Video in the Classroom: Problems and Promises

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Introduction

We are repeatedly reminded how important the new media technologies are in our discipline of teaching. Those who are computer literate have embraced these possibilities but for many others, the hype has become hollow and the promises invite scepticism. In the demanding, unforgiving environment of the classroom, we too often discover that:

i) many "multimedia" products are aesthetically and pedagogically unattractive, and their intellectual content small;
ii) the promise of interactive multimedia has been vastly oversold — hurriedly marketed products do not meet our expectations;
iii) many products are **not** interactive, but merely use CD-ROM technology for clever (and useful) cross-referencing;
iv) there are too many platforms which often do not work with too many software products;
v) the technology is often unreliable, as, for example, when computers crash — this is an unacceptable problem particularly with large classes; and
vi) the hardware is not as portable and convenient as, say, a text book.

As a result, teachers are now demanding from these new technologies:

i) quality;
ii) stability and reliability of software and hardware; and
iii) simplicity of set-up and operation.

My discussion specifically concerns the reproduction of live, dynamic events in the classroom. Showing dynamic images of processes, particularly those in biology, is often essential if students (and indeed, teachers) are to gain deep understanding of dynamic events. To illustrate this point, imagine how difficult it is to describe to another person what a sport like football might entail, using only static images such as photographs and diagrams. Image manipulation has also become extraordinarily evocative and useful: consider for example, how educated we have become about the weather because of time-lapse images that show the dynamics of the atmosphere.

The technologies currently available confront both the producer and user of dynamic images with difficult choices and unresolved issues. In particular, the storing and reproduction of dynamic images within multimedia productions often provide vivid illustrations of the problems listed above.

Essence of the Problems

We live in an analog world and our senses, particularly vision and hearing, respond to analog signals. Most early recording platforms (e.g. video and audio tapes, vinyl records etc.) are analog in principle, whatever the actual physical medium used. Computers operate in a digital world because of benefits in handling information digitally in accuracy and ease of transmission. The interconversion of analog and digital signals requires **compromises** and subjects the signals to losses in informational content each time they are thus treated.

Movie films and video display discrete images 24-30 times a second, thereby satisfactorily mimicking continuous events. Loss of information (effectively, loss of quality) starts with the initial recording which requires processing the moving images into digital-like steps. Each image is also recorded via discrete silver grains or video scan lines whose signal varies in colour and intensity along each line. Once these steps are made, some informational content is permanently lost. Analysing motion using frame-by-frame viewing reveals this loss of information, in time (when images are blurred) or in space (when resolution is limited by film grain size or the scan lines). The original recording requires choices and compromises (e.g., film speed/grain; TV format, number of scan lines/resolution etc.). Understanding these choices is important in reproducing high quality dynamic images.

However, these media can also offer significant benefits derived from **Image Processing** and image manipulation. The remarkable potential of digital processing of very weak, noisy signals is shown particularly in space research and medical imaging. We have benefited enormously from images that would not be possible to obtain even a few years ago.

Classroom Media Choices

I will briefly outline the advantages and disadvantages in the choices of media appropriate for use in the classroom. We have three analog technologies: **movie film**, VHS **video tape** and **laser disc**.

Film

Currently, educational films have almost vanished from the classroom. However, they are familiar and worth mentioning because their use graphically demonstrates important practical considerations.

Advantage:

- Superior image quality — when highest quality is required, images are still mostly shot on film even for TV programs

Disadvantages:

- Cumbersome medium, very fragile (e.g., susceptible to dirt, scratches, breakage etc.)
- Non-copyable images, impossible to include in other classroom presentations (e.g. class and lecture notes)
- Expensive medium (film), players (projectors)
- Very linear format that allows no random access

Note that the last is particularly limiting. It is usually impractical or impossible to show a class different selected segments of a film.

VHS Video Tape

Advantages:

- Universal and familiar
- Easy to record, copy, edit
- Very cheap

Disadvantages:
- No accurate random access
- Mediocre image quality
- Serious loss of quality on copying, editing
- Poor control over image play rates (freeze, slow and reverse motion)

Laser Disc

Laser disc technology has been around for 20 years, but has hardly appeared in Australia and is still uncommon elsewhere. This is unfortunate since in practical terms, it offers many advantages in the classroom.

