DATA COMPRESSION SYSTEM FOR VIDEO IMAGES

MRS. P.S. RAJYALAKSHMI

MR. R.K. RAJANGAM

DIGITAL SYSTEMS DIVISION
ISRO SATELLITE CENTRE
BANGALORE 560 017 INDIA

ABSTRACT.

In most transmission channels, bandwidth is at a premium and an important attribute of any good digital signalling scheme is to optimally utilise the bandwidth for transmitting the information. The Data Compression System in this way plays a significant role in the transmission of picture data from any Remote Sensing Satellite by exploiting the statistical properties of the imagery. The data rate required for transmission to ground can be reduced by using suitable compression technique. A data compression algorithm has been developed for processing the images of Indian Remote Sensing Satellite. Sample LANDSAT imagery and also a reference photo are used for evaluating the performance of the system. The reconstructed images are obtained after compression for 1.5 bits per pixel and 2 bits per pixel as against the original of 7 bits per pixel. The technique used is uni-dimensional Hadamard Transform Technique. The Histograms are computed for various pictures which are used as samples. This paper describes the development of such a hardware and software system and also indicates how hardware can be adopted for a two dimensional Hadamard Transform Technique.

KEYWORDS.

Data Compression, Hadamard Transform Coding, Quantizers, Walsh Vectors, pixels.

1. INTRODUCTION

The requirement for a satellite based earth resources imagery has been well established by the NASA's LANDSAT program. This has led to the increased user requirements on spatial and spectral coverage and timely delivery of the data. Accomplishment of these objectives require sensors operating with a bit rate of hundreds of megabits per second, and a large bandwidth is required for transmitting this data to ground. By exploiting the statistical properties of the satellite imagery, the data compression techniques provide reduction in data transmission rate leading to smaller bandwidth for the transmission of same information. The efficiency of data compression algorithm is measured by the compressing ability, the resulting distortion and also by the implementation complexity. Due to the latest technology of LSI and VLSI, onboard implementation of data compressors, of late requires less hardware and hence has become simple and reliable.

2.0 THEORY

Basically image data compression is classified into two different categories. The first category exploits the redundancy in the data and the compression is achieved using predictive coding, DPCM etc., whereas in the other, called transform coding, compression is achieved by an energy preserving transformation of the given image into another array so that maximum information is packed into minimum number of samples.

2.1 Transform Coding

The purpose of image transform coding is to produce coefficients which are much less correlated with one another thereby reducing the inherent redundancy in the description of the image. This has the effect of compacting as much information as possible into few coefficients. By coding only those coefficients in a suitable manner for transmission, it is possible to reduce the amount of data to be transmitted with minimum degradation in the image. The optimum transform for compressing the bandwidth of the images is Karhunen Loeve Transform (KLT) which provides least mean square error in the coding performance.(1). But the KLT is comparatively difficult to achieve since it requires statistical knowledge of the image source apriori. As a result KLT is rarely used in practice.

The Slant Transform has fixed basis vectors of a discrete saw tooth waveform that decrease in uniform steps over its length. This is suitable for efficiently representing gradual brightness changes in an image line. But this requires analog computation with its inherent adjustments and stability problems.

Most commonly used transform coding in image processing are the Discrete Fourier Transform (DFT) and Discrete Cosine Transform (DCT). For real time operations those are not well suited as the hardware is quite complex and bulky. The Walsh Hadamard Transform (WHT) was finally chosen for the present system not only due to the ease with which it can be implemented with the advanced VLSI circuits but also the extensive offline simulations have shown its efficiency to be comparable with other transform techniques. The realization of one dimentional Hadamard Transform only is discussed in this paper as the results have shown that this technique is sufficient for our objectives.

