

Practical Streaming Video on the Internet for Engineering Courses On- and Off-Campus

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Abstract

Over the last few years, the Internet has been increasingly used for education and research purposes. In particular, since the introduction of streaming video technology for the Internet, there has been a large interest in broadcasting engineering courses in part over the Internet. This paper discusses topics on how to prepare a streaming video in several inexpensive ways within an organization for engineering education. Studies have been made using different software, hardware, and video properties such as frame rate, streaming rate, and movie size. The major concern for preparing a streaming video lecture for engineering course is the visibility of diagrams and equations written on the chalkboard or whiteboard. Experiments have been done on Microsoft Netshow, RealNetwork Real Publisher, Apple QuickTime, and Vivo Active Producer. The cost and the ease of implementation were taken into consideration. This paper also presents the results of actual classroom use of streaming video for Engineering Statics course and a Leadership for Engineers course. Both courses have been taught in the Spring and Fall of 1998, and the Spring of 1999.

I. Introduction

Since Fall 1998, the College of Engineering at the University of Oklahoma (OU) has implemented a Laptop Program, which extends the use of electronic media for enhancing the engineering education. Starting from Fall 1998, the program requires every freshman engineering student to own a laptop. Over the next 4 years, all the undergraduate courses will be taught with the help of a laptop computer. A radio-frequency (RF) wireless network connection is one of the services provided by the school of engineering in conjunction with the laptop program. This allows the students and faculty to be connected to the network, both the Internet and OU's local area network. This program greatly encourages research in the use of electronic media and Internet for creating a better learning environment due to the ease of use and the universal use of computers in all courses. Furthermore, the RF wireless also has a better data transmission rate (actual rates of 200-300 kilo-bits per second, kbps) than traditional infrared or modem-based connections which helps with multimedia applications over the network.

With the current advances in network technology and streaming video over the Internet, it is now possible to broadcast actual engineering lectures over wireless networks with reasonable quality. Since lectures are a critical part of most engineering programs, it is important that any distance learning course, whether on or off campus, include quality video of lectures. Also, making the

ordinary classroom lectures into video clips and make available on the Internet enables students to review the lectures much easier so that students can learn at their own pace.

In order to put video on the Internet, video-streaming technology needs to be utilized. With streaming techniques, a student can be viewing while concurrently a new video is being transferred over the Internet. This means students can see the movie as soon as their browser downloaded the first few seconds (depending on the buffering time) of the movie. However, there are a number of concerns and problems that must be overcome. First is the data rate of the streaming video. Second is the quality, which is directly tied to the data rate. And third, the classroom environment needs to be considered to insure a quality video. Overall, what seems to be a simple problem, become complex when other factors are considered like, which streaming technology should be used (NetShow, Vivo, QuickTime, Real Player, etc.), camera type (VHS, Digital, Hi8), viewport size, room lighting, sound capture, and compression time are also considered.

The main purpose of this paper is to look into the issues mentioned above and to compare different solutions. All testing and evaluation in this paper was done for engineering lectures where data on the board is more important than seeing the professor's face. This introduced a unique set of comparison parameters that have not been addressed with traditional review papers in trade publications. Each of these is covered in this paper. This paper will first look at video capturing, then video compression. Following that, video and audio properties will be addressed. Editing software, hardware requirements, and server hosting will also be discussed.

II. Video Capturing in Classroom

Before a video lecture is digitized or brought into a computer, the lecture must first be captured using a video camera and stored on tape. The quality of the video and sound captured is important for later producing quality streaming video. The old saying, "garbage in, garbage out" is certainly true for producing quality streaming video. There are several issues taken into consideration while capturing the video lectures such as the lighting in the classroom, the contrast of the board and the writings, and the distance of the camcorder from the green chalkboard.

The videos presented in this paper were captured during a regular 50-minute class lecture. The typical lecture was given in a conventional classroom with a green chalkboard at the front and equipped with fluorescence lights. The camcorder was stationed at the back of the classroom on a basic tripod. For an engineering lecture, the action of a professor or a lecturer in the class is less important than equations and diagrams written on the board. Therefore, the capturing process needs to focus on the board at all times, and not on the professor. This also requires the professor to write clearly and not move around. All motions cause several compression difficulties and make the data rate larger.

