The Ins And Outs Of MPEG

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The Moving Pictures Experts Group, or MPEG, is a committee that was formed under the auspices of the International Standards Organization in 1988. It is a working group whose mandate is to generate standards for digital video and audio compression. MPEG meets roughly four times a year for a week at a time. Its goal is to achieve a standard which specifies the coded bit stream and decoder requirements for high quality digital and audio. Two standards have been ratified and they are called MPEG-1 and MPEG-2. They are encoding standards that convert analog video and audio input signals into compressed digital files. MPEG is regarded by many as the only world recognized standard for digital video compression. It permits a number of encoding applications ranging from video and multimedia CDs on a desktop computer, interactive TV, to digital satellite networks. This paper will examine digital video compression and the different standards of MPEG. It will also study how MPEG is currently being implemented in the broadcast industry and what its potential is as a production format.

Digital signal compression is the process of digitizing an analog television signal by encoding a TV picture to "1s" and "0s". In video compression, certain redundant details are stripped from each frame of video. This enables more data to be squeezed through a coaxial cable, into a satellite transmission, or a compact disc. The signal is then decoded inside a TV set-top box or CD player. In simpler terms, "video compression is like making concentrated orange juice: water is removed from the juice to more easily transport it, and added back later by the consumer." (1) Heavy research and development into digital compression has taken place over the past eight years because of the enormous advantages that digital technology can bring to the broadcasting, telecommunications, and computer industries. The use of compressed digital over analog video allows for lower video distribution costs, increases the quality and security of video, and allows for interactivity. Several examples can help to explain the advantages of digital compression. Firstly, digital compression would allow a cable television system operator to carry four to ten television signals on one cable television channel that now carries one service. Secondly, in the United States it costs six million dollars per year to rent a satellite transponder to distribute a single television channel. With compressed digital video, four video channels can be carried on one transponder. This cuts transponder costs by 75% per channel. Thirdly, analog video collects noise, (snow, ghosts) as it travels over the air and through cable to homes. Digital video on the other hand "arrives exactly as it was sent, sharp, clear, and undistorted." (2) The digital revolution has provided a new way of transporting information. It is also has the potential to solve many of the problems associated with timely, cost-effective delivery of broadcast-quality video and audio.

Currently, there are a number of compression technologies that are available. For example MPEG , Indeo, Cinepak, JPEG, and H.261. Digital compression can take these many forms and be suited to a multitude of applications. Each compression scheme has its strengths and weaknesses because the codecs you choose will determine how good the images will look and how smoothly the images will flow. Compression occurs through the use of algorithms which divide a video frame into blocks and then look for redundant data. This process is known as intraframe analysis. Within intraframe analysis, algorithms make comparisons between frames of video. The algorithms then drop redundant data to reduce the overall size of the file of video. This technique is called "lossy compression" and is the compression scheme used by MPEG. In general, with video compression, the more you compress a frame or data stream, the more losses occur. The trick with digital compression is to balance the compression ratio with the resulting image quality. The lossy technique effectively leaves out the video information that would be imperceptible to the human eye. MPEG compression identifies and discards

redundant data within a frame, or between frames. Compression of video takes place through the following procedure.

Codecs can either be symmetric or asymmetric. A symmetric algorithm uses an equal amount of time for compression and decompression. It is common in real time video capture in applications like video conferencing. An asymmetric codec takes more time in the compression stage to try for the the highest level of belt tightening possible. This process works best for CD-ROMs. Once a codec saves the non-redundant data, it statistically processes the arrangement of the pixels in an image. The statistical data arrangements are then encoded and the codec then uses a variety of compression methods. In the case of MPEG, discrete cosine transform, DCT, is used. A frame is divided into blocks, usually eight by eight pixels each and transform mechanisms work on each of the individual blocks. DCT converts pixel intensities to a frequency based equivalent The result is a transform yield which is a series of numbers that represent every fine detail in a pixel block. Compression then comes by eliminating the representative numbers after a certain point in the series. The consequence is compressed video with a loss of fine detail but, the level of detail is not detectable. The result is compressed video with all its benefits. Algorithms reduce video to its essence but keep it looking as rich as the original image.(3) This technique makes it possible to discard up to 99.5% of the information in a video sequence without seriously effecting the the picture quality. As a result, MPEG can attain compression ratios of up to 180-to-1.

