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Interactive Television

Complimentary StorageTek Edition

WINSTON WILLIAM HODGE

Interactive Television

A Comprehensive Guide for Multimedia Technologists

Winston William Hodge

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The sponsoring editor for this book was Roland S. Phelps, the supervising editor was Robert Ostrander, the manuscript editor was Aaron Bittner, and the director of production was Katherine G. Brown. This book was set in ITC Century Light in Blue Ridge Summit, Pa.

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Interactive Television

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To Sue, Karen, and Nancy with all my love.

Acknowledgments

Interactive television and advanced multimedia could be considered to have been born of early space flight and airplane simulators in the early 1960s. Computer-generated video, created by large mainframe computers, simulated environments for astronauts and pilots. Television projection systems were used as visual display devices and control panels were interfaced to these computers to permit the astronaut or pilot to interact with his simulated environment. Some simulators provided other environmental effects (such as G-Load simulation, pitch, and yaw) by physically controlling the participant's environment. Different flight simulators provided different levels of interactivity. This was also, in effect, early virtual reality.

It is unlikely that one would want an interactive television system that would provide the same degree of reality as provided by flight simulators, in that it would not be necessary to rotate or tilt the viewer's living room or even his chair; but it is likely that interactivity to permit the dynamic selection of data, movies, or specific kinds of news, interaction with TV talk shows or other programs, and the capability to provide near-real-time responses would be desirable.

The systems planned for tomorrow will be controlled regionally by a central facility (head end) and will provide movies or video on demand (VOD), time-shifted TV, interactive news, tele-education, home shopping, video games, and virtual reality as well as conventional television and telephone service. The service providers of these systems will be the cable television (CATV) providers, TELCO, or combination companies.

These systems will permit the user to sit in front of his or her TV, pick up a single-button remote control, point it at the screen to a menu that appears, navigate through myriad programming possibilities, select a movie, order food to be delivered to his or her home for consumption during the selected program, and interact with the program's producers with regard to his or her likes and dislikes. The possibilities are endless.

This book will discuss: the converging of TV, multimedia, and virtual reality; the technology behind video on demand, interactive TV and advanced multimedia; the architectural concepts, approaches, standards, and requirements; differences between true video on demand and near video on demand; communications require-

ments and storage systems requirements; system control, human interfaces, costs, and the future.

I would appreciate written reader feedback so that subsequent editions of the book can reflect the needs of my readers more precisely. Comments can be directed to me on CompuServe at 74220.2126@compuserve.com (Winston Hodge) or via fax at 714-692-5462.

As the principal author of this book, co-author of some chapters, and sole author of others, I would like to thank all the people who have made this work possible. Because of the timeliness of this subject matter, some of these chapters have been published in various professional journals and presented at professional conferences such as SMPTE and NCTA. Feedback from these presentations has been documented in this book. The CATV, TELCO, computer and communications industries have contributed with plans, drawings, system descriptions, and the like. But mostly, I would like to thank my cocontributors and contributors for their time and dedication to this project. I am truly indebted to them for their contributions.

To Lawrence Taylor, my partner and codeveloper of certain video server and TV set top box technology, contributor of the preface, chapters 3, 5, 6, and 11, my heartfelt thanks and appreciation.

To Stu Mabon, my chapter 3 and *SMPTE Journal* (September 1993) article coauthor, TVOD video server and friendly disk collaborator, deliberator, and friend, who provided valuable support throughout this effort, with hopes we may do more together in the future, thank you.

To Robert Block, president of International Communications Technology Corporation, the founder of Select TV, a brilliant futurist, an individual who permitted me to assist him with his over-the-air broadcast on pay-per-view technology, and coauthor of a paper we jointly delivered to the Society of Motion Picture & Television Engineers (which was only slightly modified to become chapter 13, "The Future"), thank you very much.

To Jack Powers, my CATV and TELCO engineering expert and friend, who helped me write chapters 2 and 14 and provided a good ear and valuable feedback throughout, thanks!

To Chuck Milligan, Director of Engineering at Storage Technology Corporation, who coauthored chapter 7 (which compares true video on demand with near video on demand), thank you for your help, especially in the area of mathematical modeling.

To Bud Junker, my telephone systems engineering expert, who researched demographic and other numerical data to validate concepts and helped reduce it for presentation, who proofed this entire manuscript and found errors others missed, thank you for adding to the credibility of this book.

