Bridging analog and digital video in the surgical setting

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Editing surgical videos requires a basic understanding of key technical issues, especially when transforming from analog to digital media. These issues include an understanding of compression–decompression (eg, MPEGs), generation quality loss, video formats, and compression ratios. We introduce basic terminology and concepts related to analog and digital video, emphasizing the process of converting analog video to digital files. The choice of hardware, software, and formats is discussed, including advantages and drawbacks. Last, we provide an inexpensive hardware–software solution.

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We are in a transition period between analog and digital video (DV). Although in the near future DV will dominate the ophthalmic operating-room setting, the cost of digital systems precludes their instant popularization. Even those who have shifted to DV usually still keep an archive of analog (VHS/SVHS) films they want to convert into digital media.

This review is intended to bridge the gap between analog and digital media and to encourage experimentation with digital capabilities, even if the surgeon still is recording analog in the operating room. We present basic terminology and concepts, highlight key issues and decisions, and report our experience in transforming raw analog video into digital format to be edited, stored, and distributed. An appendix provides definitions for acronyms in this paper, a glossary of commonly used analog and DV terms, and useful web-site links.

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Reasons for Transforming from Analog to Digital

Digital video offers numerous advantages. Generation loss is eliminated, quality is improved, and data can be easily stored, retrieved, and backed up as computer files. Viewing is simplified (eg, navigation within the movie by use of a sliding bar rather than the video cassette recorder's [VCR] rewind/fast-forward features), and distribution is easier and less costly (eg, e-mailing, burning onto a compact disc [CD] or DVD, and placing the video on a server). However, the most significant advantage of moving to DV is the powerful editing capability of even the least expensive systems. After a short learning period, editing becomes simple and powerful, enabling integration of the surgical video, transitions, narration, and even music and text captions via an intuitive graphic user interface. Creating a professional-looking surgical video is easier than preparing a PowerPoint® presentation.

Hardware Requirements and Costs

When video is originally recorded on tape using an analog microscope camera and VCR, it can later be converted to DV, at the cost of a 1-generation loss in quality. Moreover, analog video can be stored on 3-hour cassettes, and portions can be later converted to DV. This conversion requires a VCR (VHS or SVHS, depending

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on how the video was originally recorded), a capture card that is placed in the personal computer (PC) and enables real-time conversion of analog video into digital format, a PC with reasonable processing speed (eg, a 600 megahertz processor and 256 megabytes [RAM]), and abundant hard-drive storage space. Other storage capabilities, such as a CD or DVD burner, large interchangeable hard drives, and other magnetic/optical storage devices are often added later.

Of the above, the capture card is the most important in obtaining quality results; computer-processing power is less crucial. The microscope camera is important; however, this portion of the system is usually a piece of equipment shared by the department/group. The cost can range from $80 to $300 for a VCR and $200 to $500 for a good-quality capture card. The cost of a PC and extra storage media must be considered. A reasonable system can cost $500, not including the PC.

Three types of capture cards are currently available: a combined capture and graphics (monitor) card, a USB-connected external capture card, and an internal PCI capture card. Because data transfer rates limit the USB type and limited quality and other compatibility issues limit the combined cards, a dedicated internal PCI card is usually the best choice. A good PCI capture device will allow users to capture from different sources, such as a VCR, SVHS, DVCAM, and composite as well as music.

Editing a Digital Video File

Usually, no additional software is needed to edit a DV file because all capture cards come with bundled editing software geared toward average and experienced amateur users. This software is often a basic or "light" version of professional editing software. A novice can begin mastering the bundled video-editing software before experimenting with more powerful and difficult software options such as Adobe Premiere®.

Digital Capturing and Editing Technique

Relying on a 1CCD camera, which could be upgraded to a 3CCD, built into our Zeiss operating microscope, analog video signals are recorded on a plain, 4-head VCR and presented on a television monitor for the staff to observe. Three-hour VCR cassettes are used for taping, back-to-back, the entire length of each surgery ("speculum to speculum"). The date is noted on each cassette while the surgical logbook states the order of cases for that day, enabling one to easily locate, even several months later, portions of interest within surgeries. These portions are then captured by a standard PC, using Dazzle Digital Video Creator II (approximately $300), an internal PCI capture card. This PCI capture device has real-time MPEG2 hardware compression at fast transfer rates, which also enables the user to capture from multiple sources.

The standard capturing parameters are MPEG2, DVD quality, at 60 MB per minute. Hence, each 30-minute surgery translates into a 2 gigabyte (GB) file. These files are later edited, using the bundled video capture and editing software (Dazzle Moviestar). Editing primarily involves trimming the movie to a 4- to 6-minute version and adding titles, music, and, if desired, occasional narration. Once the editing is complete, the movie is saved as MPEG2 on the hard drive or burned to a CD and the initial raw 2 GB file is deleted. For distribution, a second, smaller file is created in MPEG1 format, at maximum resolution (352 pixels $\times$ 288 pixels).

