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PORTABLE COLOR MULTIMEDIA TRAINING SYSTEMS BASED ON MONOCHROME LAPTOP COMPUTERS (CBT-IN-A-BRIEFCASE), WITH SPINOFF IMPLICATIONS FOR VIDEO UPLINK AND DOWNLINK IN SPACEFLIGHT OPERATIONS

Center Director's Discretionary Fund Final Report
(Project Number 91-16)

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Science and Engineering Directorate

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This report describes efforts to use digital motion video compression technology to develop a highly portable device that would convert 1990–91 era IBM-compatible and/or MacIntosh notebook computers into full-color, motion-video capable multimedia training systems. An architecture was conceived that would permit direct conversion of existing laser-disk-based multimedia courses with little or no reauthoring. The project did not physically demonstrate certain critical video keying techiques, but their implementation should be feasible. This investigation of digitial motion video has spawned two significant spaceflight projects at MSFC: one to downlink multiple high-quality video signals from Spacelab, and the other to uplink videoconference-quality video in real-time and high quality video off-line, plus investigate interactive, multimedia-based techniques for enhancing onboard science operations. Other airborne or spaceborne spinoffs are possible.

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INTRODUCTION

Computer-based training (CBT) covers a wide range of electronic teaching tools and methods, but its classic form involves combining text, graphics, animation, motion video, and sound to provide a highly interactive environment for the student. Properly authored CBT is engaging and promotes better retention of knowledge than traditional teaching methods. (Plus, the "instructor" is inexhaustible!) Versatility and speed in selecting and playing video clips or stills is typically provided by having the CBT computer send control signals to a laser-disk player. Output from the laser-disk player may be displayed on a separate screen, but overlaying retrieved video on a portion of the CBT computer's screen is generally preferred.

Laser-disk-based systems are somewhat bulky and moderately expensive, so using them in NASA's mission training would involve centralization, hence scheduling complications. Many NASA personnel, particularly flight crewmembers, have notebook computers. If a small, inexpensive add-on device would convert those machines into training systems, students could work at their convenience (time and place). Although the intended prototype would be briefcase-sized, later versions could be miniaturized. Ideally, CBT output would be sent to an ordinary NTSC television, so the student could train at home or in a hotel room as well as at the office.

The main advantage of laser-disk systems is virtually instant random access to video clips and/or stills. "Editing" is extremely easy—one need only provide video frame numbers or time synchronization codes and playback speed. (There are 30 frames per second in a standard television signal). Most digital approaches require a distinct file for each clip or still, so converting a laser-disk-based course could require significant re-authoring. An important goal of this project was to allow direct conversion of a laser-disk-based course by digitizing the laser-disk image into a single file and deriving digital byte offsets from analog frame counters. This could have significant implications where large bodies of laser-disk courses already exist, such as in the airline and automotive industries.

Motion video digitizing and compression schemes work by sampling an analog image, converting it from lines to pixels, then reducing the number of bits required to store the digital information. Some approaches use add-in hardware boards, while others are software only. The differences lie in image size, speed of motion, storage space required, and of course, price. With or without hardware assistance, certain software techniques are typically used:

Cosine transforms

Averaging color pixels (humans are much more sensitive to detail than color)

Describing repeated pixels once, with a counter telling how many times to repeat it (intra-frame coding)

Storing a reference frame, then describing only the changes to it until a certain percentage of pixels have changed, when a new reference frame is stored (interframe coding)

The first three can be done in real-time, while interframe coding typically requires off-line processing.