Although, most of the camcorders have sensitive built-in microphone they are generally low quality and do not clearly capture voice recording with background noises that are common in a large classroom. This is due to the relatively long distance between the lecturer and the camcorder. In addition, student voices are also recorded when the camcorder's built-in microphone is used. As a solution, a small, inexpensive remote microphone was used as the

sound input device instead of the built-in microphone. It is small and can be clipped onto the lecturer's tie or collar. The remote microphone is connected to a pocket-size transmitter, which then sends the signal back to a receiver. The output of the receiver is then connects to the camcorder as an external microphone. The sound quality is excellent when even using inexpensive wireless microphones.

The next main issue with the classroom is the actual writing surface. Surprisingly, a dark black or green chalkboard and white chalk under normal classroom lighting works well. The important factor in recording writing on a board is the contrast and glare. The plain green chalkboard used in this study provided one of the highest contrast and the best visibility. Additional lighting actually made the texts and drawings look blurry on the board. However, one problem with the chalkboard is the smeared chalk when erasing. This is easily solved however, by using a wet sponge instead of a regular eraser, for cleaning the board. This eliminated the thin chalk film and greatly increased the contrast. The disadvantage of using the wet sponge is the board takes about 30 - 45 seconds to dry. Substituting the chalkboard with a whiteboard solves that problem, but because of its smooth surface, whiteboard reflects a glare on its surface. The glare regions do not view well on video and some writing becomes unreadable.

Another major concern is how far should the camcorder be positioned. Most camcorders come with digital zoom feature. However, some digital zooms will simply dither the image to give a false sense of zooming. Therefore, the camcorder should be placed close enough to the board so that it will stay within the optical zoom range.

III. Video Compression for Streaming Format

After capturing the lecture, the video needs to be brought into a computer that has a video capture board installed. The videos discussed in this paper were digitized using both PC and Macintosh computers. Therefore, both Audio/Video Interleaved (.AVI) and QuickTime (.MOV) file format are used as the general file types in this study. They are the main two file formats currently available for basic digit video.

When the video is actually captured, most video-capture boards will use their own proprietary hardware compression techniques whether it is AVI or QuickTime. The built-in hardware compression is generally faster in compression time compared to software compression because the video is being compressed while it is being imported from the camcorder. While the software compression requires the video to be in the computer first and then put the video run under compression software. Although the quality of the hardware-compressed video is higher, two problems exist. First the file size is still too large and the compression and decompression schemes (codecs) are not common to other viewers. If a movie file is big, a higher data transfer rate is required to play the movie smoothly. Since videos are designed for streaming over the Internet that can only transfer up to 150kbps over the wireless network connection, the size of the video files has to be very small. In addition, for viewing the compressed video, viewer needs to have the similar codecs and the plug-ins or player installed. Hence, the common codecs for audio and video needs to be used which is possible with recompression in software. This step is further discussion in the following sections.

Next, the movie size is also another important consideration because some of the compression technique requires the movie to be compressed into a certain size in order to perform optimum compression. There are two types of raw video format being discussed in this paper. First is the analog video format, which is used in VHS or Hi 8 camcorder. The second is the digital format, which is used by digital camcorder. The digital format was used for the two test courses at OU because it provided slightly higher video quality and the digital camcorder is relatively inexpensive. The standard movie size captured in digital format is 720x480 (3:2 ratio), while for the analog format is 640x480 (4:3 ratio). Currently due to the digital video capture board limitation, a digital video can be brought in only in standard settings, that is 720x480, 30 frames per second, and uncompressed. Thus the maximum file size is 2 gigabytes at a time or in about 9.5 minutes long. On the other hand, for analog video, the file size depends on how well the hardware can compress. With the video capture board used in this research, a 5 minutes analog video (30 frames per second, 24 bits color depth, 44kHz and 16bits stereo sound) is about 284 Mbytes. The final compressed video lecture using software compression for a 9.5 minutes segment is approximately 8 Mbytes for both formats. Although the processing time is longer for compressing a digital video, the final quality of the compressed video is higher. The video capture boards and camcorders used in the experiments will be further discussed in section VI.

IV. Video and Audio Properties Implemented

Currently, there are several software available in the market that can be used to produce streaming video for teaching engineering courses. However, this paper only studies four common video compression software, they are Netshow Encoder 3.0, Real Publisher 5.0, Apple QuickTime Sorenson, and Vivo Active Producer 2.0. Netshow and Real Publisher movies can be encoded only on the Windows NT platform while the Vivo Active and QuickTime movies can be encoded on both Macintosh and Windows NT. Throughout this research, a movie with the size of about 320x240 and with the frame rate of 10 frames per second was found to be sufficient for the equations and diagrams viewable in the streaming video. The audio settings were also set at the minimum audible level, so that the streaming rate for audio could be minimized.