It is recommended the user capture video at the highest possible MPEG2 resolution, even if the eventual goal is to produce an MPEG1 movie. This is partly because computer resources are expanding continuously and because the emerging DVD-burning technology in the next 2 to 3 years will handle gigabyte-size files. Capturing a 240-line analog recording using 300, 400, and even 500 lines resulted in noticeable quality improvement.

Full Digital Systems

The most expensive barrier to full digital transformation in the operating room is the price of a microscope-mounted digital camera. Once this video camera is obtained, the process of recording, capturing, editing, and exporting is faster, easier, and higher quality. In addition to a digital microscope-mounted video camera, a digital recorder (eg, a home DV camera or a dedicated computer nearby) is needed to store the video files. The DV cassettes store approximately 30 to 60 minutes of data each, while the DVCAM can record up to 3 hours. Thus, even large hard drives will fill up relatively quickly if an entire procedure is filmed. However, the significant improvement in video quality is useful, especially for large-screen presentations at meetings.

Discussion

This short review should assist surgeons in digitizing their videotaped surgeries. The transformation, while feasible and relatively inexpensive, may not prove to be smooth because of incompatibilities within a complex computer system. Although video quality is dependent on hardware and software considerations, surgeon-dependent factors contribute far more to the quality of the resulting surgical video. We consider good "footwork" to be the most important factor in surgical video quality. A poorly taped surgery is a "dead end" and usually cannot be improved later. Three important factors in recording—centration, zoom, and focus—are dependent on the surgeon's ability to maneuver the microscope pedal while concentrating on the case.

Centration is often poor during more crucial stages of surgery, primarily because the field, as seen by the surgeon, often extends beyond the field viewed by the camera. In addition, even if both fields are equivalent (which they usually are not), the surgeon's circular view is cropped to achieve the camera's rectangular view.

Zooming in helps highlight finer details. However, it may be difficult to operate at higher magnifications. Thus, a tradeoff exists between ensuring a safe procedure and the quest for a better video. Furthermore, at higher magnifications, centration and focus are more difficult to maintain.

Finally, focus, often the most difficult skill in surgical videomaking, has been extensively addressed.[1] Although most if not all surgeons believe they are focusing well throughout the procedure, the video is often out of focus, sometimes significantly. This can stem from 2 causes. First is that a camera is not perfectly confocal with the surgical microscope. Second is inadvertent accommodation by the surgeon. The first factor results in uniform blurring throughout the movie and can be addressed by resetting the diopter setting of the eyepieces.[1] The second usually manifests as intermittent periods of blur and occurs during the relatively stressful portions of surgery.

Appendix

Acronym Definitions

CCD = charge coupled device
DVCAM = digital video camcorder
PCI = peripheral component interconnect
USB = universal serial bus
VHS/SVHS = video home system/super video home system

Definition of Terms

Analog versus digital video. Although both can be recorded on magnetic tapes, digital video is a binary computer file while analog video contains raw-like signals. The digital version is more robust and easier to handle. Digital video is easier and more affordable to edit, manipulate, store, and distribute. Although the music industry completed the transition (ie, records and cassettes were replaced by music CDs and MP3 players), the video industry is currently in a transition period from VCR to DVD.

AVI. Audio video interlaced, one of the oldest video formats, was created for Microsoft's Video for Windows application. The first video editing systems and software mostly used AVI by default. Despite the large files created and numerous other problems, it remains popular.

CODEC. Short for coder–decoder (compression–decompression), CODEC is the mathematical algorithm by which bulky raw video files are compressed to a reasonable size with some quality loss. This process can be done using software or hardware, which is much faster and results in superior quality. Examples of CODECs include the various MPEGs. CODECs differ in maximum resolution, compression ratio, computer resources needed, and the ability to preserve the quality of the original video.

Compression. This involves manipulating video signals so they occupy less space, resulting in smaller computer files. There is some loss of quality, however. With compression, multiple pixels of the same color in a movie frame can be encoded in a more compressed manner. In addition, frame size, number of frames per second, color contents, and sharpness can be reduced. A combination of these elements also can be achieved. A more powerful approach involves selecting "key-frames" that are saved as such, and intermittent frames that are reduced to their difference from the previous key-frame. CODECs and computer resources are needed to unfold (decompress) these video files.