To Don Dulchinos, Director of Research at Cable Labs, thanks for your help with the valuable information you contributed to this book's preface and chapter 4. These valid and significant CATV statistics demonstrated the reasons why this topic should be covered.

To Roger Pence, Director of Engineering at the NCTA Science and Technology Department, who provided me input from his published writings relevant to chapter 10 (ATM), thank you for your contribution.

To Jim Chiddix, Senior Vice President of Engineering and Technology at Time-Warner, my profound thanks for your advice and copies of your numerous published papers and relevant drawings and charts that found their way into various portions of my book, and for helping me obtain current but preliminary MPEG 2 specifications.

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To David Hench, Hodge Computer Research's (HCR) Managing Director of Imaging Transforms, thank you for assistance in proofing chapter 5 relevant to the various image compression technologies.

To Gordon Smith, Vice President of Technology at HCR, patent holder of 7 image compression patents, digital imaging inventor, contributor to chapter 5, and technical proofreader of the entire book, thanks for your considerable time and effort.

To Aaron Bittner, who put a lot of effort into this book's final edit, thank you for your careful attention.

Much of this undertaking was a partnership dedicated to bringing together under one cover the various ideas that, when combined, would provide one integrated volume on the subject of interactive TV and advanced multimedia. This book is intended to be the single-volume reference manual on this topic, the guide for the ITV/multimedia practitioner and/or enthusiast.

This book was created using distributed computing technology and communications facilities. It was initially prepared on a Macintosh computer, simultaneously on a Local Area Network and a Wide Area Network connected to other MACs and PCs. Word processing was done mostly on Microsoft Word (MACs and PCs), but partially using WordPerfect because this was my partner's preferred word processing software.

Communications between various geographic locations was facilitated using Apple Remote Access and Microphone II Pro. Sometimes the manuscript was sent via CompuServe or the Internet when the recipient was not immediately available. Sometimes the document was faxed, and then (using OCR software) converted back to machine-readable and editable form. As can be seen, we used the tools of our trade to create this document, because most of it was created via telecomputing. A list of software used in the preparation of this book is as follows:

- Microsoft Word (word processing)
- Microsoft Excel (spreadsheet)
- Cricket Graph (graphing)
- Microphone II Pro (modem control)
- Xerox Acutext (OCR)
- FAX STF (fax software)
- Apple Remote Access Server (remote networking)
- Adobe Photoshop (pictorial conversions and editing)

- MacDraw (drawing program)
- XyWrite III (word processing)
- QuarkXpress (desktop publishing)
- Novell Netware 3.12 (local area networking)
- Word for Word (format translation)
- Graphics Workshop (bitmap editing)

and others . . .

And all the above software ran under Macintosh Operating System 7.1, MS-DOS 5.0, MS-DOS 6.2, Novell Netware 2.0, and Windows 3.1.

Needless to say, this was a fun and inspiration-filled project, and I hope the reader attacks this book with the same enthusiasm that I have.

Introduction

This book is provided to you by Storage Technology Corporation (StorageTek) because StorageTek believes that video applications represent one of the most exciting emerging technologies today. StorageTek's investment in this technology is evidenced by its many products that are particularly well-suited to video storage, such as its RedWood©, MediaVault©, and Iceberg© storage systems. These products and their video applications will be described later in this introduction.

Interactive television and advanced multimedia have their origins in space flight and airplane simulators in the early 1960s. Computer-generated video, created by large mainframe computers, simulated environments for astronauts and pilots.

The interactive television systems planned for tomorrow will be controlled regionally by a central facility (headend) and will provide movies or Video On Demand (VOD), time-shifted TV, interactive news, tele-education, home shopping, video games and virtual reality, as well as conventional television and telephone service. The service providers using these systems will be the cable television (CATV) and telephone companies (TELCOs), or alliances between them and major studios.

Video On Demand is a descriptive title for an immediate response to requests for video or multimedia programming, either on a TV screen or on a computer display. The degree of user response immediacy determines whether the system is True Video On Demand (TVOD) or Near Video On Demand (NVOD). Viewer response time measured in seconds usually refers to TVOD systems, while user response time in minutes generally refers to NVOD systems. Computer interactivity will usually require TVOD because these operations are business applications where user latency time must be minimized.

