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Digital Video Technology - Today and Tomorrow
11th Office Information Technology Conference Paper Abstract

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Digital video is probably computing's fastest moving technology today. Just three years ago, the zenith of digital video technology on the PC was the successful marriage of digital text and graphics with analog audio and video by means of expensive analog laser disc players and video overlay boards. The . state of the art involves two different approaches to fully digital video on computers: hardware-assisted and software-only solutions.

Hardware-assisted delivery currently provides full-motion, full-screen video of very high quality. Various technologies such as DVI, MPEG and others provide this delivery with reasonably modest hardware requirements. Software-only technologies initially promise no added hardware cost for delivery, but at this point, provide somewhat lower video quality and less than full-motion delivery rates. Software video also places significantly greater demands on the CPU and video subsystem, since all of the video decompression is performed there, rather than in custom-designed chips, as is the case with hardware-assisted video. These requirements effectively negate the cost benefits of software video, but as CPUs increase in power and video chipset integration advances, hardware and software technologies will merge.

Both video technologies are currently in use and saving money within the DOE, and both have their place today and tomorrow. While nascent software-only digital video technologies are improving every day, this presentation will focus on proven hardware-assisted technologies in common use today, as well as those just becoming available.

Throughout this paper, I will try to remain fairly nontechnical, focusing on the concepts behind the various technologies rather than the nuts and bolts. I will also do my best to impart some sense of the excitement and adventure that we feel in this field. I'll touch on what digital video is, why we use digital video, how the technologies differ, and where the future of digital video is heading, and finish with some examples of digital video in use in the DOE today. I hope that after reading this paper you not only be well informed about digital video technology, but motivated to learn more about how you can start to employ digital video in your enterprise and start working better for less.

If you have questions, would like more information or to contact the author, please refer to the biographical section at the end of the paper.

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1.0 What Is Digital Video?

The movement towards multimedia training, educational and gaming applications seems as unstoppable as the Windows juggernaut itself. Riding close behind what most of us consider "traditional" multimedia (encompassing sound, graphics and animation), is the movement towards digital video-enabled applications. As some people ask if this doesn't represent a solution in search of a problem, we will briefly explore that question a bit later. To start out, let's take a quick look at just what digital video is, later moving to why it is becoming so important to the way we do business, both within the DOE and the business community at large.

Most of us have seen video incorporated in computer applications in one form or another. From advertising kiosks at airports and shopping malls, to interactive video disc (IVD) training applications, the vast majority of this digital video is really a combination of digital images (from the computer) and analog video (from video tape or laser disc). This merging of analog and video information is performed in the computer by means of an overlay board that takes the analog video stream and lays it on top of the digital images created in the computer itself. This hybrid video has been around for years and provides very good image quality. It is not a fully digital stream, though; it costs more to create and distribute and is otherwise limited in several ways.

1.1 Analog/Digital vs. Fully Digital Video

The cost of pressing an analog video disc remains very high, especially when compared to the cost of writing a CD-ROM disc in-house, as analog laser disc technology simply does not provide for an inexpensive, in-house alternative. The gulf between these costs grows even more significant once you consider the cost of remastering the analog laser disc versus simply rewriting a CD-ROM. While analog mastering is still in the capital expense range, CD-ROM discs can be very inexpensively produced in-house after the cost of a $3 to $4K CD-ROM writer; at about $20 per disc. Delivery station costs are also very high for IVD. Between the laser disc player and overlay board, costs of $3 to $4K per workstation are typical, compared with as little as $300 to $400 for digital video boards. Finally, as IVD requires the merging of analog and digital signals, it is inherently a non-networkable signal, while the fully digital DVI, MPEG or software-only video signals are. More on this later.

Though digital video on personal computers has always been an exercise in compromise in terms of cost and performance, the balance has begun to turn in favor of content developers. It has become possible over the last few years to move to fully digital, highly flexible, easily editable and completely networkable products. These products deliver quality matching that of analog video at lower and lower costs. Deciding where you will choose to step onto this technology curve is really a question of finding the point along it at which the benefits outweigh the costs of going into digital video for your enterprise.