Walsh Hadamard Transforms are analogs of the Discrete Fourier Transforms (DFT). Their basis functions are sampled Walsh functions which can be expressed in terms of the Hadamard matrices H(n). These matrices can be generated using the following recurrence relation.(2).

$$H(K) = \begin{bmatrix} H(K-1) & H(K-1) \\ H(K-1) & -H(K-1) \end{bmatrix} \qquad K=1,2....n$$

where H(0)=1 and $n=\log_2 N$; N being the number of terms in the series. For example, with K=1 and K=2 we have Hadamard Transform of the order N=2 and N=4 as shown below.

$$H(1)= \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \qquad H(2) = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \end{bmatrix}$$

In the above it can be seen that the number of sign changes i.e, the sequencies are not in natural increasing order. When the sequencies are arranged in natural increasing order it becomes Walsh Hadamard Transform. Each of the basis vectors of the WHT is a series of plus and minus ones and it performs the decomposition of a given function into rectangular waveforms as distinct from the sine and cosine waveforms asssociated with the Fourier Transform. It is this property which allows the transform to be computed so easily. For carrying out one Dimensional Transform coding, each line of the picture scene is first divided into blocks of 16 pixels. From so many earlier works the optimum size for block is found to be 16.(1). Then these pixel blocks are multiplied by Hadamard matrix of the order 16 to get 16 coefficients. The first coefficient is an average of the picture elements within the block and it is modelled by a Raleigh Density. Each of the remaining coefficients is made of linear combinations of the picture elements and this is modelled by Gaussian Density.

2.2 Bit Selection

The number of bits for transmission from a block of 16 coefficients is decided by the number of quantization levels (whether non linear or linear) in each coefficient. There are generally two ways in which the quantization levels are fixed namely, Zonal Sampling and Threshold Sampling.(1). In Zonal Sampling, only the low sequency components of the image are transmitted in full while higher components are not transmitted at all as most of the energy of the image is contained only in the low sequency components. In Threshold Sampling the threshold is fixed and a decision is made to transmit sequency coefficient adoptively whenever it crosses the threshold. This is highly adaptable but the hardware complexity is quite high. The technique that is adopted in this study does not fall under any of the two categories. From a large number of software simulations on the nature of the various images, the number of bits required for transmitting the various sequencies have been found out and accordingly compression algorithm has been worked out statistically.

3.0 SOFTWARE SIMULATION

For carrying out the software simulation 12 picture scenes including imageries from LANDSAT, BHASKARA, Aerial Survey and some portraits have been used. The digital imageries are classified into sizes of 512 pixels x 300 to 700 lines depending on the size of the imagery. Each line of digitised image is grouped into blocks of 16 and the 16 coefficients are obtained by multiplying with the Walsh Hadamard Matrix of order 16. The range of values of the 16 coefficients for all the blocks of each of the image are tabulated in TABLE-I. The statistically significant quantization levels of the various coefficients have been found out from the table. For the coefficient C1 uniform quantization is adopted for the full range. For the coefficient C2 the sequency values are concentrated mostly over the middle of the range and subsequently C3 onwards the value reduces and tapers down to near zero. The selection of the number of bits is done such that the lower sequencies have more bits and higher sequencies have less bits. Nonlinear quantizers have been designed for C2 to C9 as per the tables II, III, IV & V. The number of bits for transmitting the 16 pixels of the information are also highlighted in the Table VI from which it is seen that only 2 bits are transmitted for every 112 bits of imagery leading to the compression ratio of 1:4.67. The Compressed picture is reconstructed using the inverse Hadamard Transform and also carrying out the reverse operations on the quantizer. The original and the reconstructed pictures are shown side by side and the effectiveness of the compression has been analysed for compression ratio of 4.67 and 3.5 as shown in Appendix-A.