Digital compression methods fall into different camps. While there are different forms, there are just a few standards in the world. One of these important standards is MPEG. The MPEG compression market is currently divided into two camps: MPEG-1 and MPEG-2. Each video compression standard serves a different purpose. MPEG-1 is the first standard which was adopted in 1991. When MPEG began its work to develop a standard for digital compression, its goal was to develop an algorithm that could compress a video signal and then be able to play it back off a CD-ROM or over telephone lines at a low bit rate. This rate was less than 1.5 Mbits per second and the data rate of uncompressed audio CDs. The intention of the group was to achieve a quality level that could deliver full-motion, full screen, VHS quality from a variety of sources. This standard was not one of broadcast quality, but was good enough to display on a computer monitor or to playback from a consumer multimedia device.

The MPEG-1 standard is primarily intended to process video at what is known as SIF (Source Input Format) resolution. That is 352x240 pixels at 30 frames per second. This process is one-fourth the resolution of the broadcast television revolution standard called CCIR 601. The broadcast television standard calls for 720 x 480 pixels. (The figures given here are for NTSC television; however MPEG is also compatible with PAL, the European television format). It is possible to display SIF resolution video at the CCIR broadcast standard level by interpolating additional pixels. However, there is a big problem in doing this because interpolation does not and cannot restore the detail lost in the original down-sampling.(4) MPEG-1 occurs in three parts, video, audio, and systems. The systems part of the standard gives the integration of the audio and video streams with the proper time stamping to allow synchronization of the two.

The quality of decompressed digital video is measured by three elements. These elements are the number of displayable colors, the number of pixels per frame (resolution), and the number of frames per second. Each of these elements can be traded off for another and all of them can be traded for better transmission rates. However, it is impossible to combine all of them at the quality of the broadcast television standard of CCIR 601 at CD-ROM bit rates.(5) Distribution networks, such as cable television, realized the potential of the MPEG standard of digital compression to increase services and lower costs. However they were limited to CD data rates. The result was the need for a new standard that suited the purposes of the broadcast industry. The result was MPEG started a second effort that has become known as MPEG-2.

The creation of MPEG-2 by the ISO committee was created not as a replacement for MPEG-1. It was developed because the standard of MPEG-1 did not serve the requirements of the broadcast industry. So the group developed a compression algorithm that processed video at full resolution that would match CCIR 601 video (704 x480 NTSC, 704 X 576 PAL). MPEG took advantage of higher band widths available to deliver higher image resolution and picture resolution. It targets increased image quality, support of interlaced video formats, and provision for multi-resolution scalability. It allows compression at high resolution and higher bit rates than MPEG-1. MPEG-2 runs at a data rate of 6.0 Mbps and is designed for broadcast quality video that delivers better quality at a faster data rate. MPEG-2 allows for compression ratios that fit six to ten digital channels into the band width required for one analog channel. MPEG-2 is like its predecessor in that the standard consists also of the three layers video, audio, and system. The video quality of MPEG-2 technology is superior to MPEG-1, however MPEG-1 is useful and still being used because it serves its own purpose. The two standards are "complementary technologies designed to address the needs of specific markets and data transfer rates."(6) MPEG-1 operates on a much smaller band width which allows for a greater number of channels per a given signal range. It is actually designed to provide higher quality video output than MPEG-2 at single-speed CD data rates. For many many broadcast uses, MPEG-1 provides cost-effective and more-than-adequate video quality. The presence of the different standards gives the opportunity for a a system designer to pick the compression technology that is right for for their particular application. Also, since "MPEG 1 is a subset of MPEG 2, any MPEG -2 decoder will be able to decode MPEG-1 syntax video."(7) The advantages of both MPEG video compression standards include significant overall system saving costs, higher quality, and greater programming choices.

Along with the development of MPEG-2 began work on the MPEG-3 standard. This third standard was directed towards the market of High Definition Television, HDTV. MPEG-3 targeted HDTV applications with sampling dimensions up to 1920 x 1080 x 30hz and coded bitrates between 20 and 40mbit/sec. However, after research, it was discovered that MPEG-2 and MPEG-1 syntax could work well together for HDTV rate video. It just took some compatible fine turning and the maintenance of an optimal balance between sample rate and coded bit rate.(8) MPEG-3 no longer exists because HDTV became part of the MPEG-2 standard.