As mentioned above, an analog movie size has an aspect ratio of 4:3 and for digital movie is 3:2. These ratios are set by the camera hardware and can not be modified during capturing. In addition, most of the compression techniques require the movie size to be divisible by 16 for higher compression. Since the analog and digital use different movie size ratio, if a uniform movie size is to be implemented, the final compressed video will most likely be stretched vertically or horizontally. Therefore, in order to avoid scaling of the movie, different movie sizes have to be implemented for compressing digital and analog videos. The sizes chosen for different compression techniques are for the optimum quality and streaming performance. Table 1 shows the general video information and parameters that were used in the experiments discussed in this paper where four different kinds of compression methods are compared.

	<i>Analog Video</i> (pixels)	<i>Digital Video</i> (pixels)
Netshow Encoder	320 x 240	336 x 224
Vivo Active Producer*	320 x 240	342 x 228
Apple QuickTime	360 x 240	360 x 240
Real Publisher	320 x 240	360 x 240

*The movie size is not necessary divisible by 16.

Table 1. Movie sizes for different compression software

The other settings for the movies that effect the data rate include setting the frame rate to 10 frames per second (fps), the audio to 11kHz and 8 bits, and mono voice quality. As will be identified in section VI, the digital format provided the highest quality among all formats and thus used for capturing the classes in this study.

V. Editing Software

There are several features that need to be considered while choosing compression software. First digital format produces large file sizes (2 gigabytes for 9.5 minutes), so the whole video lecture needs to be divided into smaller segments when importing them into the computer. For a 50-minute lecture, the video can be divided into six 9.5-minute segments and stored as different movie files. Usually, a 9.5-minute movie might take up about 40 to 100 minutes to be processed depending on which software is used. Therefore the total processing time is about 4 to 10 hours. For this reason, without the batch-processing feature, one needs to be attended at all time in order to get all movies processed. On the other hand, analog format produces smaller video file sizes (450 Mbytes for 9.5 minutes). Hence the compression time is also shorter. However, the video quality suffers significantly from high hardware compression by the video capture board.

Platform dependency and the player control panel are another two criteria to be evaluated. To serve the purpose of teaching an engineering course, the targeted viewers, students, generally use the Windows platform on their computers. However, there are still some researchers and faculty members using Macintosh and Unix platforms. Table 2 provides a comparison of the platform where the movies can be compressed or played on.

For playing a relatively long video clip, having a dynamic navigation control over the video is helpful. For example, a student can always use the slider or the seek-bar to get back and forth to the section that he/she missed or is unclear about without playing the whole video again. Most of the players will allow the video producer to display information about the movie on the player such as the author, the date, and copyright information (refer to Figure 1 for information display panel on Netshow player). Some players such as Netshow player and Real player even allow user direct forward to a certain preset marker. Table 2 gives a comparison of several features in 4 different kinds of software mentioned. Figure 1 shows different interface of the players. All of the play back players or plug-ins are free and downloadable from the web.

The four compression software studied in this paper are capable in producing quality streaming video, however, there are pros and cons in each of the software. For the courses mentioned in the abstract section, Apple QuickTime Sorenson technique is used for compression because of its batch-processing capability and its slider function on the player. First the whole video lecture is brought into the computer in about six 9.5-minute segments. Then, they are processed using a video editing tool such as Media Cleaner Pro for further compression with QuickTime Sorenson compression format and other desired video settings such as frame rate, movie size, audio quality, and streaming rate. Among the four software studied, Media Cleaner Pro takes relatively long hours to process a video into QuickTime Sorenson format, however, with the batch processing feature, one just need to be attended for one hour for importing the video from the camcorder to the computer. Then, Media Cleaner can be set for processing all the segments overnight. This in fact saves large amount of man-hours.

In comparison to QuickTime Sorenson, Netshow has a faster compression rate. However, the quality produced is not as high as QuickTime Sorenson. Vivo Active movie does have a comparable quality as QuickTime yet there is no navigation bar or slider available on the player. Hence, the viewer needs to replay the whole movie in order to get back to a particular section. Real Publisher produces reasonable quality video but it does not resize the raw movie into the desired size. The movie needs to be compressed down to the desired size in another editing software before it can be run in Real Publisher.