APPROACH

Originally, separate devices were to be developed for Macintosh and IBM environments, with extensive software manipulation of digital video within each device. Investigation revealed that this would require an excessively large hardware and software development capability. Since reasonably inexpensive, commercially developed digitizing hardware was becoming available as this discovery was made, the concept evolved towards a single device that could be driven by either platform. The core of the effort involved (1) integrating decompressed video with graphics from an external laptop computer and (2) making the discreet-file-based decompressor look like a continuous-stream laser-disk device in the eyes of the laptop computer. Video was the main focus, as audio capability is generally embedded in processors and file schemes capable of handling video. Converting signals from VGA to NTSC was originally a research issue, but disappeared as inexpensive commercial products proliferated. Figure 1 depicts the selected hardware architecture.
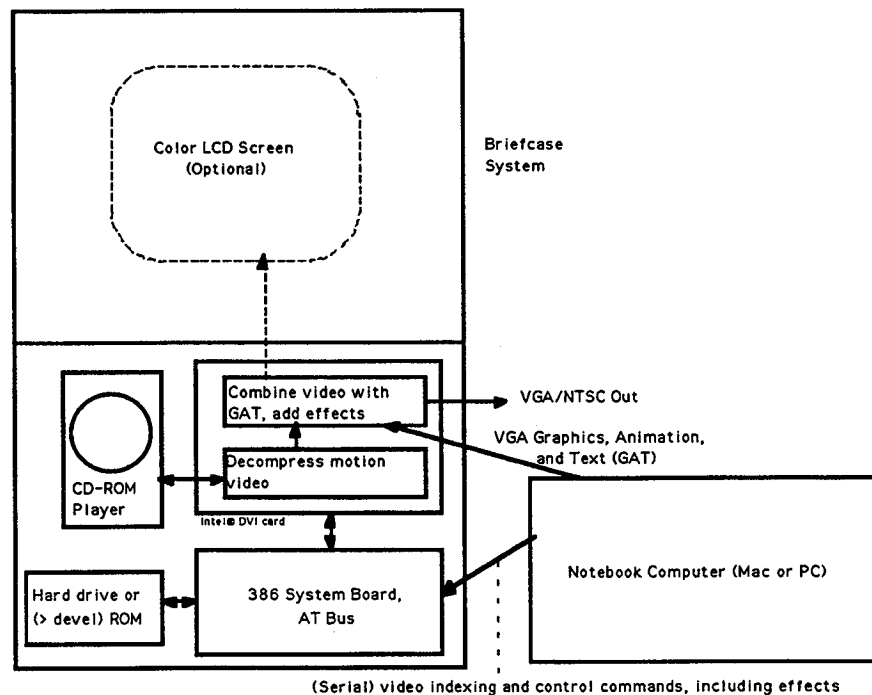

Figure 1. CBT-in-a-briefcase video concept.

An 80386-with-ISA expansion board architecture was chosen for its simplicity and relative ease of implementation. The Intel/IBM Action Media II expansion board used relies on Intel's Digital Video Interactive, or DVI™, technology. DVI™ relies on a pair of very fast graphics chips, one for manipulating individual pixels, the other for processing entire frames of pixels. The board is designed to be upgradeable via software improvements. An essential feature is the ability to "key" the DVI™-generated video (still or motion) to a VGA graphics signal generated internally or externally relative to the host PC. Figure 2 illustrates the two types of keying.

Although the DVI™ hardware was designed to support analog or external keying, establishing a software environment for delving into the core of the project became an Achilles heel. Resources for developing machine-level drivers for the DVI™ hardware were not available, and

