.

More info? Circle 113

JVC GR-DVXU

The JVC GR-DVXU is another palm-sized camera that incorporates some unique features. It has a built-in flash that allows artificial light to supplement continuous lighting in a single burst. The current model does not have a FireWire connector, making it impossible to digitally transfer clips or stills without a supplemental DV deck. A small LCD monitor is provided, as well as a fixed viewfinder. I had a hard time finding a comfortable position in which to hold this camera. The rectangular body is not conducive to long periods of handheld shooting. Manual focusing is possible by turning an external knurled wheel. An interesting feature of the GR-DVXU is the power pack, which allows you to use two batteries with the camera. This pack attaches to the bottom of the camera and does not impede any of the camera's functions.

Brightness adjustment is provided for the LCD monitor, but color adjustments are not possible. The LCD screen can be reoriented so you can videotape and monitor yourself at the same time. A self timer is also provided.

More info? Circle 114

Hitachi MPEGCam

The Hitachi MPEGCam represents a remarkable value for the multimedia professional. Its small, 19-ounce case contains a video camera, PC acquisition hardware, and storage for MPEG 1A video suitable for CD-ROM delivery and intranets. Downloading MPEG files is an easy task through an optional SCSI adapter or from PCMCIA Type III cards. The 260MB Type III cards can be accessed through the standard PCMCIA ports of Macintosh PowerBooks or Windows-based laptop computers.

MPEG 1A files are easily viewable on Win 95 / NT and Mac OS, thanks to QuickTime 3.0. QuickTime 2.5 supports the MPEG 1A, but only on the Macintosh. MPEG 1A files can be viewed in Netscape and Microsoft Internet Explorer. They have a data rate of 1.5MB per second, which is too much data for Internet streaming. However, the MPEG 1 really shines in CD-ROM delivery and intranet networks, as these platforms have a bandwidth appropriate for the file size. MPEG 1 files can be incorporated into QuickTime Virtual Reality (QTVR), Macromedia Director, Authorware, Dreamweaver, Microsoft Powerpoint, and Directshow, to name but a few.

The Hitachi MPEG Cam records at a resolution of 352x240 pixels, at 30 frames per second for motion picture images, or 704x480 pixels for still images. Twenty minutes of video or 3,000 JPEG images can be recorded onto a 260MB card.

More info? Circle 115

Sony PD1 DVCAM

Another offering in the palm-size digital video camera category is the PD1 from Sony Electronics Inc. The PD1 encodes video signals in the same color space as other DV cameras, but it differs from conventional DV cameras in that it can lock the audio in sync with the video signal. Locked audio—available only on DVCAM and DVCPRO professional video tape formats—offers a superior method of laying down audio tracks locked to the video source. Unfortunately, the PD1 does not exploit this important asset. The external microphone is positioned on top of the camera at a 90-degree angle to the source. The sound recorded from the microphone has a distinct airy quality. Voices were often difficult to decipher because of the many reflected sounds also recorded.

The PD1 has a fixed viewfinder and a movable LCD screen with chroma (saturation) and brightness adjustments. The LCD had a noticeably grainier image than other DV LCD screens, with a significant amount of color noise in the shadows. Like other digital video camera screens, the PD1 LCD automatically re-orients the image when the screen is positioned to face the subject. While a built-in speaker is available, the headphone output is more useful. Manual exposure adjustment is not possible, though an automatic exposure lock is provided.

I found the zoom to be very responsive, even though I had some difficulty slowly zooming in or out without hesitation. The sliding zoom button was difficult to master.

Overall, the PD1 exhibited a great image. The footage acquired through the Radius FireWire card was remarkably clear, and exhibited a wide tonal range. The camera, even with its shortcomings, was a pleasure to use.

More info? Circle 116

Worth the Expense

The DV format is far superior to analog video for multimedia production. Acquisition via FireWire connection is far cleaner and easier than with any other acquisition product. Analog cameras are initially less expensive today, but when we evaluate the computer hardware necessary to achieve equivalent results, the extra expenditure for a digital video camera is justifiable.

Recording in DV format does not ensure the cleanest edited tape nor the best quality obtainable for the Web, unless the camera has a FireWire port used as a direct digital link between the camera and computer. If the FireWire connection is not employed, serious degradation may result.

MPEG cameras are also a cost-effective means of uploading high-quality video into your computer. Hitachi's MPEG camera is ideally suited for CD-ROM authoring and intranet delivery. MPEG files are too large for Internet delivery and must be compressed to a suitable data rate. Unfortunately, MPEG files are not encoded in component format, and therefore are more difficult to compress. ◀

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