Advantages:
- Controls similar to domestic VCR
- Superior image quality
- Superb freeze framing capability (allowing inclusion of diagrams, photographs, text etc.)
- Accurate, rapid random access to any frame (above), including those within video sequences
- Bar code remote control capability that allows teachers to label lecture/classroom notes for immediate access to selected images
- Extremely reliable, safe for student usage
- Easy interaction with and control by computer
- Multiple (multilingual) sound tracks available

Disadvantages:
- Players not common, perceived to be expensive, actually cost little more than domestic VCRs
- Lack of published material available
- Not recordable
- Medium moderately expensive (discs cost $25-400)

CD-ROM

This technology was designed for storing music, still images and text, for which it is still superb. Its success has prompted developments to extend its capabilities into reproduction of video signals, for which it is basically inadequate (see later). I outline here its main deficiencies **in the context of video reproduction**.

Advantages:
- Players fairly common
- Excellent random access
- Cheap medium
- Easily integrated with other media via computer

Disadvantages:
- Generally poor to unacceptable image quality
- Unstable platform (ever changing: 2X/4X/8X etc. drives)
- Software/hardware compatibility problems

The limitations of CD-ROM (again, I emphasise, in the context of video reproduction) appear to be insurmountable and have led to the development of DVD technology. Before discussing DVDs (below), we will briefly review why these limitations exist.

The Problems of Storing Digital Images

Video consists of 25 (PAL format) or 30 (NTSC format) images or "frames" played back per second. Each of these frames is split into discrete "scan lines", not all of which form the image. PAL images have 625 lines, NTSC have 525 lines. (A complication is that each frame is generated by interlaced "fields" which each effectively contain half the image; "odd-" and "even-" fields play alternately.) The quality of the image is partly determined by its resolution along each scan line. Numerically, "broadcast quality" images are quoted as having a resolution of about 750 lines/inch whereas a typical image recorded on to a VHS tape can be played back at about 200-300 lines/inch.

In creating digital versions of these analog images, each point in the analog scan line is converted to a pixel whose numerical value is related to colour, brightness etc. The number of pixels along each line is an arbitrary choice which controls resolution, now expressed as the number of pixels along the line.

Consider the typical analog-digital conversion of a single full frame of an NTSC colour image. The frame now typically measures 640 X 480 pixels, and so the total number of pixels per image is 307,200. (A PAL frame is more).

Playing these back at 30 frames/sec. requires the handling of 9,216,000 pixels/sec.

If each pixel is allocated 24 bits of colour information, the total delivery of digitised information required is around **27.6 MB/sec**. Add a sound track, and the figure is even higher.

No consumer-level CPU or hard disk today can handle this volume of data! Furthermore, storing even a short video clip requires a tremendous amount of digital storage. The CD-ROM was originally designed to hold 650 MB, which would total about 20 of these images. Accordingly, computer software and hardware designers have utilised various compromises that are vital if CD-ROMs are to store dynamic images. For example, one can:

i) make image size small;
ii) cut the number of frames displayed per second; and
iii) keep colours simple.

In addition, constant improvements in the hard drive mechanisms and reading heads have considerably increased the rate of information transfer: hence the increasing speed of CD-ROM drives (2X-12X). The resultant dynamic images have improved from the original early QuickTime technology (which I consider very poor) to being at best acceptable. However, the limitations inherent in the CD-ROM format have obliged manufacturers to develop a completely redesigned system.

The "DVD"

The acronym DVD was originally used to describe the newly developed "Digital Video Disc" which is the same size and appearance as a standard CD-ROM. The name has since been changed to "Digital Versatile Disc", to better reflect its interactive and creative possibilities.

The current DVD format makes use of several technological advances, notably:

i) shorter wavelength lasers for scanning the disc;
ii) better optics for imaging the information recorded on the disc (higher numerical aperture of lens, more accurate focussing);
iii) more scan lines in disc, closer together; and
iv) better modulation characteristics, error correction in the signal being read.

In addition, DVDs can be double layered; the imaging system can scan either of two superimposed layers (one semi-transparent), and thus, the capacity of the disc is doubled. Furthermore, the two sides of the disc can be used in this fashion, creating a relatively immense storage capacity.

For technical comparison - in DVDs:

Track spacing:	0.74mM	*v.*	1.6mM in CD-ROM
Min. length for a pit:	0.4mM	*v.*	0.83mM in CD-ROM
Laser wavelength:	635-650nM	*v.*	780nM in CD-ROM

Disc rotation speed (1X): constant linear 3.49 m/sec. (similar to that of CD-ROMs)
Data transfer rate is around 11.08Mb/sec.
Data Capacity (12 cm. disc, CD-ROM size):
4.7 Gb, single layered disc; **8.5 Gb** on double-layered;
Up to **17Gb** on double-sided, double-layered disc.