	Netshow Encoder	Real Publisher	Apple QuickTime 3.0 Sorenson	Vivo Producer
Batch processing	No	No	Yes*	Yes
Player control:				
Seek bar or movie slider	Yes	Yes	Yes	No
Information display	Yes	Yes	Yes	No
Direct to markers	Yes	Yes	No	No
Common codecs:				
Audio	MPEG 3	Real Audio	QDesign Music	H. 723
Video	MPEG 4	Real Video	Sorenson	G. 263
Compression time (for one minute actual video)	2:30	5:00**	25:00	10:45
Platform dependency:				
Encoder	Windows 95/98/NT	Windows 98/NT Macintosh	*	Windows Macintosh
Playback Player	Windows Macs, Unix	Windows Macs, Unix	Windows Macs	Windows Macs

* QuickTime 3.0 is a video format that uses various codecs that can be installed and used by any other editing software such as Media Cleaner or Premiere on both Windows and Macintosh platforms.

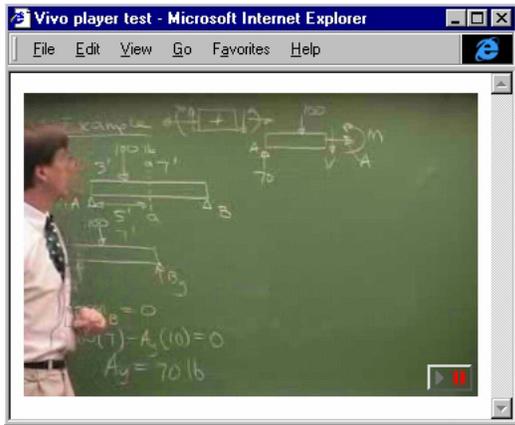
** Does not automatically compress the movie size. Resizing was done in Premiere (5 min)

Table 2: Comparison of features of four different compression techniques.

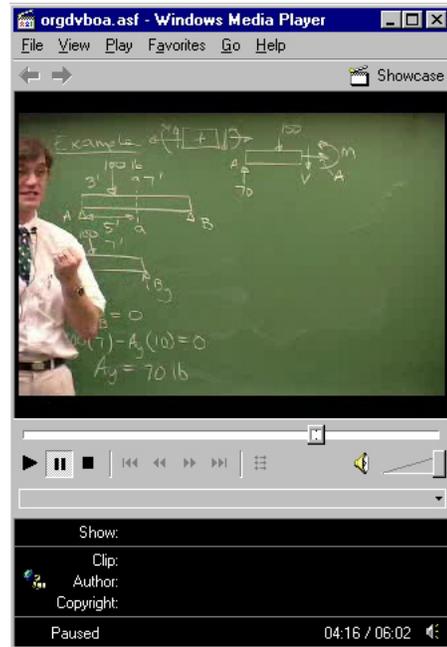
VI. Hardware and Video Format

Choosing the right equipment can increase the cost effectiveness for producing a quality streaming video. Essentially, there are only three pieces of equipment required, a camcorder, a computer, and a video capture board. However, to produce higher quality video, other tools are needed such as a remote microphone and a fast hard drive.

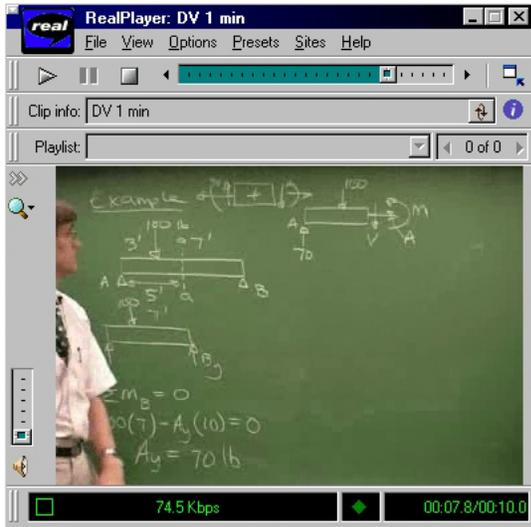
The compression time is directly related to the hardware performances. The compression time is measured by running the video compression using the hardware configuration discussed in section VI. After the video capture board and software are installed on the computer, the video captured is ready to be brought into the computer. The video is first played back from the camcorder while the software came along with the video capture board being turned on. For importing digital video, a SCSI hard drive is required because the amount of data being brought in per second is large. If the writing speed of the hard drive cannot handle the capture rate of the board, loss of data such as frame drops will occur. The Windows and Macintosh systems configuration used are listed as in Table 3.



