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Reading List

Many of the video compression standards discussed in this article are continuously evolving, and the best place to find up-to-date information is at the web sites of the respective standardization committees. The official MPEG web site is http://drogo.cselt.stet.it/mpeg and the official ITU site is http://www.itu.ch. A very useful nonofficial MPEG web site is http://www.mpeg.org. These sites also contain a very large number of useful links to other information sites. Information about the Advanced Television Systems Committee (ATSC) digital television standard that has been adopted in the United States can be found at http://atsc.org.

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VIDEO, DIGITAL. See Digital television.
VIDEO GAMES. See Computer games.
VIDEO, INTERACTIVE. See Interactive video.
VIDEO, MULTIMEDIA. See Multimedia video.

VIDEO ON ATM NETWORKS

With the integration of digital video compression and network technology, networked multimedia applications, such as video on demand, videoconferencing, digital library, distance learning, and interactive visual communications are becoming more and more important. In these applications, compressed digital video is a major component of multimedia data (1,2).

The delivery of real-time video over networks has characteristics different from conventional data transport. For example, sufficient bandwidth for a guaranteed timely delivery of video information is required. The bandwidth required depends on the video compression algorithm and the desired video quality. For real-time, two-way communication, low delay (latency) is necessary. Long delay between users can make the communication ineffective. Low delay variation is another requirement for multimedia delivery even in one-way applications to avoid large buffers and possible problems in clock recovery. Another concern is the effect of transmission impairments. Because of the nature of compressed video, a single transmission error may propagate to subsequent frames and cause synchronization failures and severe degradation of visual quality at the receiver. The traditional error recovery method for data transport, such as retransmission, is not suitable because it causes too much delay. Therefore, special video coding and a forward error correction code is needed at

The asynchronous transfer mode (ATM) is a cell-based high-speed, networking technology supported by broadband integrated service digital network (B-ISDN) international standards. It is defined for operation over a number of physical media supporting bit rates ranging from megabits per second to gigabits per second. Because ATM is developed to support integrated services that include video, voice, and data, it provides the features necessary for supporting multimedia applications. ATM is emerging as an ideal networking technology for multimedia transport because of its high bandwidth, flexibility in bandwidth usage, low delay, low-delay variation, variable bit-rate capability, and guaranteed quality of service (QoS).

Although ATM was designed to support integrated services, it has some limitations which affect video transport. Being a cell-switched technology, it introduces packetization delay. When the network is congested, it may result in cell loss and cell-delay variation. In this article, we provide information related to video, ATM, and issues related to the transport of compressed digital video over ATM networks.

VIDEO FUNDAMENTALS

Analog Video

Video is a time sequence of two-dimensional frames (pictures). Each frame is represented by a sequence of scanning lines. As shown in Fig. 1, there are two ways of displaying or scanning a frame, progressive scan and interlaced scan. In the interlaced scan, a frame consists of two interlaced fields. In the progressive scan, a frame consists of only one field. A movie in a theater is in a progressive format. An analog TV signal is in an interlaced format consisting of 30 frames (60 fields) per second. The interlaced format conserves bandwidth because it sends only half a frame every 60th of a second, but because of the property of human eyes, gives the impression that we are viewing 60 complete pictures per second. However, interlaced scan results in motion artifacts when some part in the image moves between the two half-frames.

A color image can be represented by three component signals. The RGB color component system is one way to represent a color in the three primary colors. Red (R), Green (G), and Blue (B) components are combined to synthesize a color. Alternatively, a color can be represented using a luminance

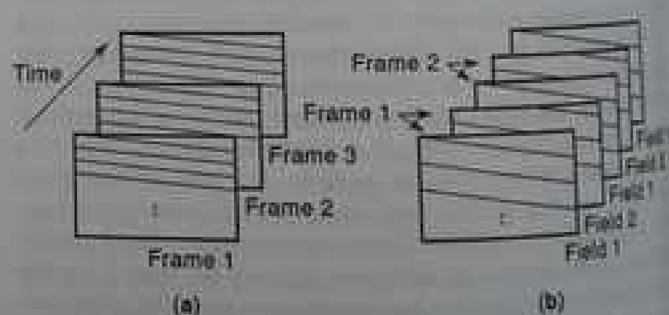

Figure 1. (a) Progressive and (b) interlaced scan. In the progressive scan, a frame consists of only one field. In the interlaced scan, a frame consists of two interlaced fields. The interlaced scan conserves bandwidth

Table 1. CCIR 601 Specification

	NTSC	PAL/SECAM
Luma sampling freq.	13.5 MHz	13.5 MHz
Chroma sampling freq.	6.75 MHz	6.75 MHz
Frames/second	30	25
Number of luma samples/line	858	864
Number of chroma samples/line	429	432
Number of active luma samples/line	720	720
Number of active chroma samples/line	360	360
Number of active lines/frame	486	576
Sample resolution	8 bits	8 bits
Data rate	167 Mbps	166 Mbps
Color subsampling	4:2:2	4:2:2

(brightness) signal and two chrominance (color) signals. Because the human visual system is less sensitive to color information than brightness information, chrominance signals can be represented with lower resolutions than luminance signals without significantly affecting the visual quality.