2.0 Why Use Digital Video?

While many other uses for digital video exist, we will focus on three training-related areas: just-in-time training (JIT) or performance support systems (PSS), simulations and more realistic testing.

Many of you have heard of or perhaps even seen JIT or PSS systems in use already. Simply put, JIT and PSS provide training or more precisely, step-by-step instruction in a particular process on an as-needed basis, often right at the job area. For example, suppose you were assembling a pump subsystem and received notice that an engineering change order (ECO) had been issued that altered the method of securing that pump subassembly to its frame. You could turn on your PC, choose a menu option for pump assemblies or perhaps new ECOs, call a digital video program from a server on the other side of your plant and view a digital video program detailing the ECO and its implications on your work. When finished with the module, you could take a short quiz, manipulating a simulated assembly on screen and learning first-hand of the new requirement. A record of your training and testing results could then be tracked at the server. Digital video provides the means for this support.

Simulations are another area in which digital video is a real boon. For example, AlliedSignal Kirtland Operations site (in Albuquerque, New Mexico) has developed for the DOE Emergency Operations Center (EOC) an interactive role-playing simulation of an emergency situation involving hazardous waste. Learners take on the role of an EOC manager, interacting with staff, the media and other characters, making choices about how to handle the various developing situations at the site of the emergency. By choosing well you proceed effectively through the scenario. Choosing poorly however, leads to some rather nasty consequences. As this is a time-based scenario, both performance assessment and feedback occurs in real-time. Both the rate of the situation's progress and the level of difficulty of the scenario are adjustable, enhancing the learning experience.

Improved testing through digital video support can come into play in areas that require the application of abstract concepts to real-world scenarios. For example, while you would certainly prefer to have a highly trained security force that thoroughly understands the concepts of arrest authority and the employment of deadly force, how would you effectively test for this? Would you write test questions that paint a scene and then require a yes/no response to various different scenarios? Ask for essay responses? Whatever methodology you choose, how would this compare to actually being in a situation requiring a split-second decision on whether to slap leather or stand down? Using video to present threat scenarios and then asking those same questions gets to the heart of the matter far more effectively than any written test. Once again, digital video provides the questions to these answers, you might say.

Now we'll take a brief look at some of the technologies for hardware and software digital video with an eye to how we can use them to provide digital video technology simply and affordably.

3.0 Hardware-Assisted Digital Video

Hardware-assisted video delivery methods are here today, providing very high-quality products at reasonable prices. Let's look at the two major contenders at the moment; the Digital Video Interactive (DVI) and Motion Picture Experts Group (MPEG) standards.

DVI, an IBM and Intel initiative, provides two different levels of video quality; these are referred to as Real Time Video (RTV) and Production Level Video (PLV). As the name implies, RTV can be captured in real-time, by means of a daughter card that snaps onto the DVI delivery board. This allows for easy project prototyping, or video "proofing," without the extra time, effort and expense involved in having your video compression performed by a third party. While video quality of RTV is lower than we have come to expect from analog VCRs, the total cost of the DVI capture/playback board is only about $1,400.

PLV compression results in much higher-quality video at a given file size, but requires the services of an outside compression bureau, typically at a cost of $150 to $200 a minute. DVI provides full motion video with high-quality audio. DVI playback requires the assistance of a delivery card (such as an Intel ActionMedia II board), that provides support for both the video and audio streams in either RTV or PLV format and costs about $1,000. Authoring tools and third-party add-ins to control DVI more artfully are readily available.

MPEG is a relative newcomer on the digital video scene, but has already won some very powerful supporters in the industry. Unfortunately, there is no simple and inexpensive way as of yet to capture prototype-quality MPEG video, as there is with RTV-level DVI video. On the other hand, while it is still very expensive to build a PLV compression station for DVI (on the order of $100K, a very good MPEG compression station can be assembled for a third of that cost.