Compression ratios. Uncompressed video can reach over 100 MB a minute, requiring a full 40 GB hard drive for capturing a mere 4 hours. Hence, compression is important. Drawbacks of compression include that some resolution is lost and significant computer resources are needed to compress and decompress at real time. Compressed video files of relatively high quality start from around 10 MB a minute and can reach about 60 MB a minute for very high quality (DVD) video; a CD might hold as few as 10 minutes of DVD-quality video.

Generation quality loss. This is created when an analog videotape is edited or copied to another and is theoretically absent from digital video editing. Digital video is a computer (binary) file and thus retains practically all information, no matter how many times it is viewed, edited, or copied. In contrast, analog video deteriorates in quality every time it is copied (or edited) as well as after repeated viewing. This is analogous to music CDs versus music cassettes and digital photography versus film. Any distributed analog video is, at best, a third-generation copy (raw recording –> edited master –> distributed video).

MPEG1. Originally designed to reproduce VHS quality in digital format at a resolution of 352 pixels × 288 pixels, this is the low-end universal standard for compressing video. All computers should be able to run MPEG1 by clicking on the file. Although limited in resolution and less efficient in compression ratio, MPEG1 can be considered the generic CODEC and is still in common use, except when higher quality is needed or the file size is limited.

MPEG2. Enabling resolutions as high as 720 pixels × 576 pixels with an excellent overall quality, MPEG2 is used for achieving DVD quality. MPEG2 was originally designed to become the standard for digital broadcast television. However, because software decoding is slow and resource consuming, hardware decoding is usually necessary for MPEG2 video applications. Because of the larger files created by the higher resolution and the requirement for specific software/hardware encoders, we usually edit and store our surgical videos as MPEG2 but distribute them as MPEG1 (at some reduction in quality). Computers equipped with a DVD can usually run MPEG2 files. A computer lacking a DVD can be made compatible with the MPEG2 format by installing DVD software, such as DVD Express.

MPEG3. Commonly known as MP3, this is the accepted standard for compressing and playing music files. This is not a video CODEC.

MPEG4/Div X. At a maximum resolution of 640 pixels × 480 pixels, this relatively new CODEC might replace MPEG1 with superior quality and significantly better compression ratios. If DivX is not supported by your computer, a freeware CODEC can be easily installed. Although we initially decided to use MPEG4 for distributing videos, lack of standardization and too many complaints of incompatibility forced us to revert to MPEG1.

NTSC/PAL. National Television Standards Committee/Phase Alternating Line. Although NTSC is the standard in the United States, PAL is the standard in Europe and portions of South America. An analog video can be one or the other. Converting videotapes from one system to the other usually degrades the quality significantly. Maximum NTSC quality is 720 pixels × 480 pixels, at 30 frames per second, while maximum PAL quality is 720 pixels × 576 pixels at 25 frames per second. The rate of frames per second is derived from electrical frequency in each country (60 Hz versus 50 Hz). Both NTSC and PAL achieve similar quality. NTSC/PAL only relates to analog video, such that the only NTSC/PAL "remnant" in digital video is the rate of frames per second (25 versus 30) chosen.

Screen resolution. In video, quality is related to the number of pixels viewed on screen. While computer monitors easily reach 1280 pixels × 1024 pixels and more, television resolution is far lower, 720 pixels × 576 pixels at most. These numbers denote the number of horizontal pixels × vertical pixels (data points) of the entire picture. Lines mean the vertical resolution.

VCD/DVD. These are formats for playing digital video on a DVD player or on a computer. Although DVDs require a DVD player for viewing and a DVD burner for copying, they provide excellent quality. A video CD (VCD) is created by using an MPEG1 format burned on a CD and played on a computer with a CD drive. Although more universal, it can be played on DVD players. A minor difference between a VCD and a regular-data CD containing an MPEG1 file is that only a VCD will run on a DVD player.

VHS versus SVHS. VHS uses a vertical resolution of 240 lines and VHS in "long play" mode is further degraded to 200 (or even 160) lines, while Super VHS (SVHS) plays at 360 lines. In comparison, digital video formats, such as Hi-8 digital, record at 400 lines, while DVD can reach 500 to 520 lines. SVHS equipment is more expensive than VHS. To achieve SVHS quality, the initial (microscope) camera, editing equipment, and the video player require SVHS capability. Distributed SVHS tapes cannot be viewed on a regular video player, limiting their usefulness.

Video Across the Internet. Streaming video over the Internet is becoming feasible with the broadband Internet connections now available (using such CODECs as ASF, REAL, and low-resolution MPEG4). Compression is key. The drawback is the significant reduction in quality. Surgical videos tend to degrade to uselessness when broadcast over the Internet.

Links

- For video hardware information: www6.tomshardware.com/.
- For video editing and conversion: www.VCDHelp.com.
- For DivX, a freeware version of MPEG4 technology: www.divx.com.

Reference

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