4.0 HARDWARE ASPECTS

The Block Schematic of the hardware is shown in Fig.1. The 7 bit digitised image data is converted to parallel and then fed to the Arithmetic Logic Unit (ALU) and other circuits for carrying out the Walsh Hadamard Transform multiplication. The Walsh vectors are programmed in a PROM which are also fed to the ALU. The ALU performs the functions of additions and subtractions sixteen times depending on the Walsh Vectors when each pixel arrives at the ALU input. Output of the ALU which correspond to the coefficients C1 to C16 are stored in a RAM sequentially in 16 locations and these are available at the other input of the ALU for the next iteration. Thus, the operations are carried out in the ALU sequentially 16 times as the pixel 1 to pixel 16 arrive at the input of ALU, for obtaining the final transform coefficients. These are latched at the output. These coefficients are passed through the quantizer PROM wherein the number of bits for transmission are decided. These bits are serially shifted out for final transmission along with the Frame Synchronising Code. The full encoder consists of 75 ICs and the power dissipation is only 12 watts by using 54 F series ICs. Work is under progress for the design of the quantizer using two Dimensional Hadamard Transform Technique. It is proposed to find out the periodicity of occurrence of the coefficients and then decide the different nonlinear quantizers for each coefficient. For implementation of the same the present hardware has to be suitably augmented with additional quantizers leading to marginal increase in the hardware. But this is expected to give much more compression ratio.

5.0 CONCLUSION

The purpose of the work described in the paper is to evaluate the effectiveness of the Walsh Hadamard Transform Technique for compression of the Satellite Video Imagery. The software results show a very good performance and the compression ratio is quite appreciable. The hardware is also simple to implement and hence will be more attractive for spacecraft applications. The development of the system has been influenced strongly by the earlier works done on these techniques.(3).