Further, MPEG encoding performed by third parties is quite a bit less expensive than PLV compression, currently running from $60 to $120 a minute. MPEG playback requires of one of several different MPEG delivery boards now on the market, ranging in price from about $300 to $1,500. Like DVI, MPEG encapsulates audio within the same stream of data as the video. Unlike DVI, MPEG easily allows for the control of the quality of the video and audio streams independently. MPEG playback provides full motion video quality with high-quality audio. Existing MPEG capture and editing tools are also superior to those supporting DVI at the moment, and with DVI's marketplace decline, this gulf is likely to grow. Authoring and third-party tools to control MPEG more artfully are also readily available, with more.

3.1 MPEG vs. DVI

It may seem natural to ask which is the better technology, DVI or MPEG? While each has its own strengths, it might be more important to consider which technology will be available over the next three years. As for technical prowess, DVI has the advantage of being editable in finished form, as the video can be called on a frame-by-frame basis. MPEG does not easily provide this frame-accurate digital editing. DVI is an older, more mature technology and has a larger installed base than MPEG. While DVI provides simple capture capabilities allowing for very inexpensive prototyping and product review, it remains a proprietary scheme, requiring delivery boards currently available only from Intel, costing approximately $1,000 each. Further, the installation and support of DVI products is complicated.

MPEG is rapidly emerging as the new technology leader in hardware-assisted digital video. MPEG delivery boards are becoming mass-market items, with companies such as Sigma Designs leading the charge into the consumer marketplace. Both CD-I and CD-V (video) products employ MPEG video. Games, educational and other titles are also beginning to proliferate on the MPEG platform. You might wonder why we should care that about these markets; well, the answer is very simple. The potential of a larger installed base of products, wider title availability and lower cost all add up to greater probability that the technology will endure in the computer marketplace. At $300 to $400 per workstation and with rapidly increasing availability from a number of vendors in the very near future, MPEG has gained broad industry support in a very short time and appears to be the hardware-assisted technology of choice for new projects. On the other hand, DVI has entered a decline that is based not so much upon lack of technical prowess as a relative lack of marketing successes in the face of stiff competition.

4.0 Software-Only Digital Video

Well then, if wider availability and lower cost of the delivery platform is good, isn't the promise of total availability and no cost even better? By completely eliminating the need for specialized hardware, doesn't software-only video provide the best of all worlds for digital video? Unfortunately, at least for the time being, the answer to that question is both yes and no. While the concept of digital video delivered without the need for any additional hardware is very appealing, the reality is that this is simply not yet attainable. On top of that, the current quality of software-only video, while rapidly improving, is not yet in the league of hardware solutions.

Without the special support for the acceleration of software compression and decompression algorithms (codecs) built into some of the newer video chipsets, software video is limited to quarter screen, 15fps playback of less than RTV or MPEG quality, at best. Even at that level, the minimum delivery platform for software video is a 486DX2/66, preferably with a powerful disk-channel and very fast video acceleration capabilities built into the chipset. At this point, however, software-only digital video remains an oxymoron.

Why are the hardware requirements of software video so great? The answer lies mainly in the compression ratio of the video and the resultant data transfer rates necessary to support its playback. Hardware-assisted digital video methods provide about 150 to 200:1 compression ratios, and require only about 150Kbps (single-speed CD-ROM) playback rates. In theory, software-only digital video should be just that, video decompressed and delivered by nothing more than the software. The reality is that, as powerful as they are, CPUs are general-purpose devices that are not designed for video decoding as are the chips on DVI and MPEG boards. To compensate for that limitation, software video methods utilize much lower compression rates overall than do hardware methods, and therefore require much higher data rates for equal-quality playback. The result is a loss of quality and frame rates.

What software video does provide, however, that hardware-assisted technologies lack so far, is scaleability. Though the quality suffers on lesser systems, software video codecs provide universal product deliverability, whether or not you have the added equipment to improve its quality.