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certain machine-level documentation had not been made public until near the end of the project, so we had to rely on commercially available development tools.
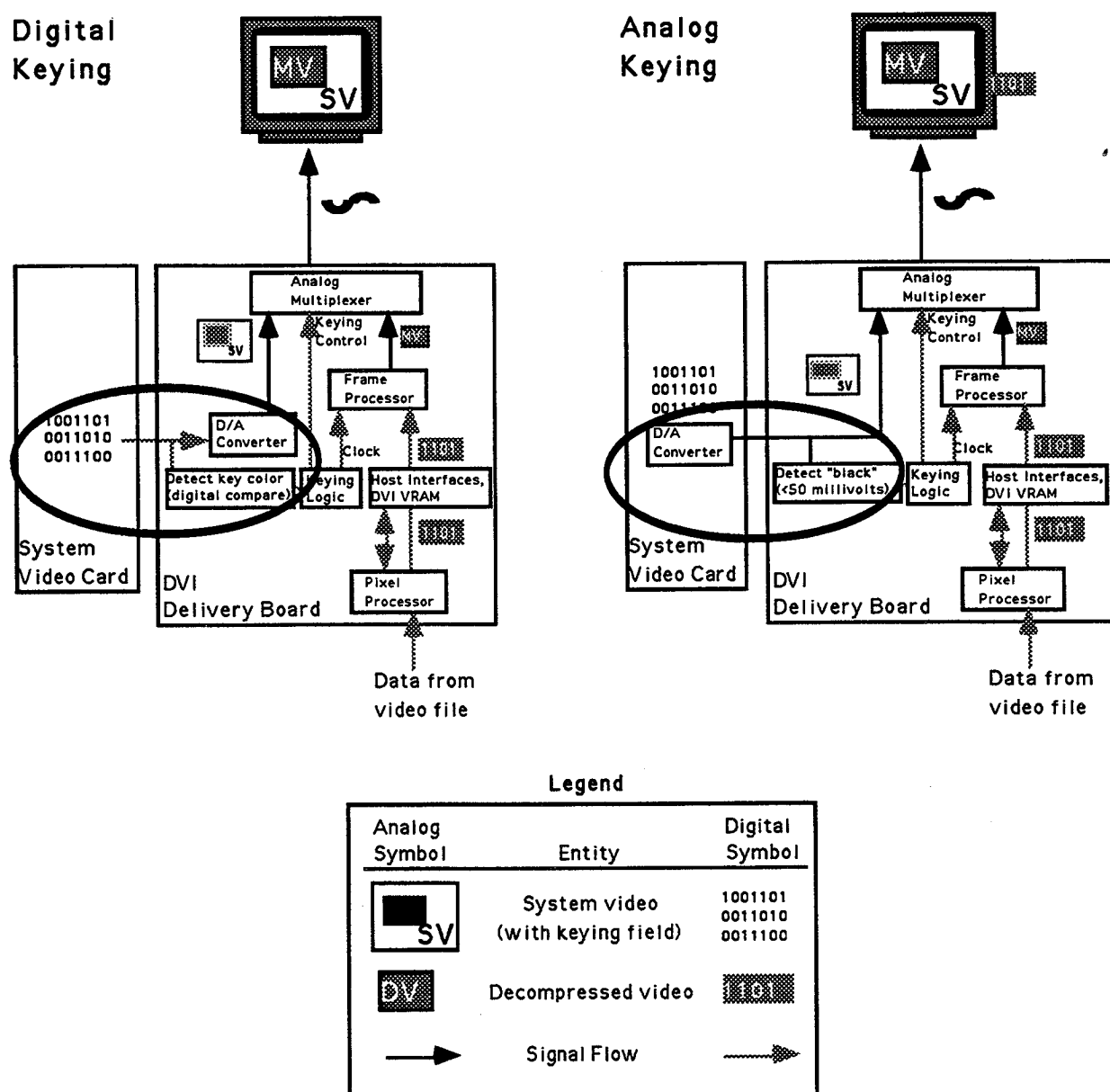

Figure 2. Digital versus analog keying in a DVI™ environment.

Figure 3 shows the hardware setup used for attempts at analog (external) keying. A tower configuration PC represented the device to be developed. (Note: The DVI™ video board includes a dedicated SCSI controller designed specifically for CD-ROM players.)

Initially, Intel's DOS-based "AVSS" environment was used, but it failed to support external keying. Experiments were then conducted with IBM's "Action Media Developer's Toolkit" under OS/2, which relies on external keying because OS/2 does not support digital feature connectors on display cards. However, the Microsoft C (Version 6.0) debugging environment was not compatible with the then-current version of OS/2 (2.0). Working with an unmodified sample player program, the audio track of a DVI™ motion video file would play when the notebook machine was connected, but video display could not be obtained. It was essential that a graphics-type VGA signal (e.g., Windows,