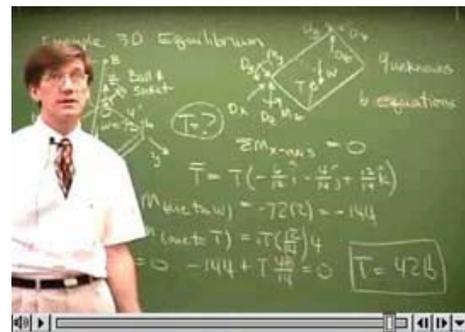
Vivo Active Player
(Embedded into web page)
342x228, 144 dpi



Windows Media Player
(Netshow files .asf, .asx)
336x224, 144 dpi



Real Player
(Real Video files .ram, .rm)
360x240, 144 dpi



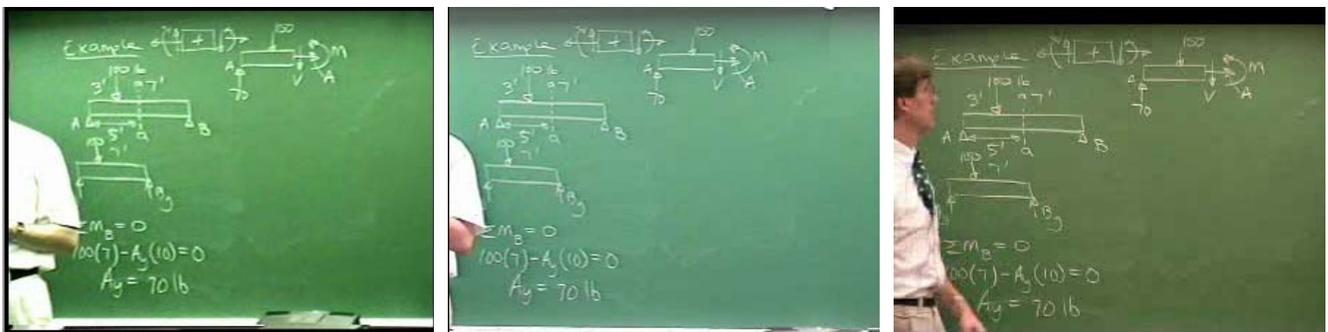
Apple QuickTime 3.0
(QuickTime Movie .mov)
360x240, 144 dpi

Fig. 1: (indicate

Windows NT platform	Macintosh platform
<ul style="list-style-type: none"> • Pentium II 266 MHz • 9Gbytes Ultra Wide SCSI hard drives • 128Mbytes SDRAM • SCSI interface card <p>Video capture board:</p> <ul style="list-style-type: none"> • Analog : Winnov Videum Capture board • Digital : DPS spark DV board 	<ul style="list-style-type: none"> • PowerComputing PowerCenter Pro 210 • 128Mbytes RAM • 13Gbytes Ultra SCSI hard drives <p>Video capture board:</p> <ul style="list-style-type: none"> • Analog : Miro DC 20 • Digital : Radius Moto DV board

Table 3: Computer used for video compression

For this project, 3 different types of video format were examined, Digital, Hi-8, and VHS. These three are used for representing the standard video format for broadcast, industrial, and home consumer quality. To obtain the digital format, a Canon digital camcorder is used for capturing the video. On the other hand, VHS and Hi-8 format were used for capturing analog video. Figure 2 below shows 3 snapshots of the movie compressed using different video format. As shown, digital video has the highest contrast and video resolution. The number of horizontal pixels shown in Table 4 portrays that the quality or resolution of the digital video is higher than Hi-8, and VHS video.



VHS Quality

Hi8 Quality

Digital Quality

Figure 2: Quality comparison on three types of video format. All were Compressed using Netshow Encoder at 336x224. (Printed size is half of the original size at 144 dpi)

	VHS	Hi-8	Digital
Camcorder model	RCA CC641	Sony Hi8TRV-85	Canon Optura
Number of horizontal pixels	240	400	480
Standard	Consumer	Industrial	Industrial/Broadcast
Common tape length(min) in short play mode	30	120	60
Signal	Composite	S-video	Digital (Firewire IEEE 1394)

Table 4: Standard comparison of 3 different kinds of video format.