Some point out that perhaps the primary reason Intel has moved from the world of hardware-assisted digital video (DVI) to software-only video is that software solutions sell more powerful CPUs, and CPUs are where the big money is. Whether or not this is the case, the question of how we provide decent software-only video performance remains. The answer to that question has been the design of chipsets that contain hard-coded instructions designed to accelerate software video streams to full-motion, and further, to stretch quarter-screen video up to full-screen sizes. Companies including ATI, Diamond, Matrox, VideoLogic and others have announced, and perhaps even shipped, video cards that do just that; providing built-in capabilities to accelerate and stretch (pixel interpolate) the video stream. Sound a bit like hardware-assisted video? Right now, even at the cost of just $200 or $300 over that of a standard video card, these "software-only" solutions are no less expensive than the hardware technologies they replace, and typically provide lower-quality video.

5.0 The Future of Digital Video

Over the course of the next year or two, several developments are likely to prove of interest in the digital video field. With current video codecs providing compression ratios of 150 to 200:1, we are able to squeeze full-motion video down to a 150 to 300Kbps transfer rate requirement (single to double-spin CD-ROM drive or network throughput levels). While greater compression ratios are probably possible, it seems more likely that efforts will be focused instead on improving the quality of the video stream available at these 150 to 300Kbps rates.

Faster CPUs will continue to be developed of course, with ever increasing capabilities to take on such compute-intensive tasks as audio and video decompression. Even more significant, however, will be the increased integration, both on the motherboard and within the CPU itself, of video and audio decompression and playback capabilities.

Along those lines, there is talk of building video codecs into chipsets on the motherboard within another year. Advanced digital signal processor (DSP) chips capable of handling these audio and video codecs in real-time are also beginning to emerge and are, in some cases, headed straight for motherboard integration. After that, perhaps in the P6 (Intel's next generation CPU), these codecs will be built into the CPU itself. These and other advances will eventually make the question of hardware vs. software video fade into inconsequence as digital video technologies merge and proliferate.

6.0 Delivering Digital Video

Now that we've covered the what's and why's of digital video, let's take a look at some of the how's. We will touch on both standalone and networked delivery, though as the integration of computing and communications accelerates, networked delivery solutions will almost certainly dominate.

6.1 Standalone Delivery

Programs incorporating digital video are springing up in all disciplines of business at an increasing rate. Training, simulations and performance support applications have lead the way, but reference, education and gaming are quickly catching up. From the low end of 15fps, 1/16th screen software video right up to full-screen, full-motion MPEG and DVI video, the delivery of these programs is often performed on a standalone PC or Mac system with either large internal hard drives or interchangeable media (such as CD-ROM or magneto-optical cartridge). Fortunately, these storage requirements are growing more manageable as capacities rise and cost-per-megabyte falls.

DVI and MPEG both require about 8-10Meg of storage per minute of full-motion video (including audio). With hard drive prices approaching $.50/Meg, it has become more practical to purchase Gigabyte hard drives for use in individual workstations. As internal hard drives are fixed devices, however, we still have not addressed the need to find a suitable transfer medium with which to distribute large, digital video applications. This leads us to magneto-optical and CD-ROM drives. Of the two, CD-ROM has proven to be the more suitable media, for both distribution and delivery.

Magneto-optical drives are expensive (about $5K each in the 1Gig format), and employ relatively pricey data cartridges (about $100 to $200 each), but are very fast, approaching hard drive data transfer speeds. As CD-ROM recorders have fallen to less than M/O drives prices, the equation has shifted dramatically in favor of the CD-ROM drive. While not as fast as M/O, modern double-spin (and now, even quad-spin) CD-ROM drives provide more than adequate transfer rates for digital video delivery, and cost from $200 to $500 each. At about $20 per CD for in-house produced discs, the cost per megabyte of CD-based delivery is extremely low. When you consider speed, distribution media cost and general availability, CD-ROM clearly emerges as the medium of choice for digital video distribution and delivery.

6.2 Networked Delivery

By nature of being a fully digital data stream, digital video signals are as networkable as any other data stream. While networking the digital video stream is far from a trivial undertaking, it is being done both in industry at large and within the DOE community today.

Some of the advantages of networking digital video include obviating the requirements of a large drive or CD-ROM at each workstation, the ability to take advantage of very large hard drive arrays or CD-ROM "jukeboxes" on servers, and centralized student progress tracking and record keeping. Some of the difficulties encountered in networking digital video include building an adequate server platform, providing the necessary bandwidth in the network cabling, and providing a means for ensuring that the video data being delivered over the network takes priority to the nonvideo traffic on the network, as video and audio data traffic is uniquely time-sensitive and dramatically more "bulky" than the ordinary data traffic common to networked delivery.