Interactive television is principally a consumer-oriented function, most popular in the U.S., and used primarily for entertainment, shopping and education. It permits the viewer to select programs and goods from screen-based menus. It permits the user to interact with the program he or she is viewing to make choices while watching. This technology is especially useful for educational programs, such as interactive question-and-answer sessions.

Multimedia, generally computer-based, employs multiple forms of media such as video, audio, text, graphics, etc., to communicate with the computer operator, providing powerful and effective human-machine communications. Advanced Multimedia is a smoother, higher-resolution, higher-fidelity form of multimedia that provides TV-type sound and imaging. Multimedia titles may be offered on demand, just as any other interactive service. Multimedia on demand will provide the viewer the advantage of having a huge multimedia library at his or her disposal, without the expense of purchasing the CDs or CD player. The user will only have to pay for the information that he or she actually uses.

It can be seen that, depending on the set top box controls available for a TV set, as this science evolves, less and less difference will exist between Interactive Television and computer-based Advanced Multimedia. The technologies are converging.

The entertainment portion of this activity includes event selection, program viewing, inquiry responses and event alteration. Examples include selection of a movie, ordering a product from a commercial, viewing a program, changing a program or its outcome, and jumping forward or backward in the movie. The viewer is afforded the benefits of 1) event immediacy, 2) the ability to select the event content, and 3) privacy of his or her purchase.

Interestingly, the non-entertainment activity also includes event selection, program viewing, inquiry response and event alteration. Examples include the selection of video clips from a database, viewing the video clips, interaction with the database, the selection of additional video clips, viewing the video clips, continued interaction with the database, continued viewing of video clips . . . until the subject under investigation has been fully resolved. The average non-entertainment application generally has a much higher level of interactivity associated with it than does the entertainment application (video games excepted). Many entertainment applications can be supported by Near Video On Demand servers rather than their significantly more expensive True Video On Demand cousins.

Entertainment applications are obvious, such as movies, sports, shopping, education and the like. Non-entertainment applications may include automotive, real estate, banking and education systems where PCs or TV sets are networked to video servers. Each has a slightly different use but with a common philosophy.

Automotive application

In an automotive show room, prospective customers could select the model of car they are interested in and be shown a video clip of the selected vehicle, pointing out the uniqueness of the various options available, power plant selections, color combinations, interior decor, etc. By selecting preferences from a menu, a profile of the customer's wants and desires can be produced for the salesman's use in selecting the proper demo for the customer's trial drive.

In the service department check-in area, a customer can select from a menu listing the items he or she wishes to have serviced, or view video clips on various symptoms of malfunctions he or she is experiencing, selecting only those video clips that contain the symptoms that apply to them.

Even well-trained service technicians, familiar with the brand of cars sold by their dealership, require large numbers of reference manuals that define the order, techniques, and specifications for repair and service operations. Advanced Multimedia will make it possible for a service technician to request full-motion video clips detailing and demonstrating the proper removal, replacement, adjustment, and testing of any part of any car. This multimedia system is actually an advanced electronic library system.

Real Estate Application

Customers interested in the purchase or rental of real estate property can select from a menu of property types, location, size, amenities desired, price range, etc. They can then be shown high-resolution, full-motion, full-color video clips selected from the stored database of properties. Using the menus and navigation system, they can select those properties they would like to visit in person.

Banking application

Banks can store a signature image of clients in a database, along with their signatures. Check imaging is another important storage requirement for this industry.

Education

Video On Demand for classroom or in-home training could provide instantaneous access to required instructional information, and the viewer could concentrate on areas where he or she is most interested.

Large corporations or government institutions would be able to save significantly on employee education. Interactive PC-based systems allow the student to progress at his or her own rate, as determined by the choices of subjects or answers to questions selected from the on-screen menu. This gives the effect of a one-on-one student/instructor relationship, which is much more productive than having one instructor for many students.

System requirements

Storage capacity There are many parameters that define the data capacity requirements. These include video resolution, quality of the picture, amount of preprocessing performed prior to MPEG-2 encoding, amount of motion in the scenes, number of scene changes, and the amount of panning. Companies such as Warner Brothers' California Video Center are currently developing technology that provides preprocessing of video prior to MPEG-2 encoding to facilitate quality superior to VHS, at the low bit rate of 1.5 Mbps (megabits per second). Thus, for purposes of our discussion, 1.8 gigabytes (GB) will be the required storage capacity for a 120-minute movie. Nine-gigabyte disk drives are currently available in the marketplace, with 4GB drives common. Six compressed movies can be stored per 9GB of disk storage.