VII. Serving and Hosting Streaming Video

The major concern in configuring a server for hosting streaming videos is the network bandwidth. Without determining the bandwidth that the user's Internet connection can handle, the streaming video will not be continuous. For example, if the streaming rate is set higher than the maximum data rate a user can receive, then the video will be pausing half of the time and this can be very annoying. Therefore, particular attention is given to low bandwidth (100kbps or lower) application around the campus or within an organization. Wireless connection provided by the College of Engineering at the University of Oklahoma could transfer up to 1.5Mbps for each transceiver, which are installed around the College of Engineering as the signal transmitter and receiver. However, a transceiver could serve up to 10 connection at a same time. Therefore, the target-streaming rate is set to 100kbps. It is also found that to provide reasonable audio and video quality of streaming video, 100kbps is sufficient.

There are two ways of serving out streaming video. The first one is stream it from regular web server without any special software and the other is to use a video-streaming server. For serving only a few videos, a basic web server works well. However, if the number of videos and viewers increase to over 30 or 40, a dedicated streaming server becomes necessary. For the experiments described throughout this paper, all the streaming videos were tested on a web server running Microsoft Windows NT Server 4.0. The processed videos were placed on the server and then linked by HTML code to the video on the server. This required no special streaming software on the server.

It should be noted that QuickTime, Vivo and NetShow videos do not need any server software to broadcast. RealPlayer streaming video did require special software running on the server to allow users to stream the video. In all cases, each visitor to the web site started a separate video streaming session. If the number of visitors is large, then multicasting technique can be used to minimize the number streams at any given moment. This technique requires a dedicated server and special server software which can be costly.

VIII. Cost and Ease of Implementation

The equipment that was used for this research to produce the streaming video for both courses, Statics and Leadership, was relatively inexpensive. First, the digital camcorder was approximately \$1500. A computer with digital video capture board and an Ultra Wide SCSI hard drive installed was less than \$3000 (the SCSI interface is needed for high data transfer from the camera to the hard disk). Additional accessories such as remote microphone, tripod, and compression software cost another \$1000. The above figures do not include the cost for Internet connection, the cost of setting up server, and or the time needed to tape the video or process it later for serving on the web. The computer that was used to process the video was also used to serve the video. Once the video lectures are organized properly, they can also be reused in subsequent semesters and thus save time, money, and effort.

For the courses mentioned, the whole process for preparing a streaming video was done by a graduate student. Once the initial video is set up and developed, the whole process of taping a 60 minute lecture, processing the tape, and placing on the server can be done automated with batch

and thus the actual operator time is small. For processing a regular 60 minutes video lecture, the total computer time required is about 12 hours, of which only one or two hours of actual operator time is needed. It should be noted that the live streaming is possible so that the full process can be automated, but the quality of the compressed video will be low. For best results, the video needs to be processed off line.

VIII. Conclusion

Implementing streaming video is actually fairly simple and can be done with relatively small investment. From the test done at the University of Oklahoma for two different engineering courses, it was found that producing streaming video for a lecture is time consuming, yet, if the lectures are properly organized and can be reused for others, the time can be justified. It was also determined that the type of camera (Digital Video, Hi8, SVHS) had only minor effect on the final quality of the streaming video. The compression methods had the most effect on the size and quality of the final video.

Furthermore, to decrease the data rate and still have high quality, the movement in the video must be kept to a minimum. The camera should not pan and the instructor needs to use only a predetermined portion of the writing board. This does cause the instructor to change his or her writing style, but the increased video quality is worth the effort. Illustration of this teaching technique can be found at www.eml.ou.edu/statics.

There are several other future research possibilities in this area that can improve and enhance the implementation of streaming video. For example, currently, to view a streaming video, viewers are required to download and install a plug-in for any given video format. There is research being done at various companies to implement Java based streaming video so that plug-ins are not required.

References

1. Addeo, Eric J. "Applications of Leapfrog Teleconferencing Technologies to Distance Learning" Proceedings of 1994 American Society of Engineering Education Conference
2. Grebler, Ron. "Desktop Digital Video" Prompt Publications, 1997
3. Hampe, Barry. "Video Editing of Your Presentation", Syllabus Magazine, Vol 12, No. 1, August 1998
4. B.T.Hakes, "Compressed Video for Instruction: Operations and Applications" Association for Educational Communications and Technology, 1995
5. URL: <http://www.microsoft.com>; Microsoft Inc.
6. URL: <http://www.real.com>; Real Network
7. URL: <http://www.vivo.com>; Vivo Software Inc.
8. McMakin, Matt, Samuel Murphy, and Jeff Sauer, "Showtime for Streaming Video", NewMedia, Jan 1999.

Bibliography

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