CURRENT STATUS OF DATA COMPRESSION IN TELEMETRY

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ABSTRACT

Reduction of bandwidth for signal transmission is of paramount concern to many in the telemetry and wireless industry. One way to reduce bandwidth is to reduce the amount data being sent. There are several techniques available to reduce the amount of data. This paper will review the various types of data compression currently in use for telemetry data and how much compression is achieved.

KEYWORDS

Telemetry data compression, lossless data compression, latency

INTRODUCTION

Much of the data compression currently being used in telemetry is for image compression. Color image data utilizing three components for color (with 8 bits for one component and 4 for the other two), and using a conservative 512 pixels per line, 512 lines per frame, and 30 frames per second yields about 125.83 M bits/sec. Add to that more than one video feed, audio and telemetry data, and it is clear why the compression would be needed.

A lot of work has been done in the imaging area to achieve some excellent compression rates – but these methods tend to be lossy (that is the image is not exactly what the original image was). In many cases the error that is introduced is not noticeable.

In this paper, several industry representatives were interviewed to determine what compression methods are currently being used in the telemetry area. Results of these interviews and of some of the current literature are summarized along with the compression and latency of the techniques. Examples of how the compression techniques are being used will also be given.

TELEMETRY COMPRESSION USAGE BY ITC VENDORS

Upon surveying the vendors at the International Telemetering Conference (ITC) at Las Vegas in October 2003, it can be seen (in Table 1) that most of the data compression currently in use for Telemetry is in the video area. Those who indicated video or image compression are mainly using the MPEG (or a form of MPEG) for the compression.

Company [1]	Is data compression used?	Type of comp	application
Raytheon (Tucson)	Yes	erice, variable length packets, dither, broadband 3 MSB	Data
Delta	Yes	MPEG-2	digital video
PSL	yes	wavelet	flight video
L3	Yes	wavelet, PK-zip (not implemented yet)	image
Redstone	Yes	JPEG	image
Lincoln Labs	Yes	JPEG 2000	MFAS (seeker)
AMPOL	Yes	3 to 1 data, video MPEG II	recorder
General Dynamics	Yes	LZ-O	Sensor, climate, archiving at receiver end
Integral System	yes	custom	storage, recorder
AP labs	Yes	JPEG	video
EMC2	yes	MPEG	video
Enerdyne	yes	IRIG 210, MIPEG, MPEG2	video
Enertec America	yes	MPEG	video
Heim Data	Yes	MPGE-2	video
WSMR	Yes	MPEG IV	video
Marconi	Yes	MPEG, Parabit	video, data comp.
ACRA control	Yes	MPEG-2, CVSD, IRIG 106	video, voice
Apogee Labs	yes	μ law	voice
Qualcom	Yes		voice
Seimens	Yes		voice
JPL & NASA	Yes	ICER,LOCO, eRice, szip	Video, images, data, data archiving
Avtec Systems	Yes		
CMC Electronics	Yes	wavelet	
ITS	yes	video	
Tybrin	Yes		
Veridian	Yes		
Astro-Med	none		
BeloBox	None		
Edward's AFB	None		
Eglin AFB	None		
Emhiser Research	None		
ENDEVCO	none		
Herlex	none		
J-Tech	None		
M/A Com	none		
NavAir	None		
Nova Engineering	None		
RSS	None		
SBS	none		
Spiral Technology	None		
Symnetricom	None		
SYPRIS	none		
TSI	None		

Table 1: Vendor response at October 2003 ITC [1]

SUMMARY OF COMMONLY USED TELEMETRY COMPRESSION TECHNIQUES

The ITC vendors indicated several different types of compression techniques. These techniques are summarized below:

CVSD: Continuous Variable Slope Delta modulation. This is a method of digitizing a band-limited audio signal. It consists of a 1 bit analog-to-digital converter encoding an incremental increase (as a one) or decrease (as a zero) in signal amplitude into a serial bit stream. [2]

Erice/ szip: This data compression technique consists of two parts – the preprocessor, and the adaptive entropy coder. The pre-processor uses a predictor (previous frame, previous image, previous sample, no prediction, or another prediction input by the user) to decorrelate the data. The data is then coded in a variable length entropy code. More information on this technique can be found in Chapter 16 of [3]. This is a lossless technique.

ICER: ICER is an image compression technique. It was developed by the Jet Propulsion Laboratory for the Mars Exploration Rover. It is a wavelet-based image compressor designed for use with the deep-space channel. It can perform lossless or lossy compression of images. The transformed images are then coded using entropy encoding to compress the bit sequence. [4,5]

IRIG 106: This is an IRIG (Inter-Range Instrumentation Group) Digitized audio telemetry standard. This standard uses CVSD to digitize an audio signal and then inserts this coded data into a pulse code modulated stream for transmission. [2]

IRIG 210: This is an IRIG standard for the digital transmission of monochrome television images. This standard utilizes the HORACE protocol. The HORACE protocol uses a delta modulation (differencing of pixels) in the horizontal direction. This standard also allows selection of subsampling or pixel stagger to help reduce the amount of data sent. [6]

JPEG: Joint Photographic Experts Group (JPEG) uses the Discrete Cosine transform to achieve compression. Truncating the number of terms of the transform to recreate the image allows for sizable compression. This results in a lossy compression. This committee was founded by the ISO and CCITT. [7]

LOCO: Low Complexity Lossless Compression. This technique applies autoregressive prediction models, Golomb codes and runlength codes to achieve compression. [8]

LZ-O: The Lempel-Ziv codes are dictionary based codes, where the dictionary is sent as the code is generated. For more information on the LZ algorithms see [7], for a brief history/summary of the techniques, see [3].

