Development of an Introductory Course in HDTV

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Abstract

High definition television is an emerging technology[1-9]. Its presence marks a major change in the way the medium of television will be presented in the near future. A possible indicator of HDTV's impending success in the marketplace would be the emergence of DVD (digital versatile disk) as the fastest growing new video medium to date. DVD movies are designed to use both NTSC television capabilities as well as the new standards for television and digital display. The next step in this process is the conversion of broadcast television to this new and vastly different technology. This change is now taking place. Many television stations are broadcasting at least a portion of their programming, simultaneously, in HDTV and the older NTSC format. The coming changes will create a large demand for technicians trained in the medium of HDTV.

I. Introduction

The purpose of this research was to develop a technology course for 2nd year EET students that will introduce them to HDTV and allow for reasonable success in seeking and obtaining a career in industry maintaining HDTV transmission and reception systems.

Knowledge required will range from a modest background in digital representation of analog signals to an extensive understanding of practical diagnosis and maintenance of signal transmission and reception equipment. Topics that need to be covered will include: analog to digital signal conversion, audio and video compression, digital compressed signal decoding, a comparison to current NTSC TV technology and standards, industry standards and definitions and their development pertaining to HDTV, a brief overview of similarities and differences in worldwide implementation of the technology, hardware diagnosis and repair, transmission system design and implementation. Most mathematical and basic principles background will be covered in the regular EET course work. The major obstacle to this planned course will be the introduction of transmission of digital signals.

The recent development of an HDTV transmission standard that is being accepted by industry is paving the way for implementation of a major change in today's broadcast television. Television transmission stations are expected to spend an estimated 7 million dollars each just to implement the upgrade[9]. There will be a large market for technicians familiar with the systems used and the standards regarding their implementation. Moreover a new secondary market will be created in the current digital realm of the World Wide Web and other digital signal carriers. There will be, without a doubt, a plethora of opportunities in the next several years.

Basic skills necessary in the workplace will include: an ability to design and implement a digital broadcast system, an ability to diagnose and repair the systems involved, an ability to interpret and implement industry standards and changes to those standards, and an ability to address the problems of combined transmission and reception of both the old technology and new standards simultaneously. To this point, two books have been identified[1,2] as possible texts for classroom work, however, no ideal text has presented itself. A current copy of the industry standards pertaining to signal transmission, audio compression, video compression, and broadcast standards has been obtained. Due to its new and dynamic nature, this technology is still evolving. Several, well maintained, Internet sites have been identified as resources to be used to keep abreast of changes and industry developments. The most practical classroom materials will be obtained from the HDTV and AC-3 standards themselves.

II. Course Outline

This is a one credit introductory course/lab that will meet once a week, two hours at a time, for 15 weeks. There will be a mix of a brief lecture followed by a lab most weeks, with a couple of class periods being fully lecture.

1. HDTV Overview
   - NTSC television review and broadcast fundamentals
   - Digital signal broadcasting
   - Compare and contrast signal strength requirements

2. Computer Networking
   - Implementing a video server
   - Network Cabling and Hardware
   - Network protocols
   - Error detection and correction
   - Setting a video receiver

3. Network Traffic Monitoring
   - Bandwidth
   - Analysis hardware
   - Interpreting network traffic
   - Monitoring system usage and resources

4. Digital Imaging
   - Image digitization (Analog to Digital conversion)

- Color depth
- Image size and resolution
- Image resampling

5. File Compression
   - LZ (lossless compression)
   - Lossy compression
   - JPEG image compression

6. File Compression Continued
   - MPEG Moving Picture compression
   - Multiplexing
   - Static image components
   - Moving image components
   - Key frame aspects
   - Interlace versus progressive scan display

7. Sound Handling
   - Digital sampling
   - Bit rate
   - Audio compression
   - Dolby encoding

8. Standards
   - Why standardization
   - Who decides
   - MPEG process
   - AC-3 process
   - HDTV process (The Grand Alliance)

9. Broadcast and Reception
   - Terrestrial broadcasting
   - FCC regulations
   - Satellite Broadcasting
   - Cable broadcasting
   - Cable integration of terrestrial and satellite signals

III. Lab Development

As can be expected, the equipment needed to implement a full-fledged, real-time, broadcast student lab is cost prohibitive and technically problematic. However, a meaningful laboratory environment can be designed around a somewhat limited budget. Our proposal is as follows. A meaningful lab environment must give practical experience with a full range of HDTV related issues. Major concerns for laboratory equipment are video acquisition, MPEG encoding, broadcast capabilities, reception and decoding. Signal broadcast, reception and decoding are the easiest issues to resolve if we think creatively. Existing computers and network wiring will serve as our broadcast and reception hardware. HDTV is, after all, digital. An upgrade of a few routers to 100 Mbps equipment along with network performance monitoring software will allow a double check of actual bandwidth used. The addition of MPEG decoders to existing computers is relatively inexpensive and sound capabilities are built in to most machines already in place. This leaves image acquisition and MPEG encoding as the only obstacles to overcome. These, however, are not minor obstacles.