6.0 ACKNOWLEDGEMENT

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REFERENCES:

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3. TRW Final Report on Study of Adaptive methods for Data compression of Multi Spectal Scanner Data.

TABLE - I

RANGE OF VALUES OF THE A.C. CO-EFFICIENTS OF HADAMARD TRANSFORM

SEQUENCY NO	LANDSAT IMAGE-1	LANDSAT IMAGE-2	BHASKARA IMAGE-1	BHASKARA IMAGE-2	MURPHY BABY	PORTRAIT OF A BABY	LANDSAT IMAGE-1 OF WEST BENGAL	LANDSAT IMAGE-2 OF WEST BENGAL	LANDSAT IMAGE OF COASTAL AREA	LANDSAT IMAGE-1 OF HIMALAYAS	LANDSAT IMAGE-2 OF HIMALAYAS	AERIAL SURVEY IMAGE
C_2	-20 TO 19	-23 TO 18	-18 TO 14	-15 TO 17	-27 TO 24	-28 TO 26	-13 TO 8	-15 TO 10	-19 TO 14	-13 TO 14	-20 TO 15	-23 TO 20
C_3	-12 TO 12	-12 TO 12	-10 TO 13	-11 TO 13	-14 TO 14	-17 TO 17	-10 TO 6	-11 TO 8	-12 TO 10	-9 TO 10	-13 TO 11	-15 TO 14
C_4	-11 TO 10	-11 TO 10	-11 TO 9	-11 TO 11	-18 TO 13	-15 TO 16	-7 TO 3	-8 TO 5	-11 TO 6	-7 TO 6	-9 TO 6	-11 TO +10
C_5	-8 TO 7	-6 TO 6	-11 TO 5	-6 TO 5	-9 TO 6	-9 TO 9	-7 TO 2	-7 TO 4	-7 TO 5	-5 TO 5	-6 TO 4	-9 TO 9
C_6	-7 TO 6	-7 TO 6	-5 TO 6	-10 TO 6	-8 TO 7	-8 TO 9	-6 TO 2	-7 TO 3	-7 TO 2	-6 TO 4	-7 TO 4	-9 TO 9
C_7	-6 TO 6	-6 TO 5	-5 TO 5	-5 TO 5	-7 TO 7	-7 TO 8	-6 TO 2	-7 TO 3	-7 TO 5	-5 TO 6	-7 TO 7	-9 TO 7
C_8	-5 TO 5	-5 TO 4	-6 TO 5	-4 TO 4	-6 TO 6	-6 TO 6	-4 TO 0	-4 TO 1	-5 TO 1	-3 TO 2	-4 TO 2	-7 TO +7
C_9	-3 TO 3	-3 TO 3	-2 TO 2	-2 TO 2	-3 TO 2	-3 TO 3	-4 TO 0	-4 TO 1	-5 TO -1	-3 TO 2	-3 TO 2	-4 TO +4
C_{10}	-3 TO 3	-3 TO 3	-4 TO 2	-2 TO 2	-2 TO 2	-3 TO 3	-4 TO 0	-4 TO 1	-5 TO 2	-3 TO 2	-3 TO 2	-4 TO 5
C_{11}	-3 TO 3	-3 TO 3	-3 TO 2	-3 TO 3	-2 TO 3	-4 TO 3	-4 TO 0	-4 TO 1	-5 TO 1	-3 TO 2	-5 TO 2	-4 TO +5
C_{12}	-3 TO 3	-3 TO 3	-3 TO 3	-2 TO 4	-3 TO 3	-4 TO 0	-4 TO 0	-4 TO 1	-5 TO 2	-3 TO 2	-5 TO 2	-4 TO +4
C_{13}	-3 TO 3	-3 TO 3	-4 TO 2	-3 TO 3	-5 TO 3	-4 TO 4	-4 TO 0	-4 TO 1	-5 TO 2	-3 TO 2	-5 TO 3	-4 TO +4
C_{14}	-3 TO 3	-3 TO 3	-3 TO 3	-4 TO 2	-4 TO 3	-4 TO 4	-4 TO 0	-4 TO 1	-5 TO 2	-3 TO 2	-5 TO 3	-4 TO +4
C_{15}	-3 TO 3	-2 TO 2	-2 TO 3	-2 TO 3	-4 TO 3	-4 TO 4	-4 TO 0	-4 TO 1	-5 TO 2	-3 TO 2	-5 TO 3	-4 TO +4
C_{16}	-2 TO 2	-2 TO 2	-2 TO 2	-2 TO 2	-3 TO 3	-3 TO 3	-4 TO 0	-4 TO 1	-5 TO 2	-3 TO 2	-5 TO 2	-3 TO +3