The current analog color TV standard used in North America and Japan was developed by the National Television Systems Committee (NTSC). The NTSC standard defined a YIQ color system. In this representation, Y is used for luminance, and I (in-phase) and Q (quadrature-phase) are two color-difference signals modulated by a 3.58 MHz color subcarrier. The luminance and the modulated chrominance signals are combined into a composite signal. Each channel of a TV signal has a video bandwidth of about 4.2 MHz, but requires a bandwidth of about 6 MHz to accommodate FM audio and channel separation. The phase alternating line (PAL) and the Sequential Color Avec Memoire (SECAM) standards used in Europe are based on a YUV color system. The YUV color system is similar to the YIQ color system except that the color-difference signals are defined slightly differently.

Digital Video

To use current state-of-the-art computers and digital networking technologies for processing, storing, and transmitting video signals, the analog video signal must be converted into a digital video signal. With compression techniques, digital video provides good quality video with a much lower bandwidth compared with that needed for analog video. With the much reduced bandwidth, many video applications become possible.

To convert an analog video into a digital format, each scanning line in the image is sampled, and the sampling points or pixels (picture elements) are represented by discrete values. CCIR 601 recommendation [International Radio Consultative Committee now changed to ITU-R (International Telecommunications Union-Radio)] (3) defines the format for digital television signals by digitizing NTSC, PAL, and SECAM signals. The number of active samples (pixels actually displayed) per line are specified to be the same in all systems even though the total numbers of samples per line differ. The important features of CCIR 601 are listed in Table 1.

The CCIR 601 defines a YCbCr color space which is a scaled and offset version of the YUV color space. Cb and Cr represent color difference signals of B and R from luminance signal Y. Because human eyes are not very sensitive to color signals, CCIR-601 specifies a sampling ratio of 4:2:2 between the luminance and the two chrominance signals to reduce the transmission rates of the Cb and Cr chrominance components. The 4:2:2 subsampling means that the color-difference signals Cb and Cr are sampled with half the sampling frequency of the luminance signal Y and for every four samples of Y, there are 2 samples of Cb and 2 samples of Cr. Figure 2 shows the sampling patterns of commonly used subsampling formats.

Video Compression

The digital video format in CCIR 601 results in a high data rate (about 166 Mb/s). Different applications may use different digital video formats which result in different uncompressed data rates. The uncompressed data rates of some common video formats are listed in Table 2. These data rates

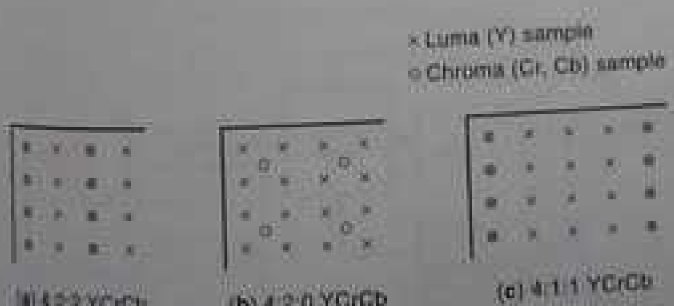

Figure 2. Examples of subsampling format: Subsampling is used to reduce the transmission rates of the Cb and Cr chrominance components. There are two samples of Cb and two samples of Cr for every four samples of Y in the 4:2:2 subsampling.

Table 2. Bandwidth Requirement of Broadband Services

Formats	Uncompressed Bit Rate, Mbps
CIF, 352 × 288 pixels (video conferencing) 4:2:0 30 frames/s	36
QCIF, 176 × 144 pixels (video conferencing) 4:2:0 30 frames/s	9
Digital TV (CCIR 601)	166
HDTV, 1280 × 720 pixels (high-definition TV) 4:2:2 30 frames/s	442
HDTV, 1920 × 1080 pixels (high-definition TV) 4:2:2 25 frames/s	829

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