On September 1993 in Bruxelles, work on a new MPEG initiative began called MPEG-4. This standard targets low bitrate coding of audio-visual programs and will require the development of fundamentally new algorithmic techniques. The sampling dimensions are up to 174 x 144 x10hz and coded bit rates between 4800 and 64,000 bits/sec. The MPEG-4 standard, when completed, will enable a whole new list of exciting applications. These applications include: interactive mobile multimedia communications, video phones, mobile audio-visual communication, multimedia electronic mail, remote sensing, electronic newspapers, interactive multimedia databases, multimedia videotex, games, interactive computer imagery, and sign language captioning. (9) MPEG-4 is currently in the application identification stage and November 1998 is the target date for official sanction of the proposed standard.

One thing that is important to understand and remember about MPEG is that it is a standard for decoders. The standard defines the byte stream so that a MPEG-compliant decoder chip can display the video. Quality issues arise and are determined by the choice of the encoder. The purchase and type of encoder is made at the discretion of the user.

Digital signal compression is something relatively new to the broadcast industry. The technology that is driving digital video is quickly developing, changing, and effecting broadcasting. However, the use of digital technology is still in its infancy stage. Already there have been early implementations of systems that employ MPEG technology to deliver digital audio and video in the broadcast industry. Immediately, broadcast television makers realized the potential of MPEG technology to increase the channel

efficiency of satellite transponders and cable networks. MPEG has become a major player because it is the only cross-industry compression ratio graphic standard that enables "the playback of VHS quality video and CD quality audio at single speed CD (150kb/s) and T-1 (1.544Mbs) data transfer rates." (10) Along with this technical superiority, there are three major industry dynamics that have ensured the wide acceptance and use of MPEG in the broadcasting industry. Firstly, the giants of the consumer electronics industry have been investing heavily in video CD, a digital and video playback device. Electronic companies are beginning to position digital video as the eventual replacement technology to the analog VCR. Marketed as an enhanced CD player, "video CDs can also play MPEG -1 video files at a price of about $100 more than an audio CD player."(11) Secondly, the broadcast industry has selected MPEG for most of its existing digital video distribution implementations. These include the Hughes/RCA digital satellite system and a number of video on demand trials sponsored by Bell regional holding companies. (12) Thirdly, the computer industry is rallying around the MPEG standard. A growing number of computer applications are MPEG-enabled. There are more than 50 low-cost, MPEG-1 encoders for PCs. The impact of these industry endorsements has led to high manufacturing volumes and driven down the cost for MPEG playback circuits. The result is MPEG having a strong presence in the broadcast industry. MPEG-1 is becoming a "defacto industry standard for content providers, broadcasters, consumer electronic companies and computer manufacturers."(13) There are also several other examples of MPEG usage in the broadcast industry. The examples are far from being industry-wide, but show the early development and growth of MPEG in the industry.

MPEG-1 is currently being used for many broadcast applications even though its SIF resolution is not capable of broadcast-quality video. It is used in the broadcast industry in "test-bed" operations to prove the viability of digital video applications. Many cable companies are experimenting with using digital video for television commercials, "an application for which the quality of the video is presumed to be less important than for a movie, sporting event, or other primary television programming."(14)

In early 1995 in San Francisco Bay, KRON, an NBC affiliate started to utilize an MPEG-1 compression system for multicast programming. This is achieved because MPEG provides very high compression ratios and video and audio can be transmitted to remote sites using telephone lines. MPEG allows the television station to digitize and compress audio and video content as it is transmitted. It is then multicast simultaneously to any number of remote sites. The audio and video can also be stored digitally for rebroadcast at a later date. Once the information is delivered, the content can be "decompressed for full-motion, VHS-quality playback, with fully synchronized, CD-quality sound. At this point, it can be easily broadcast from the local site using traditional technology."(15)

The development of the MPEG-2 video compression standard has been eagerly awaited by the television industry. The reason, digital compression when utilized enables a huge expansion of video services, the much touted 500 channel cable TV system. It also promises to save broadcasters millions of dollars in satellite transponder fees, since up to ten times the current amount of programming can be poured through each transponder. The technology of MPEG-2 has already been put into motion by the broadcast industry and telephone companies who are now getting in on the act of video compression. Bell Atlantic in New Jersey has started to use MPEG-2 encoders to transmit digitally compressed cable programming. This enables bell to provide video dial-tone services commercially. US West, NYNEX, Ameritech, and Pacific Bell also have video dial-tone services in the works. Also, the major cable companies in the United States are currently planning trials of their video services and are expected to utilize video MPEG compression. The MPEG standard has already been put to use in the broadcast industry by many other companies.