RAID (Redundant Array of Independent Disks) technology is a convenient way to store a selection of movies. The StorageTek Iceberg RAID storage system employs an advanced high-reliability facility using RAID 6+ technology. This technology employs two separate parity disks, an electronically switchable spare drive, and hardware facilities to record and validate error correction codes. Data is striped across multiple disks, and Reed-Solomon parity data is recorded on the two rotated parity disks. Each Iceberg DASD subsystem may consist of up to 185GB of online storage, facilitating the storage of up to one hundred 120-minute movies, 12,276 one-minute clips, or any variation between.

Reliability The Iceberg dual redundancy system permits online reconstruction of data (in the same parity group) such that should one disk (or even two disks) fail, standby replacement disks can be automatically switched into the system and the data reconstructed on them, permitting continued operation and enhanced reliability. This disk swap/data reconstruction operation is completely transparent to the user, except that the system can report the failure to the host system. The host can then call for a service engineer to physically replace the failed unit. At this time, no other video storage system offers a greater degree of system availability assurance.

Performance Through the use of advanced RAID technology, together with the 1GB cache, the Iceberg system offers a maximum transfer rate as high as 50 megabytes per second. Assuming that a 1.5 megabit per second (0.1875 megabyte per second) data stream is required to reproduce a VHS quality movie, then theoretically 266 concurrent video streams could be produced from the one Iceberg system. The current models of the Iceberg RAID system include 1GB of cache storage provided with hardware pointers permitting high-speed temporary storage for concurrent users.

Multiple RAID systems may be connected to a single video server system creating multiples of 266 concurrent multimedia sessions. For example, four Icebergs could be connected to one digital video server to provide 1,064 concurrent users with different video clips simultaneously.

Video server architecture

A typical Digital Video Storage Server System could consist of a StorageTek Iceberg, the server hardware/software, and an optional StorageTek MediaVault. The StorageTek Iceberg Virtual Storage system is a RAID 6+ system exhibiting very high reliability, designed for exacting applications requiring extreme data accuracy such as banking, stock market transaction recording, and government applications. As such, the Iceberg could be a superb storage component for Interactive Television and Advanced Multimedia applications. Suppose we combined an Iceberg with the server control system. It would form the Digital Video Server (DVS) system. The DVS control system would have the responsibility for interfacing the Iceberg storage system through the communications channel to either TV set top boxes or personal computer interfaces, interpreting viewer requests, commanding the storage system, formatting the data for communications with the viewer's terminal device, monitoring system status, collecting billing information, and other statistics.

Storage cost

Cost constraints are a function of the application and the expected results. In certain interactive television trials, extremely expensive systems have been installed. The goals of these tests are to gather information on customer desires and reactions to the system concept, rather than to achieve profitability in continued operations.

Online rotating memory systems typically comprise between 45% and 85% of the cost of a video server system. Factors affecting this ratio include the amount of semiconductor cache memory included in the system, the cost of the host processor, the number of video threads per disk that can be produced, and the amount of redundancy that is built into the system.

The StorageTek Iceberg system is currently capable of supplying 266 video threads from the RAID subsystem. While most RAID systems can continue to operate in the event of the failure of a single drive, and will report the failure to the host, the Iceberg can not only tolerate the failure of two drives, it can automatically electrically replace them in the system and rebuild the data on them, thereby permitting two drive failures.

While cost does not appear to have been a significant factor in many of the tests currently under way, this is only a temporary situation. Unless server costs are significantly less than $1,000 per thread, it will be difficult for service providers to generate revenue streams sufficient to amortize the capital investments and remain profitable.

Video server archival storage

The need to collect and manipulate massive amounts of data, fueled in part by the advent of interactive television, has customers clamoring for low-cost storage.

The computer, telephone, and cable television industries traditionally have viewed the data they create and use as unique types of information. These objects carry names such as video recordings, audio sound tracks, video clips, and sound bites. In fact, all data types look the same to a memory device once they are digitized into strings of 0s and 1s.

StorageTek has assembled a bundled package of its most sophisticated automated tape library system and software that is targeted at the video archival storage market. It is titled MediaVault. MediaVault combines the RedWood SD-3 Helical Cartridge Subsystem, a WolfCreek automated tape library, and the server hardware and software needed to control the library, and is anticipated to be the base storage technology for many emerging, storage-intensive video and multimedia applications. MediaVault will provide a low-cost storage solution that brings standardization and robust random retrieval to automated archives across the video industry.