The increased storage capacity of the medium has been coupled with **Image Compression**. This technology is based on the premise that in any series of moving images, much of the information remains constant and so is redundant. The algorithms concentrate upon managing the changing information while retaining the shared information.

The image compression system used in DVDs is called "**MPEG-2**"; the process is very complex and involves transforming sequences of images into blocks of eight, reducing their information content and then recreating the images during playback. A new feature is that it allows continuously variable (i.e., user-controlled) levels of compression, dependent upon type of image being portrayed, moment to moment. This advanced feature is called "**variable bit rate encoding**" and reportedly can eliminate up to 97% of image data without affecting image quality. In practice, the technique is heavily dependant upon human assessment and control during the initial compression (i.e. immediately before creating master discs). When compression is carried out well, the images are, by subjective and anecdotal account, remarkably good, very close to broadcast quality. However, some demonstration discs (not viewed by this author) are also reputedly quite poor and display serious artefacts.

The **end result** of all these advances means that at an average data transfer rate of about 3.5Mb/sec., the single sided disc will hold **2hr. 13 mins**. of **video**, plus MPEG **digital sound in three languages**, plus the ability to carry up to four channels of captions. Double-sided, double-layered discs should hold up to 9 hours of studio-quality video.

DVDs for Teaching?

I now subjectively comment on the potential of this technology for teaching purposes, based partly upon my experience with laser discs which (see earlier) demonstrate various useful capabilities in the classroom.

According to many commentators, **random access** of images should be easy but I have not seen this capability demonstrated and theoretically, if images *per se* do not exist on the disc, it is difficult to imagine how specific frames (e.g. diagrams etc.) can be precisely recalled upon demand. Likewise, inclusion of **stills** is "easy" but how this is organised within the mastering of motion picture images is not clear to me. Freezing of single frames should be easy; **variable speed forward play** is reported to be easy but **reverse play** is not possible.

A possible alternative to true random access is provided by author-defined **program sequences** displayed on a menu at the start of the disc. Thus, the author of the disc decides which various combinations of sequences (equivalent to the "chapters" on a laser disc) might be appropriately grouped together and in what order, and can then program these options into the menu. As far as I can tell, however, these choices are fixed immutably by the author, and the user cannot otherwise tailor the sequences to his/her own lectures.

The caption channels offer the possibility of making available user-controlled **overlays** (e.g., superimposed labelling, diagrams etc., where appropriate). The medium is also apparently flexible enough to offer the viewer choice of viewpoints in movies or sports events, for example, so that a scene can be viewed from one of several possible angles (recorded synchronously on separate tracks). Obviously, such options will greatly inflate the production costs.

So, in summary:

Advantages (to be treated with scepticism!):

- excellent (broadcast) quality
- 2+/4+ hrs. capacity
- versatility, interactivity
- multiple (multilingual) sound tracks
- medium very cheap (like CDs)
- complete computer compatibility (with appropriate video card)
- players competitive with VCRs (e.g. $A600-800)
- some user controllable features such as overlays
- robust medium; DVDs should not age like tapes
- excellent sound
- high quality (e.g. S-VHS output) options
- backwardly compatible with CD-ROMs

Disadvantages:

- no true random access
- not (yet) recordable
- promised release of movies etc. have not eventuated
- NTSC and PAL still are different formats

When is this technology going to happen?

The technology is already here. For example, here are some estimates of the sales of DVD players:

Toshiba: 1 mill. in Japan by 1997
Pioneer: 11 mill. by 2000
Time-Warner: 10 mill. players in the U.S. by 2002

The major companies have already made major investment in the technology. The most significant stumbling block has come from Hollywood whose major studios have not permitted release of first-run movies on DVDs for two main reasons. First, they have serious copyright and intellectual property concerns: DVD images are so good that they can be copied very well on to VHS tapes and thus pirated. Secondly, studios insist on control over release dates of new films in different geographical areas of the world. Thus, studios insist that DVDs of first release films bought in the U.S., must be unplayable for example, in Australia until a predetermined date has been passed.

The importance of these considerations for teachers is that until DVD technology becomes part of the consumer electronics market and thus widely available, familiar and cheap, authors will not commit resources and time to the authoring and production of DVDs for teaching. I think this technology has wonderful potential, but like many areas of the multimedia industry, the companies that have repeatedly promised to deliver this technology to us, have not yet done so.

DVD Web Site

A useful place to start exploring this technology is:

http://www.unik.no/~robert/hifi/dvd/