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as opposed to a DOS display) be present to provide enough sync information to satisfy certain drivers. Audio playback was also obtained with a Macintosh Powerbook attached.
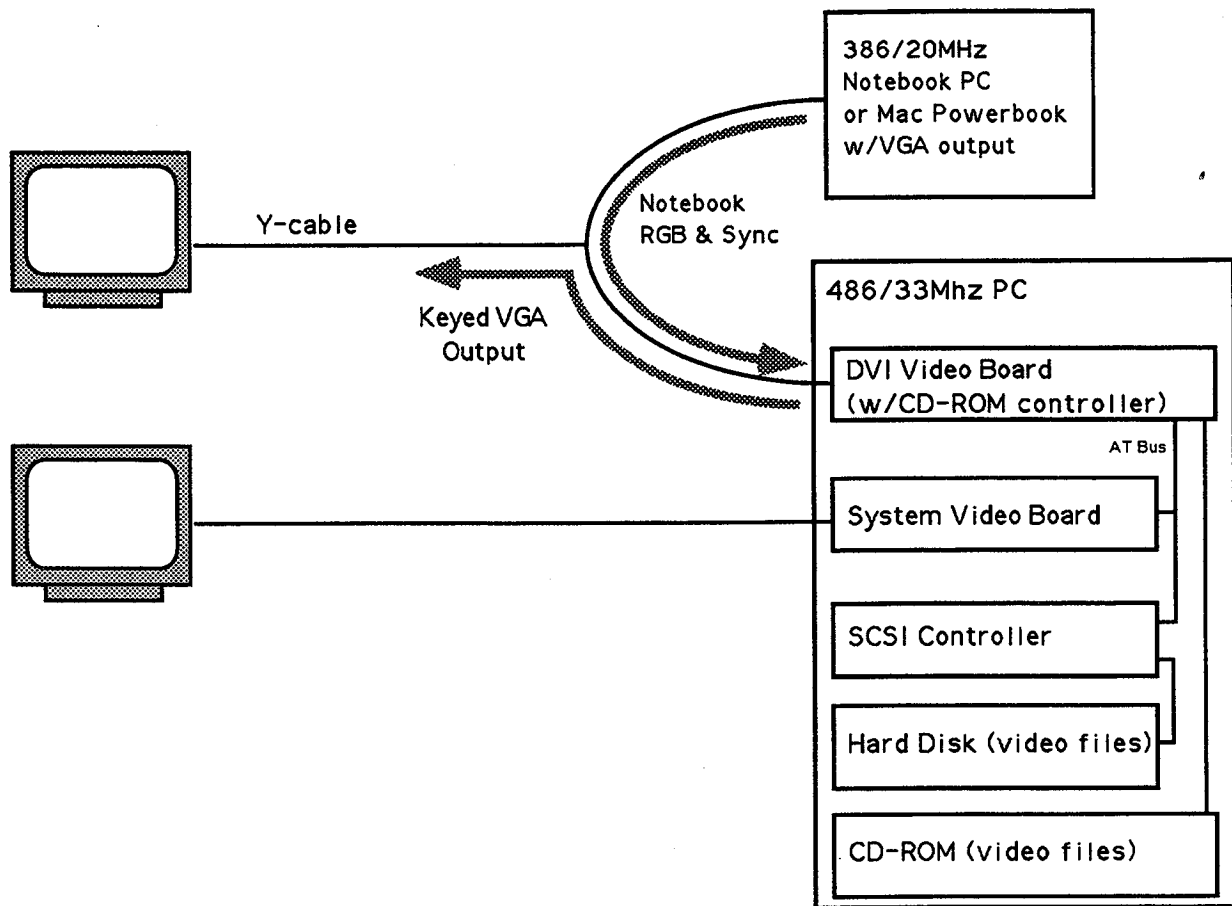
Figure 3. Equipment setup for CBT-in-a-briefcase development.

A DOS-based, Microsoft C-compatible environment called New World was obtained. Analog keying support was lacking at first, but, due to inputs from this project and other developers, the manufacturer produced a new version that, according to its documentation, had the necessary features. Unfortunately, a three-way clash occurred involving video output from the DVI™ board, system video from the sample playback program we were working with, and debugger output. Use of a third display card and monitor would probably have resolved the conflict, but this was not available. Contact with other developers indicates that relatively little work has been done with external keying for other than mundane support of the OS/2 operating system.