TABLE. II QUANTIZER FOR C2

Input		Mean Output
-28	to -63	-32
-19	to -27	-23
-10	to -18	-14
- 2	to -9	-5
-1	to +1	0
2	to 10	5
11	to 20	16
21	to 63	26

TABLE. III QUANTIZER FOR C3/C4

Input		Mean Output
-15	to -63	-17
-10	to -14	-12
-6	to -10	-8
-2	to -5	-3
-1	to +1	0
2	to 5	3
6	to 10	8
11	to 63	13

TABLE. IV QUANTIZER FOR C5/C6/C7

Input		Mean Output
-7	to -63	-9
-2	to -6	-4
-1	to +2	0
3	to 63	5

TABLE. V QUANTIZER FOR C8/C9

Input		Mean Output
-4	to -63	-4
-2	to -3	-2
-1	to +2	0
3	to 63	4

TABLE. VI

No.of bits/block before compression	No. of bits/block after compression		
7 bits/pixel x 16	C1	-	5
	C2	-	3
= 112 bits	C3	-	3
	C4	-	3
	C5	-	2
	C6	-	2
	C7	-	2
	C8	-	2
	C9	-	2
	C10 to C16	-	0
		=	24 bits
Compression ratio	112/24 = 4.67		

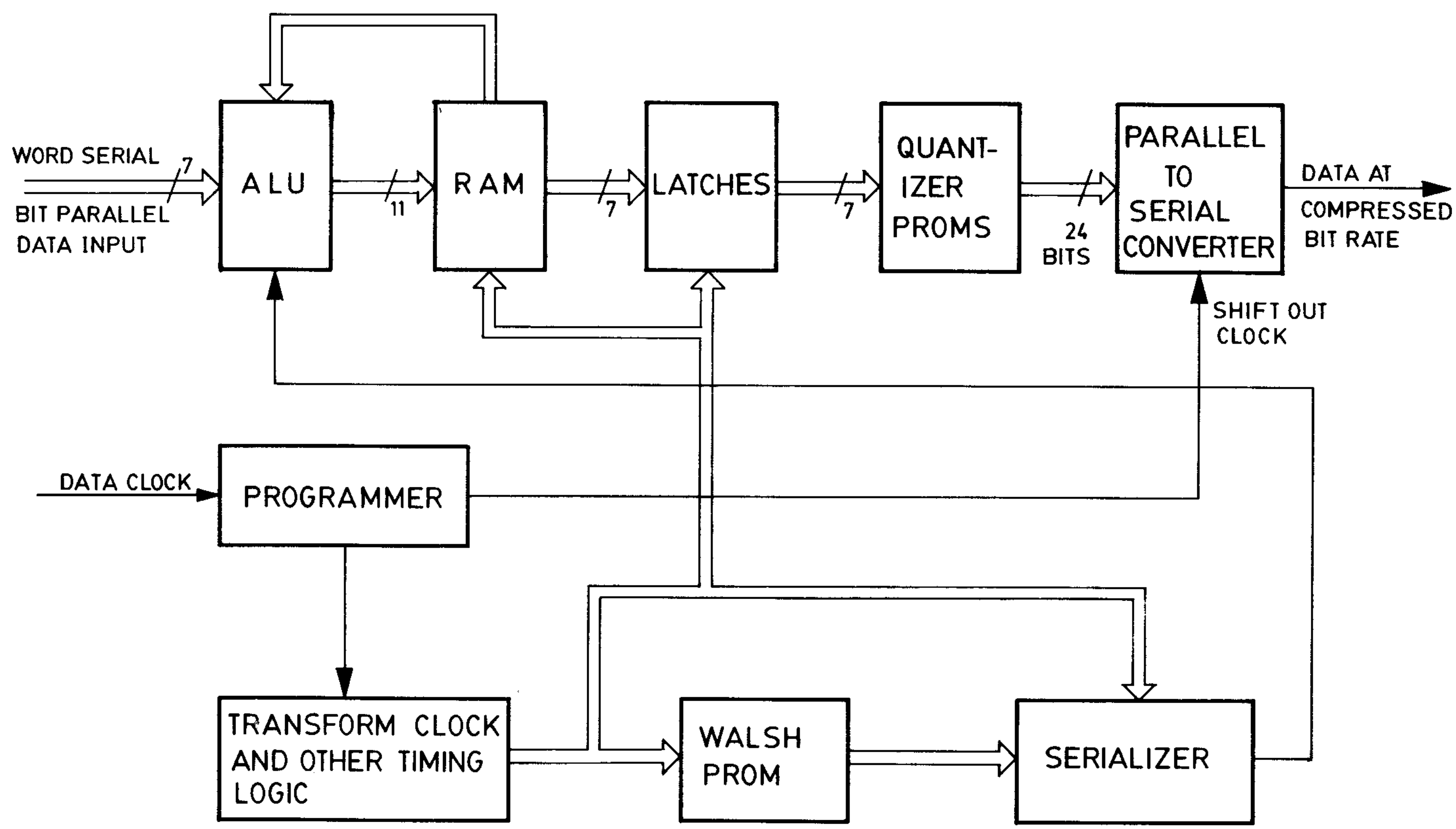

Fig.1, Block Diagram of the Data Compression Encoder.