MPEG: Moving Pictures Expert Group committee developed this standard as part of the International Standards Organization (ISO), and Consultative Committee for International Telegraph and Telephone (CCITT) efforts to find compression techniques for images and moving images. [7] MPEG is "a working group of ISO/IEC in charge of the development of standards for coded representation of digital audio and video. Established in 1988, the group has produced MPEG-1, the standard on which such products as Video CD and MP3 are based, MPEG-2, the standard on which such products as Digital Television set top boxes and DVD are based, MPEG-4, the standard for multimedia for the fixed and mobile web and MPEG-7, the standard for description and search of audio and visual content. Work on the new standard MPEG-21 "Multimedia Framework" has started in June 2000. So far a Technical Report and two standards have been produced and three more parts of the standard are at different stages of development. Several Calls for Proposals have already been issued. The algorithm then uses block-based motion compensation to reduce the temporal redundancy. Motion compensation is used for causal prediction of the current picture from a previous picture, for non-causal prediction of the current picture from a future picture, or for interpolative prediction from past and future pictures. The difference signal, the prediction error, is further compressed using the discrete cosine transform (DCT) to remove spatial correlation and is then quantized. Finally, the motion vectors are combined with the DCT information, and coded using variable length codes." [9]

PKzip: This compression technique uses the Lempel-Ziv 77 compression algorithm [7]. The Lempel-Ziv 77 is a dictionary based code. There are several Lempel-Ziv codes with various modifications dealing with length of the dictionary, the window used to generate the words, etc. This is a lossless code.

PSD: This method takes the Fourier Transform of the data, and transmits only the transform coefficients. If all coefficients are transmitted, the process is lossless, if some are not sent, then this becomes a lossy technique. [10, 11]

μ Law: "A *companding* operation *compresses* dynamic range on encode and *expands* dynamic range on decode. In digital telephone networks and voice modems (currently in use everywhere), standard *CODEC* chips are used in which audio is digitized in a simple 8-bit *μ-law format* (or simply ``mu-law"). Given an input sample x(n) represented in some internal format, such as a short, it is converted to 8-bit mu-law format by the formula:

$$\hat{x}_\mu \stackrel{\Delta}{=} Q_\mu\left[\log_2\left(1+\mu\left|x(n)\right|\right)\right]$$

where Q_μ is a *quantizer* which produces a kind of logarithmic fixed-point number with a 3-bit characteristic and a 4-bit mantissa, using a small table lookup for the mantissa." [12]

Wavelet: A wavelet transform of data (usually image data) is a linear transform of the data "designed to decorrelate the images by local separation of spatial frequencies. The transform decomposes the image into several subbands, each a smaller version of the image, but filtered to contain a limited range of spatial frequencies." [4]

APPLICATIONS AND COMPARISONS

Some comparisons have been done between compression techniques. The Compression ratio will defined as:

CR= (original data size)/ (coded data size, average length).

The larger the CR is, the better the compression. If CR=2 that would mean that the reduced file is half the size of the original file.

In Gary Thom and Alan Deutermann's work [13], comparing JPEG, and wavelets for single frame compression, both techniques yield visually lossless quality compression at compression rates of 10 to 20. At visually noticeable losses (acceptable video conferencing imaging), compression rates of 1000 can be reached. With inter-frame compression techniques, comparing MPEG-1 and MPEG-2 both give visually lossless results at compression rates of 10 to 20. Using lossy techniques with MPEG-2 will yield a low latency method for compression although no latency times were given. There is a trade-off between loss and latency. MPEG-1 was developed for data storage and so is not appropriate if latency is a concern.

The Rice Algorithm has already been used for data compression on several missions. Some of the projects that have implemented the Rice algorithm are: SERTS-07 (sounding rocket), CASSINI for NASA, ROSETTA for ESA (European Space Agency), and COBRA for the DOE [14]. It has been used on many other projects as well, see [14] for a more complete list.

Some of the specific applications and techniques are given in Table 2.

CONCLUSIONS

Compression is currently being used and used well for telemetry. Many of the techniques have been used for some time, but have not received much recognition. There are still concerns regarding the effect that errors have on the data. Many of the techniques either use channel coding or transmit partial packets so that recovery can be made if an error occurs. Compression can reduce transmission bandwidth by reducing the amount of data to be sent. It can also reduce the amount of storage required for the data. Data compression is a viable option for telemetry systems.

Compression Technique	Where the compression is used	Compression, CR	Latency
Rice/szip [15]	Thematic mapper/ Landsat Images	1.83	1 unit delay (unit is a sample)
	Heat Capacity, mapping radiometer	2.19	1 unit delay
	Wide field camera, Hubble Telescope	2.97	Unit delay using a horizontal line direction
	Soft X-ray solar Telescope	4.69	1 unit delay
	Goddard High resolution spectrometer	1.64 1.72	1 unit delay 1 spectra delay
	Gamma Ray Spectrometer on Mars observer	>20 28	No delay 1 trace delay
	MODIS real sensor data, transmission and storage of data [16]	2.8	71.6 sec on 300MHz Pentium II 2.744 M bits
ICER [4,5]	Image data, Mars Exploration Rovers	10.6	4 to 5 μ sec on a 20MHz RAD6000 with V_xWorks OS 761.856 K bits
LOCO [4,5]	Image data, Mars Exploration Rovers	1.9	4 to 5 μ sec on a 20MHz RAD6000 with V_xWorks OS 761.856 K bits
PKZip [17]	Advanced Range Telemetry PCM data sets differencing the major frames	1.5 to 17.5	1 frame delay

Table 2: Summary of Compression and Latency Values

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