Without debug capability, investigation of keying colors and adjustments of other parameters could not successfully be made. It is possible that the "black" voltages generated by the notebook computers were higher than the 50-mV threshold that the ActionMedia II board uses for digital keying. This consideration came to light in technical discussions with Intel after active research had ended.

An important feature of the intended design was the ability to convert laser-disk-based courseware with minimal re-authoring. This could be accomplished by digitizing and compressing the laser-disk video as a single file and storing SMPTE time codes within the file. (DVI's™ AVSS file structure provides for such substreams. Time codes can be extracted from the laser disk or generated during compression.)

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Toward the end of the time allotted for research, hardware conforming to the Motion Picture Experts Group (MPEG) began to emerge. The principal investigator (PI) did not have time to work with MPEG, but has seen demonstrations and noted excellent picture quality—an order of magnitude higher than DVI™ (in the PI's subjective opinion). Discussion with other investigators indicates that analog frame numbers can also be encoded directly into the data stream of an MPEG-1 file during compression.

Concepts for integrating the proposed device with commercial authoring systems were discussed with several publishers. If hardware development had proceeded more smoothly, two or three would have provided source code (under nondisclosure agreements) to allow the PI to develop driver software. One small company became extremely interested in the project, provided extensive technical visits, and was eager to co-develop drivers. Unfortunately, the principal engineer passed on suddenly and the company closed.

DIRECT CONCLUSIONS

The intended device could be developed if a more robust debugging environment were established. If developed, use of MPEG video is recommended due to higher quality compared to DVI™.

There is still intrinsic value in being able to convert a "plain vanilla" notebook computer into a full-color multimedia system, particularly if one has a significant investment in laser-disk-based courseware. Two factors may reduce the intrinsic value for other environments:

(1) Inexpensive digital video on everyday desktop computers and the sheer number of computers may make CBT training sufficiently accessible.

(2) Decreasing cost of color notebook computers, subnotebooks, personal digital assistants, and consumer devices.

IMPLICATIONS FOR SPACEFLIGHT

While contemplating video compression methods and data flow rates, the thought arose that this technology might be used to uplink motion video to the space shuttle. A 128-kbit/sec bandwidth, currently used for what amounts to fax transmissions, is available. Unfortunately, DVI™ requires 150 kbyte/sec for full-screen video, but it was thought that a smaller window might be transmitted. Further examination has shown that commercial desktop video teleconferencing systems available on AT-bus expansion cards would be better suited for this application, since they are designed to run in the 56- to 128-kbit range. However, DVI™ and MPEG hold potential as a means of transferring detailed full-screen video off-line, e.g. 10-minute transmission time to upload 1 minute of video. Marshall Space Flight Center and Johnson Space Center are jointly sponsoring an effort to demonstrate motion video uplink.
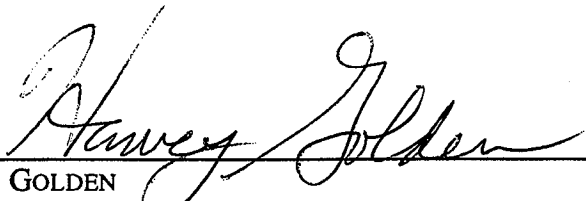
While discussing video uplink possibilities, the need for multiple-channel high-quality video downlink from the shuttle (particularly during video-intensive Spacelab missions) surfaced. The PI was able to identify other (non-DVI™) compression schemes with extremely high resolution, using about 6 megabits per second. Such wide-band channels are readily available via the Spacelab high rate multiplexer. This has led to a flight project to downlink six motion video channels simultaneously on the USML-2 mission.

APPROVAL

PORTABLE COLOR MULTIMEDIA TRAINING SYSTEMS BASED ON MONOCHROME LAPTOP COMPUTERS (CBT-IN-A-BRIEFCASE), WITH SPINOFF IMPLICATIONS FOR VIDEO UPLINK AND DOWNLINK IN SPACEFLIGHT OPERATIONS

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The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

H. GOLDEN
Director, Mission Operations Laboratory

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