The Philips company has decided to use MPEG for their new digital video CDs. They say they will start shipping movies and music videos on CDs for their CD-1 player by the end of this year. What this means is that when digital radio broadcasts begin in Europe in a couple of years, the audio received by

consumers will be MPEG coded. (16)

The Xing Technology Corporation has developed the industry's first real-time MPEG compatible video capture and compression card for desk top PCs. The product is considered the most practical and cost effective way to capture video 30 frames per second and store on a hard disk for editing and later viewing.

On March 14, 1995, Comstat Laboratories announced a licensing agreement with Wegener Communications for the manufacture of new satellite news gathering, (SNG), products that will expand applications and reduce costs for SNG customers. Wegener Communications is a manufacturer of audio and video transmission products and systems. The company's equipment is used extensively throughout the cable, radio, television, and business broadcast industries. Under the agreement, Wegener will produce MPEG-2 broadcast quality digital video encoders and decoders designed specifically for the use of SNG applications. This product is set to bring the "the economies of digital compression to satellite news gathering."(17) The compact electronics package brought together with smaller uplink transmitters and antennas will greatly expand the applications for SNG. This digital technology will permit up to eight video feeds to be transmitted over a single satellite transponder.

On April 7, 1995, Chaparral Communications Inc. and Wegener Communications announced an agreement to develop MPEG products. Chaparral is an international satellite communications company. The two companies have decided to work together in designing and manufacturing a number of satellite television products for commercial and business applications. The products will use both MPEG -1 and MPEG-2 compressed digital video technology.

On May 24, 1995, TMN Networks Inc., signed a multi-million dollar agreement to use Digital Equipment Corporation's media server technology for network origin of pay-per-view and pay television programming. TMN is the owner of the Movie network and Moviepix. This agreement and equipment will be the first in the world to deliver "a complete broadcast schedule using MPEG-2 digital compression." (18) The new server technology will replace conventional videotape machines and allow TMN to expand its Viewer's Choice from 4 to 20 channels of pay-per-view programming. This use of MPEG-2 in the broadcast industry will permit TMN to provide real-time satellite delivery, increased channel capacity, greater choice, and laser-disk quality video and CD-quality sound.

On September 11, 1995, the companies Micropolis and Texcan MSI announced a partnership to provide video-on-demand servers for local cable ad insertion. Micropolis is a leading manufacturer of video-on-demand servers and Texcan is a leading supplier of cable television advertisement insertion systems. The two companies have formed an alliance which will jointly supply the first commercial insertion system that utilizes MPEG-2 disk-drived video servers. What this means to the broadcast industry is that cable companies will be able to control local ad insertion electronically with all the commercials stored digitally. Before this partnership, ad insertion was done by manually inserting videocassettes into banks of VCRs which were located at cable head-in sites. These servers will lead to the automation of the entire ad process and at the same time provide the highest quality MPEG-2 video. (19)

On October 10, 1995, Sun Microsystems Inc. division launched a line of video servers designed specifically for network-based interactive video. The servers provide capacity for six 30-minute true video-on-demand MPEG-2 titles. Sun Microsystems wants to focus the video servers on news archiving and retrieval, corporate training, video kiosks, and video warehouse applications.

On October 17, 1995, Storage Technology announced a marketing collaboration with Hewlett Packard under a Broadcast Strategic Partners Program. Storage Tek's MediaVault video storage and retrieval unit will become part of a complete and fully integrated broadcast video server from Hewlett Packard.

