T.V. DATA COMPRESSION BY A DECAYING SLOPE THRESHOLD METHOD

by

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I. INTRODUCTION

This paper describes a method of data compression in which the incoming data stream is examined and certain of its samples are chosen for transmission over the telemetry system.‡ The particular method for choosing these samples is based upon time-varying thresholds on the slope of the data stream and is described in Section II below. The data compression obtained by this method is illustrated for the case of one of the Ranger photographs in Section III, and indicates that net compression ratios of 3 or 4 to 1 are achievable with little or no degradation.

For our purposes, we define data compression as the mapping of one function (the input data stream) into a second function (the transmitted or telemetered stream). The ratio of the transmission rate for the uncompressed first function to the rate for the compressed second function is referred to as the compression ratio. This mapping may or may not be information preserving.

II. THE SLOPE THRESHOLD METHOD

We assume that the input data stream has been sampled in time creating a raw data sequence. This need not be the case, however, and the method will also work with data in continuous time (in which case the first derivative is tested instead of the first difference).

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‡Some of the material presented here was reported by the author in "Data Compression Techniques: TV Data Compression by the Slope Threshold Method," Jet Propulsion Laboratory Space Programs Summary, 37-49, Vol. III, pp. 325-328, February 29, 1968.

The principle of slope threshold compression is to test the slope (first difference) of a raw data stream and compare it to a symmetric pair of exponentially decreasing thresholds. When either threshold is exceeded, the data is sampled and transmitted; the thresholds are then reset and the test begins again, as follows:

Let $\{f_n\}$ = raw data sequence $n=0, \pm1, \pm2, \ldots$

$\Delta f_n = f_n - f_{n-1}$ = first difference

n_m = index of the m^{th} transmitted sample

When the m^{th} sample has already been transmitted and the search for the $m+1^{st}$ sample is in progress, the upper and lower thresholds $T_U(n)$ and $T_L(n)$, are (for $a \geq 0$, $b \geq 0$)

$$T_U(n) = \Delta f_{n_m+1} + a \exp - b(n - n_m - 1)$$
$$T_L(n) = \Delta f_{n_m+1} - a \exp - b(n - n_m - 1) \qquad (1)$$

Thus, when

$$\Delta f_n - T_U(n) \geq 0$$

or when $\qquad (2)$

$$\Delta f_n - T_L(n) \leq 0 ,$$

then f_{n-1} is sampled and n_{m+1} is set equal to $n-1$. The reconstructed function is a linear interpolation of these samples. In Figure 1, we give an example of this method of operation. In this example, point 6 is not within the threshold; therefore point 5 would be sampled. Point 7 is not within the threshold therefore point 6 would be sampled. Point 8 is within; therefore point 7 would not be sampled. Point 9 is within; therefore point 8 would not be sampled. Point 10 is not within, therefore point 9 would be sampled. Thus those points surrounded by squares form the transmitted sequence.

One might inquire as to the form of the threshold placed on $\{f_n\}$ by this slope threshold method. The answer is given by summing the functions $T_U(n)$ and $T_L(n)$. This gives a pair of thresholds which begin at the value f_{n_m} and change exponentially (with time constant $1/b$) toward limiting values

$$f_{n_m} + (n - n_m)\Delta f_{n_m+1} \pm \frac{a}{1-e^{-b}} \quad (3)$$

assuming $n_m \ll n < n_{m+1}$. Note for the case b=0 that the thresholds (3) diverge. It is clear that a sufficient condition for a sample to be transmitted is that f_n fall outside the thresholds (3); however this is not a necessary condition. Clearly the slope threshold conditions (2) can be violated (creating a transmitted sample) without violating function thresholds (3). This characteristic is different from many other data compression methods and makes the slope threshold method unique. In particular, large amplitude changes with large first differences (or first derivatives) will create a transmitted sample in almost any data compression scheme; however, and this is critical, in the slope threshold method large derivative changes (even with small amplitude changes) are detected and create transmitted samples. Very often signal variations of the latter type are just those in which one is interested.

One of the principal features of this method is that its implementation is extremely simple. Figure 2 shows a diagram illustrative of one possible method of implementation.

III. EXPERIMENTAL RESULTS

Some Ranger photos quantized to 6 bits were used as the raw data and processed by the Jet Propulsion Laboratory Spacecraft and Command Section. The photo was a 200 x 200 raster of 6 bit samples. