DIGITAL VIDEO FOR MULTIMEDIA, WHAT ARE THE ALTERNATIVES?

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ABSTRACT

Digital video is becoming a viable alternative to the analog videodisc for multimedia in Computer Based Training (CBT) and other applications. The benefits of digital video are lower cost delivery platform hardware and more efficient processes for production, distribution, and maintenance. Today, there is a wide variety of hardware and software products available to implement digital video for multimedia including PLV, DVI, RTV, Motion JPEG, MPEG, Indeo, Quicktime, Cinepak, Ultimotion, and others. There is a wide variation in the quality and cost of these alternative solutions. Consequently, multimedia content developers are faced with a confusing array of options when it comes to using digital video. The objective of this paper is to compare the available methods of providing digital video to facilitate selection of the best approach for a given application. The paper includes a tabulation of performance, quality, and cost parameters to enable making informed choices. The different techniques of compression / decompression are briefly described together with the hardware and / or software needed to implement them. Decompression by software is particularly attractive since it does not increase the cost of the delivery platform. Hardware to play back the compressed video is also becoming more affordable and is the preferred solution when full motion, full screen video is required. Networking of digital video is briefly covered. The impact of emerging standards on the development of future products is discussed.

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INTRODUCTION

Video has been an important ingredient of Computer Based Training (CBT) for many years. Until recently, the analog videodisc has been the only practical method of delivering video in an interactive CBT environment. Although not yet a mature technology, digital video promises many advantages over the traditional analog medium. The biggest challenge is developing affordable methods of compressing video so it can be handled by personal computers. Once digitized and compressed, the video becomes just like any other computer file (albeit a large file). Manipulation, editing, storage, distribution, and archiving become much easier and more convenient. Another benefit is the reduced cost and footprint of the CBT delivery platform. However, the biggest potential benefit of digital video is the ability to network the system. Once all elements of the multimedia are in digital form, they can be transmitted over networks thus avoiding the handling, distribution, and storage of disks and tapes. On the downside, there is a substantial investment in new equipment and training of personnel. Outsourcing of the process can be considered as an alternative to building a new capability in-house.

The objectives of this paper are to discuss the factors involved in selecting a digital video solution, to describe the various implementation methods available, and to present guidelines for selecting the best alternative to meet the requirements of a given CBT application.

BASIC CHOICES

The basic choices involved in the selection of video for a CBT system are shown in figure 1. The first choice is whether to use analog or digital video.

There are two reasons why the analog path could be chosen. The first is that there is already a large installed base of older PCs equipped with analog videodiscs. In this case, it is likely that all the CBT workstations would have to be replaced with new equipment if a digital solution is selected. The second is that the developer is unwilling to make the necessary investment to transition into the digital video world.

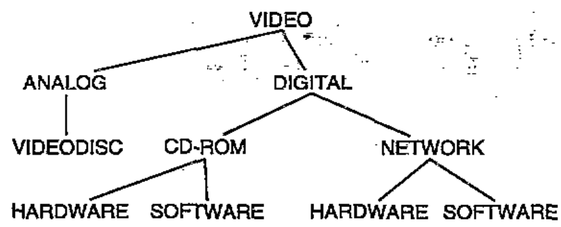

Figure 1. Basic Choices in Video for CBT

Assuming the digital approach is taken, there is the choice of CD-ROM or network. The CD-ROM is the prevalent method today but has many of the problems of the analog videodisc when it comes to mastering, handling, delivery, and updates to the content. Networking avoids all of these issues but requires an investment in servers and communications equipment.

In either case, CD-ROM or network, there is another choice to make. This is whether to use software or hardware for video decompression and playback in the CBT delivery stations. Each of these approaches can be implemented using a variety of products discussed later in this paper.

FACTORS TO CONSIDER

At this point, it is appropriate to discuss the factors to be considered when selecting a digital video implementation method. The following areas are used as the basis of a trade-off between alternative solutions:

- Image size and resolution
- Update rate
- Color resolution
- Qualitative aspects
- Accompanying audio
- Cost

Image Size and Resolution

There are three basic image sizes (shown in figure 2) although intermediate sizes are possible. Full screen is typically 640 (horizontal) x 480 (vertical) pixels, 1/4 screen is 320 x 240 and 1/16th screen is 160 x 120 pixels. Note that the resolution in pixels per inch of the display is the same in all three cases. The amount of processing required for a given resolution increases with the size of the image. For example, a full screen image of 640 x 480 requires 16 times as much processing as a 160 x 120 image. It is possible to configure the playback system to enlarge the image; for example, the 1/16th screen can be displayed at a quarter screen. The source resolution stays the same however, and a "blocky" or "mosaicked" image is the result. Also, frames may be skipped because of processor overload.

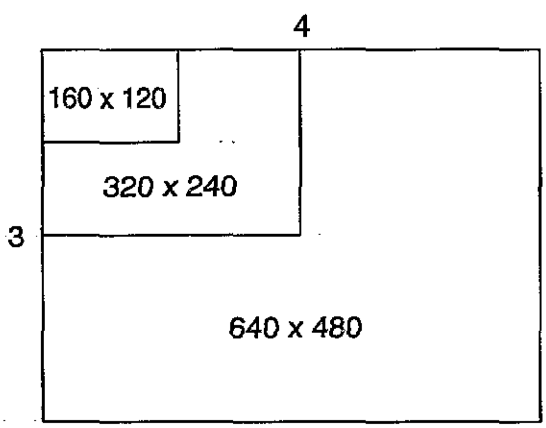

Figure 2. Image Size and Resolution

It is pertinent to consider the resolution of analog video to form a basis for comparison. The approximate indicators of resolution for some common video sources are:

Broadcast television	350 lines
VHS tape	250 lines
S-VHS tape	400 lines
Analog videodisc	450 lines

The term "lines" does not refer to the number of television scan lines, which is always 525 with 480 visible, it is the number of vertical lines that can be resolved in 3/4 of the screen width as shown in figure 3. Since the aspect ratio is 4:3, this number is equal to the perceived number of horizontal lines. Thus, VHS tape is roughly equivalent to a 320 x 240 digital image.

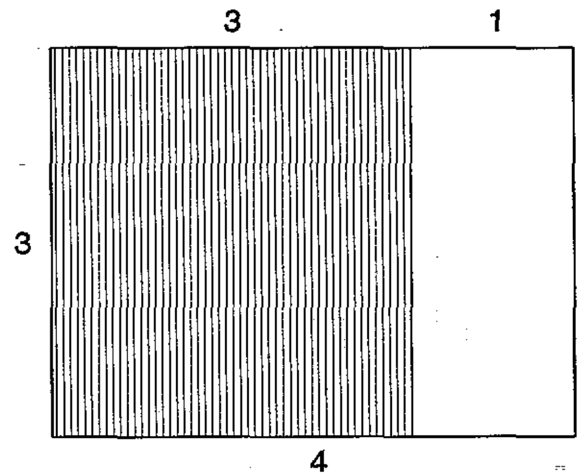

Figure 3. Measuring the Resolution of Analog Video

Update Rate

An update rate of 30 frames per second (fps) is often considered the norm. In some situations, a 15-fps rate may be acceptable and this reduces processing demand by a factor of 2:1. Actually, a 24-fps update rate is the minimum necessary for the eye to perceive continuous motion. This is the rate used in motion pictures.

Color

The use of 24-bit RGB can produce 16 million different colors. In the case of 16 bits the number of colors becomes 32,000 (approximately equivalent to NTSC video). The difference between 32,000 and 16 million colors is virtually imperceptible. If 8 bits are used however, only 256 colors are possible, which is marginal for most applications. Digital video compression schemes use techniques to provide adequate color with little extra processing compared to black and white.

Qualitative Aspects

In addition to the quantifiable factors described, there are qualitative aspects that must be considered. These are subjective in nature and the only way to judge them is to view a representative sample of the video. Compression of the video can reduce sharpness and create a fuzzy "washed-out" appearance. The scene content makes a difference. For instance, a close-up of a person's face looks better than a distant shot of a crowd of people or a group of buildings. Other artifacts that can occur are blockiness, aliasing (jagged edges), color streaking, scintillation, breakup, jumpiness, and torn edges.

Accompanying Audio

Since most video clips will need accompanying audio, it is important to consider the audio capabilities provided by a particular digital video implementation method. First, the various options for audio must be supported; second, the synchronization of the audio with the video must be acceptable. In particular, lip synchronization when a person is talking must look natural. The subject of audio is discussed later in the paper.

Cost

In the end, the choice of a digital video system will depend on its affordability. There is a trade-off between cost and overall quality. Figure 4 illustrates *the general relationship between cost and overall* quality including resolution, update rate, etc. The cost increases rapidly as one strives for better and better quality. It is difficult to put actual numbers on this curve since costs are constantly decreasing and quality is hard to define.

VIDEO FOR CBT

The use of video in CBT is focused around the type of training required. Different levels of quality, and therefore cost, can be applied to different CBT applications. There are four specific areas:

1. Training in equipment maintenance and operation. This requires detailed visual representations to show the intricacies of the machinery. Video in this case should be 1/4 screen or greater at a minimum of 24-fps.

2. Situational training such as sales, customer service and administrative duties. The video content is mainly of people rather than technical detail. For this application, the image size can be 1/4 screen or less at 15-fps or more.

3. Training with an on-screen instructor who guides the student through the course. Examples of this are training in computer skills, such as spread sheets and word processing. In this case the video can be 1/16th screen at 15- fps since most of the content will be text and graphics.

4. Training or education in which the student is drawn into the course to capture the person's attention. For this application, full screen at 24 to 30 fps is desirable.

In any event, it is critical that the customer and/or user of the CBT system see samples of the video early in the project. Customer acceptance of the video quality to be provided must be obtained before implementation begins.

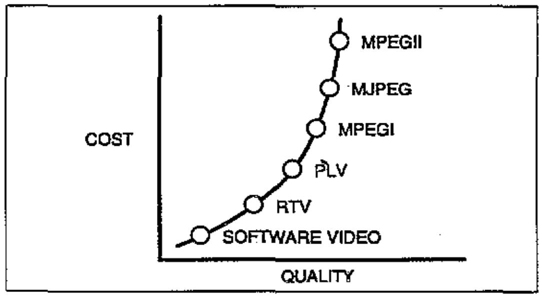

Figure 4. Cost of Digital Video vs. Quality

NEED FOR COMPRESSION

When full screen, full motion, full color video is digitized, the resulting data rate is 640 x 480 x 30 x 3 = 27 MB/second. This creates two major problems. First, a CD-ROM with a 650 MB capacity could only store 24 seconds of video. Second, no disk, CPU, computer bus, or network could transfer the data. Consequently, some way of compressing the data must be found. Many video compression schemes for PCs are designed to achieve a data rate of 150 KB/ second which is consistent with a single-speed CD-ROM. Going from 27 MB/second to 150 KB/second requires a compression ratio of 180:1. This means that 1 minute of video requires only 9 MB of storage instead of 1.6 GB.

No single approach is adequate to achieve such a high ratio, and therefore, a combination of several techniques is necessary [Ang 1991, Doyle 1994]. Compression methods rely on both redundancies in the data and non-linearities in human vision. Lossless methods such as run length encoding can achieve no more than a 3:1 ratio, so lossy techniques must be used. The lossy algorithms exploit aspects of the human vision system in such a way that *information can be removed during compression* without being noticed on playback. For instance, the eye is less sensitive to energy with high spatial frequency than energy with low spatial frequency. This deficiency is exploited by encoding the high frequency coefficients with less precision than the low frequency coefficients. Also, the eye is more receptive to detail in the luminance in an image than to the color. Consequently, the color can be sampled at a lower spatial resolution and with less precision than the luminance. Finally, video compression can take advantage of a feature in the video itself, namely the redundancy of information between adjacent frames. Many pixels do not change from one frame to the next. Also, groups of pixels forming objects move together from one frame to the next. These characteristics can be used to achieve major savings. Different compression algorithms employ some or all of the above techniques to varying degrees. The compression process is usually divided into two steps:

1. Intraframe Compression
   This step is applied to each frame individually. It consists of scaling and subsampling of the original image, color compression, and filtering of the higher spatial frequency components.

2. Interframe Compression
   This step is applied to a sequence of approximately 12 frames that have been intraframe compressed. One frame is designated a key frame, the remaining frames (called delta frames) are represented by differences from the key frame. If there is no difference, the delta frame is a "black" frame. Some interframe compression systems are very sophisticated and employ a variety of techniques such as bidirectional interpolation, and motion estimation and prediction. As a result, the process is computationally intensive.

Compression and decompression are performed by executing a pair of complementary algorithms. The decompression algorithm simply reverses the process of compression. A given compression / decompression algorithm pair may be implemented in several different ways with varying end results.

IMPLEMENTATION METHODS

The compression/decompression processes are performed by a **codec** which executes two complementary algorithms. The codec consists of two parts that can be combined into one package or the two parts may be completely separate. The various possibilities for design of a codec are as follows:

Compression	Decompression
Software	Software
Software	Hardware
Hardware	Hardware
Hardware	Software

Compression by software is performed as shown in figure 5. The video source is sampled by a capture board and the data is compressed in the CPU by a software codec.

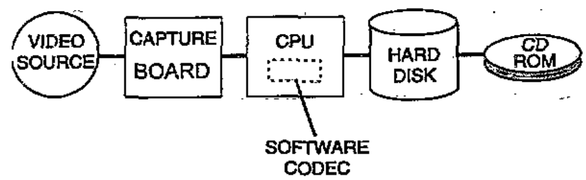

Figure 5. Video Compression by Software

The compressed file is stored on the hard disk where later it can be played back, transferred to a CD-ROM, or transmitted over a network. Compression by software usually requires much more time than is needed to decompress and is therefore termed an **asymmetric** process. The asymmetry ratio can be as high as 150:1 and depends on the type of CPU in use, the complexity of the algorithm, and the options selected. The CPU can be a PC, a workstation, or a mainframe. In general, the more time and resources expended during compression, the better the video quality on playback.

Compression by hardware is performed as shown in figure 6. The capture board includes the compression portion of the codec which does most of the work and requires little help from the CPU. The compressed data is sent directly from the capture board to the hard disk via the computer internal bus. The main benefit of hardware encoding is to achieve a *symmetric* system. This means that video can be captured and compressed at the same rate it will be played back; e.g., 30-fps, 15-fps. More data on video capture can be found in [Goodman 1994].

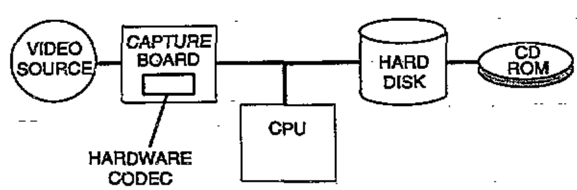

Figure 6. Video Compression by Hardware

Decompression by software is accomplished as shown in figure 7. The real benefit of this method is that no special hardware is necessary. However, the type and speed of the CPU is very significant. The difference in performance between a 386 CPU and a Pentium could mean the difference between 1/16th screen at 15-fps and 1/4 screen at 30-fps. A major feature of software decompression is scalability or the ability to automatically adjust the video playback to match the performance of the system. The same compressed video file can be played back with different resolution and frame rates depending on the CPU in use.

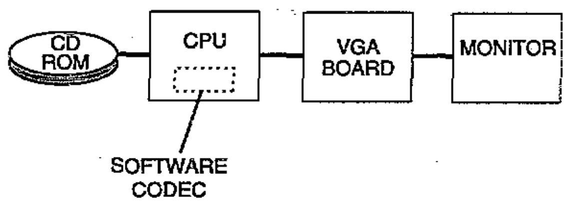

Figure 7. Video Decompression by Software

Decompression by hardware is depicted in figure 8. The decompression half of the codec is located on the playback board, the output of which is fed to the VGA card that drives the monitor. This approach is necessary if full screen, full motion video is required. It should be noted that many of these products are intended for entertainment applications since they allow 1 hour of continuous video to be stored on a single CD-ROM. Consequently, they may not provide all the features needed for CBT platforms. Examples of features needed for CBT are graphics overlay, freeze frames, jump to a frame, fast play, and reverse play. These should be taken into account when selecting a video playback board.

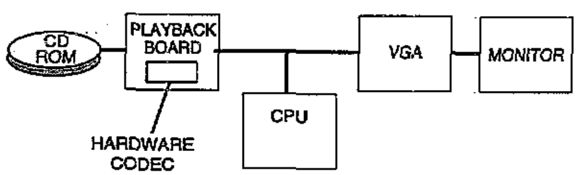

Figure 8. Video Decompression by Hardware

Software Hierarchy

A software hierarchy is necessary to control the video playback. This is true for both hardware and software codecs as shown in figure 9. A media player under the Operating System is responsible for controlling the video playback. The same media player also controls sound and animation. Device drivers are configured into the software system for each type of "device"; i.e., video codec, sound card, etc.

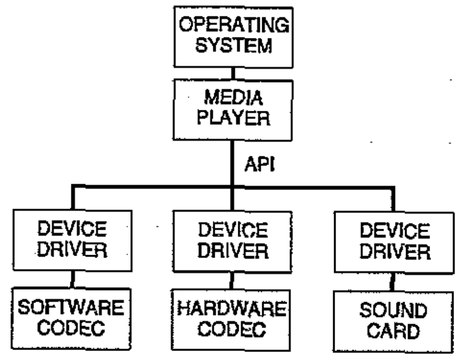

Figure 9. Software Hierarchy

The device drivers control the actual codecs whether they are hardware or software. Thus, in the case of a software codec there are four layers in the software hierarchy: OS, media player, device driver, and codec. The interface between the media player and device drivers is called the Application Program Interface (API). The most common API is the Microsoft Media Control Interface (MCI) which is supported by most suppliers of video products for the PC.

DIGITAL VIDEO STANDARDS AND PRODUCTS

So far, the discussion on digital video has been in general terms; now the characteristics of specific standards and products will be described. Further details can be found in [Sirota 1993, Ozer 1994, and Wallace 1994].

Indeo

Developed by Intel, Indeo is a codec that uses hardware for real-time compression and software for decompression. The image on playback is scaleable from 160 x 120 to 320 x 240 at 15 to 30-fps depending on the power of the CPU. Indeo is included in Microsoft Video for Windows Package.

Cinepak

This codec by SuperMac uses software for both compression and decompression. Consequently it is an asymmetric codec. Cinepak plays back images scaleable from 160 x 120 pixels to 320 x 240 pixels at 15 to 24-fps. Quicktime includes the Cinepak codec.

Ultimotion

IBM distributes Ultimotion as part of OS/2 2.1. It is an efficient derivative of Photomotion. It is a symmetric compression process using software only and the resolution is limited to 160 x 120 pixels at 15-fps.

DVI (Digital Video Interactive)

This is a hardware-based codec developed by Intel. The hardware is the Intel Action Media II board which was originally priced at $2,000 but is now much less expensive. DVI has two levels: presentation level video (PLV) and real-time video (RTV). PLV offers full-screen, 30-fps playback but compression must be done at a service bureau at a cost of $175 per finished minute. RTV can be compressed by the hardware codec at the PC level, but the quality is inferior to PLV.

True Motion

True Motion can play back full-screen video at 30 fps. The data rate is 600-KB/second which exceeds the data rate of single, double, and triple speed CD-ROM drives. Compression must be done at a service bureau at a cost of $200 per finished minute. Hardware is required for the playback and is the same as used for DVI.

Motion JPEG

This algorithm was developed by the Joint Photographic Experts Group,(JPEG). It was originally intended for still images but has been extended for video. It uses intraframe compression only and consequently has a low compression ratio and high data rate. Hardware is used for both compression and decompression in a symmetric process. A major limitation of Motion JPEG is that it does not support audio.

MPEG - 1

Of all the codecs available, those based on MPEG-1 show the most promise. MPEG-1 is an international standard developed by the Motion Pictures Experts Group, (MPEG). It includes both intraframe and interframe compression and was specifically designed for a data rate of 150 KB/second and is thus ideal for CD-ROMs. It is an open standard and any company can develop codecs based on it. Video encoded with MPEG can be played back on any device that is MPEG compatible. However, there are options during encoding that can vary the quality of the video on playback. MPEG-1 provides 352 x 240 pixel resolution at 30-fps and has interleaved audio. Hardware is necessary for playback and boards ranging in price from $400 to $800 are available.

Today, compression must be done by a service bureau at a cost of up to $150 per finished minute [Mills 1994]. Affordable hardware will be available for MPEG compression in the future [Magel 1994]. An MPEG video stream includes embedded timing data so the decoding process regulates playback at 150 KB/second. Consequently, increasing the speed of the CD-ROM drive or use of a hard drive does not improve the playback conditions. A compressed video file requires a 9 MB of storage for 1 minute of playback time.

MPEG-2

Whereas MPEG-1 was designed for CD-ROM-like devices, MPEG-2 is intended for broadcast television to replace NTSC. It supports a resolution of 720 x 480 pixels at 30-fps and consequently has a much higher data rate than MPEG-1. It is unlikely that MPEG-2 will be suitable for CBT applications in the near term. However, it does show promise for the future when networks of adequate bandwidth become available.

Comparison

The codecs and standards described are compared in table 1. The list is not exhaustive; there are other evolving approaches based on wavelets and fractals [Perey 1994].

Table 1. Comparison of Video Compression Methods

Method	Resolution	Frame Rate (FPS)	Data Rate (KB/s)	Audio	Hardware Playback	Compression Process	Quality
Indeo	160 x 120 320 x 240	15-30	150	Yes	No	Asymmetric/ Symmetric	Low-Med
Cinepak	160 x 120 320 x 240	15-24	150	Yes	No	Asymmetric	Low-Med
Ultimotion	160 x 120	15	150	Yes	No	Symmetric	Low
PLV	256 x 240	30	150	Yes	Yes	Asymmetric	High
RTV	128 x 120	30	150	Yes	Yes	Symmetric	Low
Motion JPEG	640 x 480	30	600-1500	No	Yes	Asymmetric	High
MPEG-1	352 x 240	30	150	Yes	Yes	Asymmetric	Med-High
MPEG-2	720 x 480	30	150-2000	Yes	Yes	Asymmetric	Very High
True Motion	640 x 480	30	600	Yes	Yes	Asymmetric	Very-High

ENHANCING DIGITAL VIDEO DURING CAPTURE

Unless prerecorded footage is being used, there are several techniques to use during capture to enhance the quality of the compressed video when it is eventually played back [Holsinger 1994].

1. Pay attention to proper lighting to minimize shadows.
2. Avoid black backgrounds.
3. Use close-ups rather than long shots.
4. Minimize the rate of change of scene content when panning or tilting.
5. If text is used, use large characters; font of size 10 or 12 points will not be legible after compression. It is better to avoid text in the video itself and to use graphics to superimpose the characters on the video during playback.

AUDIO

While audio does not present the same challenge as video, the subject deserves proper attention. There are three decisions to be made when capturing audio along with the video. These are:

Sampling Rate:	11, 22, or 44 KHz
Resolution:	8 or 16 bits
Presentation:	Mono or stereo

The choice of 8-bit, 11-KHz mono is adequate for narration with a male voice. This requires only 66 KB per minute which is small compared to 9 MB per minute for the video. At the other extreme 16-bit, 44-KHz stereo uses up 10.5 MB per minute; i.e., more than the compressed video. With audio compression this can be cut to about 2 MB per minute which is still significant. However, there is no need to use the highest quality audio option for CBT. Typically, 16-bit, 22-KHz mono is perfectly adequate for most CBT applications and results in less than 1 MB per minute if audio compression is used.

If MPEG is chosen as the video system, audio choices become easier because MPEG defines both video and audio compression standards. MPEG audio compressors start with 44-KHz sampled stereo sound and reduce it to less than 2 MB per minute without any discernible loss of quality. This ensures that the interleaved video and audio can be played back from a 150-KB/s CD.

The subject of audio/video synchronization should not be overlooked particularly when "talking heads" are part of the training scenario. Generally, the audio file is interleaved with the video file on a frame-by-frame basis. A good example is the Audio Video Interleaved (AVI) file used in Video for Windows. This approach does not guarantee synchronization of the final output however, because different delays may occur in audio processing and video processing. This is another reason to test the system using the identical hardware and software that comprise the CBT delivery station.

VIDEO NETWORKING

In the networked approach, a file server contains the video along with other multimedia components stored on a hard disk [Furcht 1994]. Because of the large file sizes, the disk capacity must be several gigabytes. This is not unreasonable however, since the cost of hard drives is now around $700 per gigabyte and falling. The CBT delivery stations are connected to the server by some type of Local Area Network (LAN) as shown in figure 10.

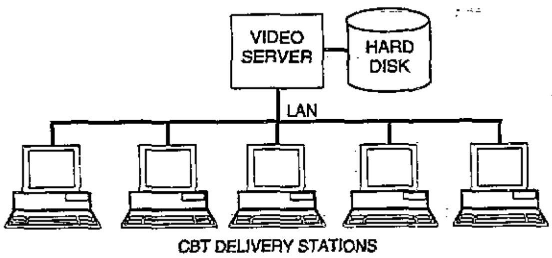

Figure 10. Transmitting Video Over a Network

There are two ways to consider transmitting video over a LAN. Th first way is to download the video in non-real time before the training session starts. The video then resides on the hard drive within each CBT workstation until new training material is required. This approach is perfectly feasible with networks such as Ethernet. Since the transfer is from hard drive to hard drive, the data rate can be much higher than CD-ROM speeds. Consequently, the time to down-load is much less than the normal video playing time. The second way of networking video is real-time on-demand transmission. Unfortunately, Ethernet was never designed to handle long uninterrupted streams of data with critical timing as in the case of digital video. Therefore, video on-demand via Ethernet is not recommended although it can be made to work in some circumstances. The implementation of digital video on demand needs network solutions such as FDDI (Fiber Distributed Data Interface) or ATM (Asynchronous Transfer Mode). Neither of these is very affordable today. In the future, ATM products will dominate the market for most networking applications. A comparison of LAN protocols is shown in table 2.

Table 2. LAN Protocols

Protocol	Bit Rate	Access Time
Ethernet	10 Mbps	Indeterminate
Token Ring	4-16 Mbps	50-500 ms
FDDI	100 Mbps	10-200 ms
Fast Ethernet	100 Mbps	Indeterminate
ATM	150 Mbps	Det by switch

When a fully networked solution is implemented all the problems with mastering, distributing, and handling CD-ROMs are eliminated. In particular, updates can be made quickly and easily.

SOME THINGS TO REMEMBER

1. Trade-off hardware versus software solutions. The cost of upgrading the CPU for a software algorithm may exceed the cost of adding video playback hardware. Consider these examples. For a 1/4 screen or less, use a software algorithm and a minimum processor of 486/DX2/66MHz. For greater than a 1/4 screen, use an MPEG playback card with a somewhat less powerful CPU.
2. Ensure the chosen solution for digital video has all the required features needed for CBT.
3. Due to the dynamic environment, buy the hardware and software as late as possible.
4. Stay with the industry standards including hardware and software interfaces to ease expansion and upgrade.
5. Consider any possible cross-platform requirements i.e. portability between Windows, System 7, Unix, and OS/2.
6. Test the whole system using the same hardware/software configuration as for the delivery platform.
7. Show samples of the video with the chosen implementation to the customer as early as possible.
8. Remember, the compression removes high spatial frequencies which blurs sharp edges and removes some detail.
9. Many small companies in digital video come and go, so make sure that your suppliers are likely to be around for awhile.
10. Be very careful when planning a network solution using digital video until the next generation of networking products is available.

FUTURE TRENDS

Digital video for CBT is still in its infancy and many improvements can be expected in the future. As price/performance of CPUs continues to improve over the years, it is expected that CPU performance will double every 2 years. The price per megabyte of hard drives will continue to fall. Hardware codecs will become inexpensive and become a standard part of computer graphics (VGA) boards. Many of the digital video products available today will disappear from the market. The most probable survivors will be MPEG and Indeo.

Digital video will be driven by the entertainment market but CBT developers will be able to take advantage of the situation. The CD-ROM will be overtaken by networking and (in due course) the ATM protocol will be the most attractive solution. One can expect a continuously improving capability over the next decade. Finally, never before in history has a new technology been so affordable.

