A COMPARISON OF VIDEO COMPRESSION ALGORITHMS

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ABSTRACT

Compressed video is necessary for a variety of telemetry requirements. A large number of competing video compression algorithms exist. This paper compares the ability of these algorithms to meet criteria which are of interest for telemetry applications. Included are: quality, compression, noise susceptibility, motion performance and latency. The algorithms are divided into those which employ inter-frame compression and those which employ intra-frame compression. A video tape presentation will also be presented to illustrate the performance of the video compression algorithms.

KEY WORDS

Compressed Video, JPEG, MPEG, Wavelets, Motion Compensation

INTRODUCTION

The requirement for secure video telemetry forced a transition from analog to digital transmission. In order to accomplish this, video compression was needed to meet bandwidth limitations. This paper compares the performance of a number of candidate video compression algorithms for the telemetry application. Performance criteria considered are quality, compression, noise susceptibility, motion performance, and latency.

DISCUSSION

Table 1[1] lists the levels of video compression available for a variety of applications. The levels range from low quality videophone to truly Alossless@ compression. This paper compares the performance of a number of video compression algorithms which lie within this range. In order to facilitate the comparison, they are divided into two categories: 1) those based intra-frame and 2) those based on inter-frame compression. With intra-frame, each transmitted video image is compressed independently, whereas with inter-frame, differences between adjacent frames are described. Generally, the inter-frame algorithms provide higher compression and the intra-frame algorithms provide better resistance to errors. Specific intra-frame

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1 Schaphorst, Richard, Videoconferencing and Videotelephony; Technology and Standards, 2nd ed., Artech House, Inc., Norwood, MA, 1999, pg. 50.

algorithms considered are DPCM (RCC/TCG 209), JPEG/NITF and wavelets. Inter-frame algorithms considered are H.261, H.263, MPEG-1 and MPEG-2. Table 2 gives typical parameters used for these algorithms and compares their performance.

Table 1. Levels of Video Compression

Compression Level	Bit Rate	Compression Ratio
Uncompressed	90 Mbps	1
Lossless Compression	45 Mbps	2
Visually Lossless	5-10 Mbps	10-20
High Quality Videoconferencing	384 Kbps - 1.5Mbps	50-200
Acceptable Quality Video Conferencing	100 Kbps	1,000
Videophone	25 Kbps	4,000

Table 2 compares the performance of seven video compression algorithms.

Table 2. Comparison of Video Compression Algorithms

Category	Algorithm	Resolution	Bits/Pixel	Image/sec	Bit Rate	Quality
Intra-Frame Compression	DPCM (RCC/TCG209)	512x480	2.5 - 3.5	15	10 Mbps	Below VHS quality
	JPEG/NITA	720x480	0.75 - 1.25	30	10 Mbps	Visually lossless
	WAVELETS	720x480	0.5 - 1.0	30	7.5 Mbps	Visually lossless
Inter-Frame Compression	H.261	352x288	0.2 - 0.4	15	500 Kbps	Hi-quality confer-encing
	H.263	176x144	0.1 - 0.2	15	56 Kbps	Videophone
	MPEG-1	352x240	0.4 - 0.8	30	1.5 Mbps	VHS quality
	MPEG-2	720x480	0.5 - 1.0	30*	7. 5 Mbps	Visually lossless

* Frame rate fixed

Note from Table 2 that specific video resolutions have been assumed for each algorithm. In almost all cases other resolutions are available, however, the listed values are commonly used.

Noise/Error Performance: Digital transmission over wireless networks does have certain inherent advantages when compared with analog transmission. Any noise inserted into the analog network reduces the signal-to-noise performance of the telemetered video signal whereas the addition of noise into the digital system has no effect until the noise builds up sufficiently to cause bit errors. Table 3 compares the performance of the algorithms in the presence of bit errors.

Table 3. Noise/Error Performance

Category	Algorithm	Resolution	Picture Structure	Comments
Intra-Frame Compression (errors within current frame)	DPCM (RCC/TCG209)	512x480	Lines	Error typically effects one-half line
	JPEG/NITA	720x480	GOB/DCT	Error typically effects one-half GOB
	WAVELETS	720x480	Sub-Band coding	Error effects single frequency band
Inter-Frame Compression (errors persist from frame-to-frame)	H.261	352x288	GOB/DCT	Background Intra-frame coding to clean up errors. FEC necessary
	H.263	176x144	GOB/DCT	Background intra-frame coding introduced. FEC necessary
	MPEG-1	352x240	Slice/DCT	Intra-frames (AI@ frames) interleaved
	MPEG-2	720x480	Slice/DCT	I-frames interleaved

As indicated by Table 3, the intra-frame algorithms provide the advantage that errors do not propagate from frame to frame. As indicated previously, the inter-frame algorithms generally out-perform the intra-frame algorithms regarding compression since only differences between adjacent frames are described rather than the entire frame. Because of their increased susceptibility to errors, however, inter-frame algorithms require some form of error control strategy. With H.261 and H.263 this is accomplished by the addition of FEC, which avoids errors plus the addition of some distributed intra-frame coding to eliminate the effects of errors. MPEG-1 and MPEG-2 also rely on the addition of intra-frame coding. Entire intra-frames are transmitted at regular intervals in order to eliminate the further propagation of errors.

Motion Performance: Motion performance is closely related to general quality performance for these algorithms. That is, the higher the overall quality, the better the motion performance. This relationship is particularly true for the intra-frame algorithms. All four of the inter-frame algorithms employ the DCT transform and motion compensation. Motion compensation is a technique employed to improve compression by reducing the apparent difference between adjacent frames. This technique can result in *blurriness* of objects in motion due to limitations in the inter-frame coding. The primary deterrent to motion performance, however, is due to the Ainterlacing@ of the video signal. That is, with standard NTSC video, each frame consists of two separate interlaced fields displaced in time by 1/60th second. The only way to avoid this effect entirely is to view the video a single field at a time at a corresponding reduced vertical resolution.

Latency: Latency refers to the delay between the occurrence of a video event and its appearance at the video output. For many telemetry applications, latency is not an issue. One notable exception is for driving unmanned vehicles. Intra-frame compression algorithms generally provide low latency. The H.261 and H.263 algorithms were developed primarily for interactive videoconferencing where delay is important. Hence they offer low delay. MPEG-1, which was developed primarily for digital storage media where latency is not an issue. Thus, MPEG-1 is not generally used for applications where latency is an issue. MPEG-2 was developed for a wide range of applications including storage and broadcast. Tradeoffs are available with MPEG-2 which can be used to control latency. Thus MPEG-2 can be used for applications such as the driving of unmanned vehicles.

Video Tape Presentation: Presentation of this paper shall include a video tape demonstration which illustrates the performance of the compression algorithms.

CONCLUSIONS

This paper compares the performance of seven video compression algorithms for telemetry applications. Specific parameters considered are quality, compression, noise susceptibility, motion performance and latency. The intra-frame algorithms considered (DPCM, JPEG, wavelets) generally outperform the inter-frame algorithms (H.261, H.263, MPEG-1, MPEG-2) regarding noise performance, motion performance and latency. Whereas, the inter-frame algorithms tend to provide better quality and higher compression.