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ISRO SATELLITE CENTRE
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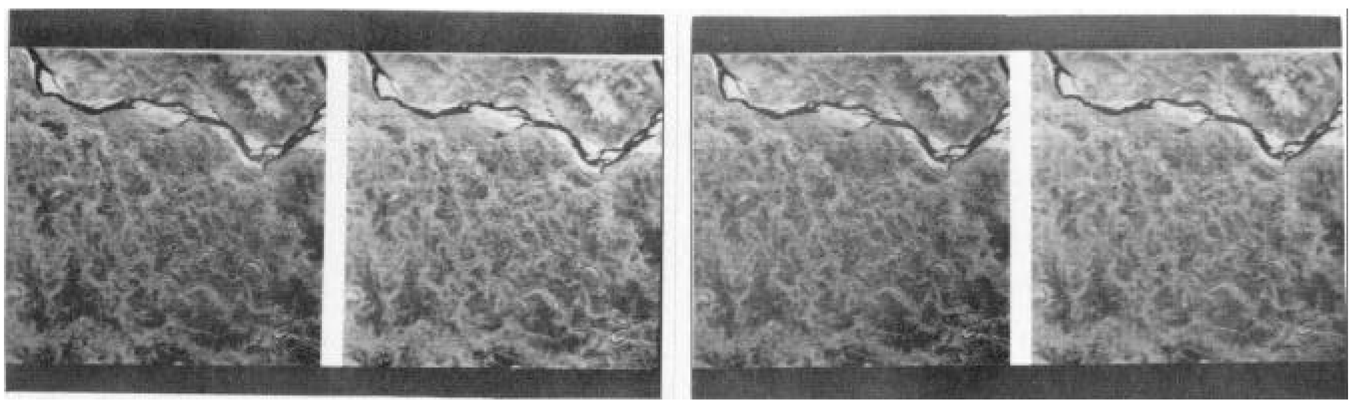
FIGURE No
REPORT No

APPENDIX

ORIGINAL RECONSTRUCTED ORIGINAL RECONSTRUCTED

2 BITS/PIXEL 1.5 BITS/PIXEL

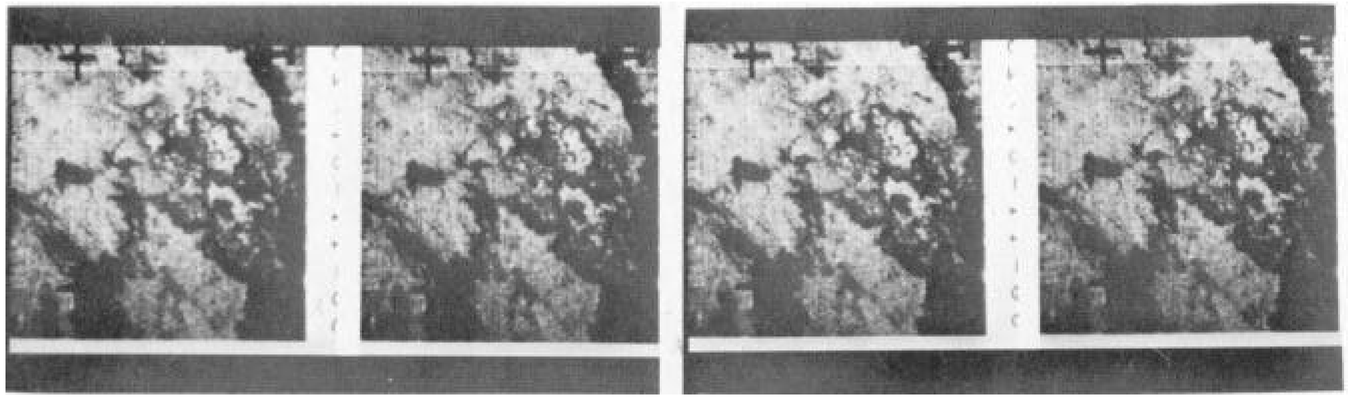
AERIAL IMAGE



ORIGINAL RECONSTRUCTED ORIGINAL RECONSTRUCTED

2 BITS/PIXEL 1.5 BITS/PIXEL

LANDSAT IMAGE



ORIGINAL RECONSTRUCTED ORIGINAL RECONSTRUCTED
2 BITS/PIXEL 1.5 BITS/PIXEL
BHASKARA IMAGE

ORIGINAL RECONSTRUCTED ORIGINAL RECONSTRUCTED
2 BITS/PIXEL 1.5 BITS/PIXEL
MURPHY BABY IMAGE