MediaVault is a storage unit that that can hold approximately 416 hours of uncompressed video. However, MPEG technology will be applied to the MediaVault which will allow the unit to store up to 25,000 movie titles. In three to four minutes, a two hour compressed movie can be retrieved by the system. This alliance between the two companies and the use of MPEG technology provides a "commercial video-on-demand network with a reliable central archival database."(20)

During the week of November 3, 1995, the Astra 1E satellite locked into its geo-stationary orbit. The Astra is the fifth company located DTH, (Direct to Home) pan-European satellite. As a result, National Transcommunication Limited and Orion Atlantic have teamed together to offer the industry's first MPEG-2 service platform to the broadcast industry. Using MPEG-2 technology, Astra 1E will use its 16 transponders to broadcast several hundred digitally compressed channels across Europe when the satellite begins official service next year. The partnership between the two companies will provide its customers with a single point of contact for a complete service. NTL and Orion are promoting their MPEG -2 transmission hard to the broadcast industry. The uplink position and satellite power are ideal for the distribution of television signals to cable head ends. The beams of the satellite can also be used for low cost transatlantic transmissions. (21)

In examination of the current broadcast picture, MPEG and digital signal compression have enormous potential. The digital revolution has started and the switch to digital by the broadcast industries is underway. Technical innovations are creating greater accessibility to expensive technologies and digital broadcast sales are faster than any previous consumer technology. It has become obvious that billions of dollars will be spent on digital networks and broadcasters will not have a choice but to make the digital transition because of competition. The broadcast industry is actually the force behind digital video transmission because of its move ahead toward better video quality, more channels, interactivity, and direct broadcast satellites. The broadcast industry in general is moving from analogue to digital video and industry analysts say the market for broadcast or video disk-based servers will be more than one billion dollars in the next five years. The future is digital video transmission.

Now the important question is where will MPEG fit in the future as a production format? MPEG appears to have a firm position already planted in the digital conversion process in the broadcast and related industries. There is a wide range of potential applications for MPEG technology in the broadcast industry and some have already begun. MPEG has established itself as a standard of digital compression in an industry that has strong interest in obtaining a single digital video standard. MPEG has become the digital video compression standard for digital television spanning the spectrum from DBS to the 500-channel cable systems. Large companies like Motorola, Intel, Sony, Philips, and Yamaha are coveting the MPEG standard as video-on-demand and multimedia become household names. It is predicted that surging demand in the industry will lead to the commoditization of MPEG chips. It has become clear that capturing and compressing digital video is critical for the remote delivery of video and MPEG seems to have cornered the market. In March of this year, Wegener Communications announced a partnership with Micropolis to market digital video file servers to broadcast television stations and networks. The file servers are MPEG-2 based systems and will replace tape-based video library systems used by television stations to execute play lists. Analog video material is encoded in real-time using Wegener's MPEG-2 digital video encoders and may be simultaneously recorded and played back from the file server. Playback is accomplished by decompressing the digitized video with a Wegener digital video encoder. This digital process allows up to six independent channels of video to be recorded and played back simultaneously and has the potential of twelve separate video streams.(22) This product represents the direction of the future in the television broadcast industry. A direction that leads to digital technology.

While MPEG does have a strong potential as a production format in the future, it is obvious however that its extensive use will take some time. Prices will be likely be too high for all cable operators to jump

into the MPEG market right now. Many broadcasters are not quite ready to plunge into the digitally compressed market because they do not have the money to invest into a conversion process that will begin with large up front losses. However, the reality of MPEG is that it is a superior compression scheme. The strong movement towards digital will eventually force broadcasters into this relatively new market.

This year has been a very important year with regards to digital signal compression and MPEG. The broadcast industry has seen cable television operators and other program distributors start to deploy digital technology for their customers. What is also important is that the industry has seen a lot of convergence, alliance, and partnerships among different companies. The convergence of the broadcast, computer, and telecommunications industries are permitting timely, cost-effective delivery of digital audio and video. Different companies are forming agreements to work together to help bring new digital technology more quickly to the the marketplace. These alliances seem to be the wave of the future with regards to digital technology. Along with these agreements there has also come competition between different sectors. Not long ago, the cable industry was thought to be the biggest potential user of MPEG technology. However, the direct broadcast industry has gotten a jump on cable operators and strong competition is likely to emerge from regional telephone companies proposing "video-dial-tone" services. The result is a broadcast industry faced with extensive competition. The road for the broadcast industry appears to lead to digital technology and a major participant on the trip is MPEG.

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