MPEG encoders range in price from a low of four thousand dollars to a high in excess of $50,000.00. Funding sources for the low range can be found. The unfortunate problem of the lack of AC-3 audio encoding in the lower price range can be turned into an educational positive. Audio can be captured and resampled later. The process of reintegration of this signal with the encoded video will reinforce the notion that the two are, in reality, handled separately. This process will preclude the possibility of live broadcasting. This, however will likely be a temporary inconvenience as hardware prices come down and a practical use is shown for the university in terms of distance education and branch campus to University Park interactions are enhanced.

IV. Course work

As this is a developing technology, material for the classroom will come from several sources. Moreover, because of the evolutionary nature of this technology, this course will be offered, initially, as a one credit introductory course. Classroom instruction will be closely tied to the laboratory environment. The offering of the first two labs in networking will allow for some time for the classroom presentation of theory to move ahead of the lab work. The sources available for classroom use include various texts on MPEG compression techniques as well as the official MPEG standards. Various sources give overview and insight into the complexities addressed by the recently adopted HDTV standards. The standards themselves appear, so far, to be the best text however. This is problematic on two fronts. First, the standards as adopted are still in a state of flux. This can be illustrated by the recent appealing to the FCC by a consortium of broadcasters. The second, and possibly the most important, is that the printed standards are highly technical in nature. This is not material that will be readily assimilated by the EET student. Our proposal is to provide a carefully ordered overview of both the video and audio compression standards, followed by the actual transmission standards. If carefully integrated with the laboratory experience, much of the mystery surrounding this technical material should be made a mute point.

Problems confronting the technician in practical situations need to be addressed. This can be best achieved by comparing and contrasting current broadcast scenarios within the analog realm. What are the differences between the broadcast of television over cable, airwaves, and satellite mediums? How are these issues addressed with the introduction of HDTV? What additional problems does HDTV create? How is HDTV integrated with NTSC television? What special problems does this integration introduce? What resources do we have at a minimum? What tools do we have to address the problems created within the realm of the least resources available?

V. Laboratory Instruction

- **Video Server**

Broadcasting a signal for a lab setting can best be achieved over a local area network. In order to accomplish this, a clear knowledge of setup and operation of a video server will be required. This course, as an introductory technology course would offer an ideal opportunity to introduce students to a networking environment and will mesh nicely with the windows networking class. A lab offering experience setting and maintaining a video server will be offered as a part of the class.

- **Network traffic**

A very large part of the development of HDTV as a form of communications that could be provided, in high quality, by all aspects of the television broadcast medium was the development of a standard that would pack a large amount of digital signal into a relatively small bandwidth. The second project in our network labs will introduce the students to network traffic monitoring and analysis

- **Digital imaging**

Starting from the origination of a picture we will introduce the principles of file size and the need for image compression. Working with raw still images, we compare full resolution, 24 bit color images with lower resolution, and lower bit rate color map to illustrate size and quality differences. This sets up a good comparison with compressed images. A few simple mathematical exercises will show substantial size files when we start to consider 30 frames per second. Integrating this lab with an exercise in network transmission of a few images will show substantial problems with time, even on a 100 Mbps network. Consider adding sound along with this signal, and the need for compression is clear.

- **File compression and MPEG encoding**

Working from raw images from the last lab, we apply JPEG compression and then attempt transmission. Clearly, thirty images won't transfer in a second. We need to transmit sound and thirty images and do it within a 16mbps limit. Now is time to introduce MPEG. This lab will conclude with experimentation with static camera pictures that contain moving elements.

- **File compression continued**

In the last lab we introduced MPEG compression. Now is the time to make the technical issues more difficult. What happens with our MPEG images when we introduce a picture with a moving camera and moving, increasingly complex elements? How do the aspect of image contrast and a wide range of motion affect the compression? What about network transmission delays? The aspect of key frames is introduced here. This is also an ideal time to deal with the image aspect at the screen. What are the benefits of interlaced versus progressive scanning? What are the drawbacks? Screen refresh rates were a major concern in the development of this technology. What does refresh rate mean? Compare and contrast 60hz NTSC with 72hz HDTV. Why did the standard settle on 72hz? For what purpose is a small amount of screen flicker?

VI. Conclusions

The groundwork for a solid introductory course in HDTV has been laid. An ambitious one-credit course has been developed. The evolutionary nature of a new technology, in flux, has been accounted for and certain flexibilities have been included. This course will certainly change and evolve with time, the input of industry, and student needs. This is a start in the development of a curriculum that must remain on the cutting edge of technology. This will maintain Penn State, DuBois' reputation as a leader in meeting the needs of students and industry in our service area.

VII. References

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Dr. Morales received his electronic engineering degree with distinction from the University of Tarapaca, Arica, Chile (formerly North University) and M.S. and Ph.D. degrees in electrical and computer engineering from the State University of New York at Buffalo in 1978, 1986, and 1990, respectively. Since September 1990, he has been working as an assistant professor of engineering at the Penn State DuBois. He is now Associate Professor of Engineering. His research interests are in mathematical morphology, digital image processing, computer vision, and neural networks. Dr. Morales has been involved in teaching microprocessors applications, computer languages, software application and local area networks for many years. Dr. Morales was recently honored by the Institute of Electrical and Electronic Engineers (IEEE) with the Best Paper Award at the International Asia Pacific Conference on Circuits and Systems for the paper " Basis Matrix Representation of Morphological Filters with N-Dimensional Structuring Elements."

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