The RedWood SD-3 Helical Cartridge Subsystem in the MediaVault subsystem is an adaptation of the D-3 digital video recording technology from Matsushita Electric Industrial Co., Ltd. It uses tape cartridges jointly developed by StorageTek and 3M and produced for StorageTek by 3M.

StorageTek laboratory test data show that the combination of the RedWood SD-3 drive in the MediaVault subsystem and the Data D-3 metal particulate tape provides approximately 50 times more durability than earlier helical technologies. Three Data D-3 cartridge capacities will be offered—10GB, 25GB, and 50GB. These capacities are in standard mode, without compression.

Extrapolating the test data, if a Data D-3 cartridge were mounted twice per day, it would have an active life of 27 years. If it were mounted and read/write activity performed nonstop 24 hours a day, 7 days a week, the Data D-3 cartridge still would last 3½ years. The unique multihead design of the SD-3 technology removes most of the debris on the tape surface and smoothes the tape prior to its contacting the read/write head.

Here are some applications in which the MediaVault subsystem could find a prominent role:

- Film animation is a burgeoning business, thanks to improved computer graphics. But the cost of storing the large volumes of graphics is a hindrance to wider use. The MediaVault subsystem would reduce this cost and safely archive the images.
- Corporations are beginning to formulate plans for their own multi-media networks that will be similar to the Internet, only more secure. The MediaVault subsystem could be the place where the majority of such information is stored.
- In a large-scale Video On Demand system, high-speed video disk servers likely would be used in combination with a MediaVault subsystem. This would allow many of the movies to be stored on RedWood tapes at a low cost.

- CD-ROM technology is growing rapidly for applications as diverse as computer-based education and magazine publication. As the databases from which CD-ROMs are cut grow larger, the need increases for an inexpensive, easily updatable media. MediaVault subsystems could be the repository for this booming industry.

The role of data and video storage in all industries continues to increase in magnitude, expense, and criticality. Providing continuous availability to multimedia now punctuates most information technology strategies. Many static graphics and pictures in data centers are expected to increase storage demands from 30 to 300 times. Multimedia leading to visualization and animation eventually will require even more storage, and will drive the need for the high performance and storage capabilities of a MediaVault subsystem.

A closer look

As described in this book, the video market has both a large current requirement and a larger emerging requirement to store and retrieve vast amounts of video data. StorageTek has solutions today for many issues and is working on new technology to provide solutions for many of tomorrow's problems.

Today StorageTek's MediaVault has the fastest tape drive on the market, with a sustained data rate of 11MBps into a SCSI-2 20MBps data bus. With this speed, an entire 50GB cartridge could be read in just 1 hour and 15 minutes. MediaVault can provide archival storage and retrieval for up to 1,000 50GB-capacity ½-inch tape cartridges. This results in a total storage capacity of 50 terabytes.

This system, if used to store NTSC video with MPEG-2 compression at the 1.5 megabit data rate, could store about 25,000 movies and transfer a two-hour compressed movie to the network servers in just three minutes. With a four-drive configuration per library, up to 60 movies can be transferred on average to network servers per hour. This provides a commercial video-on-demand network with a reliable central archival database of all the movie titles needed. Even with the new HDTV format that is coming, up to 5,000 titles can be stored on this system.

For those applications in which compressed video is not required, such as video editing and broadcast programming, this system would provide storage for up to 250 NTSC two-hour videos. This provides a good solution to the broadcast industry for storing and automatically retrieving program data.

For those requirements that do not need as much storage, StorageTek provides both 8mm and 4mm tape libraries in a 19-inch rack-mountable package. The 8mm product gives up to 54-cartridge storage capacity with each cartridge holding 7GB of uncompressed data for a total capacity of 378GB, or about 200 NTSC two-hour MPEG-2-compressed titles. The 4mm product gives up to 25-cartridge storage with each cartridge holding 4GB of uncompressed data, for a total capacity of 100GB or about 55 NTSC two-hour MPEG-2-compressed titles. Either of these products would provide excellent dedicated local archive capability, were they attached to a server.

For the future, we are exploring video server solutions that incorporate buffer memory and disk memory, as well as tape in a managed storage hierarchy, to provide a total solution for the complete storage and retrieval of video data.

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