Tackling this problem is well beyond the scope of this presentation, but there is one general rule of thumb; it is far easier to build digital video networking capability from scratch than it is to retrofit digital video capabilities into an existing network infrastructure. By planning today for the needs of digital video networking capabilities in your future and attending to some rather important details up front, you can pave the way for the employment of this technology throughout your enterprise, saving the time and expense of re-engineering your network after the fact.

7.0 Digital Video In Action

Now we will take a brief tour of two different sites across DOE employing digital video, looking at what they are doing today and where they are headed tomorrow. We will be exploring products and delivery methods of the AlliedSignal Kirtland Operations and Wackenhut Savannah River sites. Though they focus on different problems (applications creation and systems integration at AlliedSignal and networked delivery of existing applications at WSI SRS), both groups are pioneering the use of digital video enabled applications and showing us how to work better for less in the DOE today.

7.1 AlliedSignal Kirtland Operations

AlliedSignal Kirtland Operations has been involved in digital video technology for about three years now. One of the earliest digital video pioneers, AlliedSignal KO has earned the reputation of being right at the "bleeding edge" of this technology. Their primary focus has been on application development and tackling the technical considerations of integrating networked digital video into the enterprise.

Though they are currently experimenting with both software video and MPEG, existing applications have been developed for DVI delivery under Windows. While DVI is very strong technically, as mentioned earlier, it never developed the kind of momentum necessary to take over the market. Nevertheless, interactive training developed in DVI is very effective, provides excellent video quality with relatively minimal hardware requirements and has been used across the DOE community.

Existing applications developed by AlliedSignal include a foreign travel briefing, OPSEC (operations security) refresher and Termination modules. Projects in progress include a comprehensive security briefing, an annual security refresher, an EOC simulation, a new-employee orientation for DOE ALO and several training simulations for TSD and other customers.

7.2 WSI Savannah River Site

WSI SRS has been delivering digital video training since April 1993. Led by Dave Libengood, WSI SRS has also gone down the DVI path, but has stuck almost entirely to the networked fork in the road. Dave has a dedicated digital video training delivery lab supporting 38 digital video workstations from two servers, as well as five standalone workstations elsewhere across the site. These systems are up and running, delivering over 1500 applications in such diverse areas as drivers' safety, writing skills and Novell training.

Unlike Allied Signal Kirtland Operations, whose primary focus has been on digital video networking research and development and application development for use throughout the DOE community, the WSI digital video lab focus has been on the delivery of existing applications. Where the WSI effort really stands out, though, is in the money it saves DOE. Dave Libengood estimates that during the first year of operation, the lab offered real savings of over $250K. He further estimates that they will save enough to completely pay off their $700K hardware investment no later than April 1996. That's three years to completely amortize a three-quarter million dollar investment, including time spent to pioneer the usage of a new technology.

8.0 Biography

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Joshua Liberman, the author, is a Senior Technologist with AlliedSignal Aerospace in Albuquerque, New Mexico. Joshua has worked in computing for 11 years. Depending upon how you measure it, he began his hardware career in either 1987 (when he took his first PC apart) or 1988 (when he put it back together). Joshua's focus has been on Windows-based, networked multimedia systems, building, connecting and troubleshooting them. Joshua is a Certified Netware Engineer and is working on attaining his Enterprise CNE and Microsoft Certified Systems Engineer, as well. Joshua has the perfect Windows degree, a B.A. in Philosophy from the University of New Mexico.

Joshua manages a digital video lab, does networking and digital video technology research and development and provides hardware, software and networking support for a group of instructional designers creating Windows-based, interactive digital video training products. Joshua is on the steering committee of the DOE Advanced Training Technology Quality. In his off time, Joshua climbs, mountain bikes, and relaxes with his three cats, two dogs and Novell/Windows NT computer network.

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