CONCLUSIONS

Digital video has evolved to a point where it is possible to replace the analog videodisc with an all digital system. There are many varieties of digital video with a wide range of quality and cost; trade-offs are necessary to determine the optimum solution to a CBT problem. Quality will improve and costs will decrease over time. Therefore, the developer should buy the hardware and software as late as possible. It is very important to show samples of the video to the customer before committing to a solution. One should follow the standards and avoid the products based on proprietary algorithms and interfaces. This will avoid being locked into one manufacturer's product line and enable the developer to take advantage of new hardware and software. The entire CBT system should be tested using the exact platform configuration on which it is to be delivered to avoid any surprise bottlenecks. Finally, if the digital video world seems too much to handle, the possibility of outsourcing should be considered.

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large file sizes, the disk capacity must be several gigabytes. This is not unreasonable however, since the cost of hard drives is now around $700 per gigabyte and falling. The CBT delivery stations are connected to the server by some type of Local Area Network (LAN) as shown in figure 10.

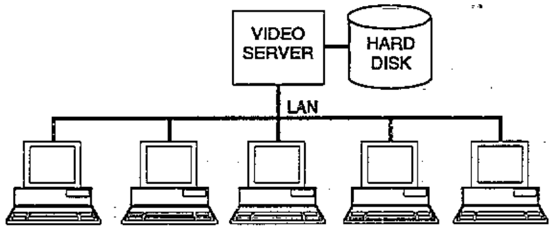

Figure 10. Transmitting Video Over a Network

There are two ways to consider transmitting video over a LAN. Th first way is to download the video in non-real time before the training session starts. The video then resides on the hard drive within each CBT workstation until new training material is required. This approach is perfectly feasible with networks such as Ethernet. Since the transfer is from hard drive to hard drive, the data rate can be much higher than CD-ROM speeds. Consequently, the time to down-load is much less than the normal video playing time. The second way of networking video is real-time on-demand transmission. Unfortunately, Ethernet was never designed to handle long uninterrupted streams of data with critical timing as in the case of digital video. Therefore, video on-demand via Ethernet is not recommended although it can be made to work in some circumstances. The implementation of digital video on demand needs network solutions such as FDDI (Fiber Distributed Data Interface) or ATM (Asynchronous Transfer Mode). Neither of these is very affordable today. In the future, ATM products will dominate the market for most networking applications. A comparison of LAN protocols is shown in table 2.

Table 2. LAN Protocols

Protocol	Bit Rate	Access Time
Ethernet	10 Mbps	Indeterminate
Token Ring	4-16 Mbps	50-500 ms
FDDI	100 Mbps	10-200 ms
Fast Ethernet	100 Mbps	Indeterminate
ATM	150 Mbps	Det by switch

When a fully networked solution is implemented all the problems with mastering, distributing, and handling CD-ROMs are eliminated. In particular, updates can be made quickly and easily.

SOME THINGS TO REMEMBER

1. Trade-off hardware versus software solutions. The cost of upgrading the CPU for a software algorithm may exceed the cost of adding video playback hardware. Consider these examples. For a 1/4 screen or less, use a software algorithm and a minimum processor of 486/DX2/66MHz. For greater than a 1/4 screen, use an MPEG playback card with a somewhat less powerful CPU.
2. Ensure the chosen solution for digital video has all the required features needed for CBT.
3. Due to the dynamic environment, buy the hardware and software as late as possible.
4. Stay with the industry standards including hardware and software interfaces to ease expansion and upgrade.
5. Consider any possible cross-platform requirements i.e. portability between Windows, System 7, Unix, and OS/2.
6. Test the whole system using the same hardware/software configuration as for the delivery platform.
7. Show samples of the video with the chosen implementation to the customer as early as possible.
8. Remember, the compression removes high spatial frequencies which blurs sharp edges and removes some detail.
9. Many small companies in digital video come and go, so make sure that your suppliers are likely to be around for awhile.
10. Be very careful when planning a network solution using digital video until the next generation of networking products is available.

FUTURE TRENDS

Digital video for CBT is still in its infancy and many improvements can be expected in the future. As price/performance of CPUs continues to improve over the years, it is expected that CPU performance will double every 2 years. The price per megabyte of hard drives will continue to fall. Hardware codecs will become inexpensive and become a standard part of computer graphics (VGA) boards. Many of the digital video products available today will disappear from the market. The most probable survivors will be MPEG and Indeo.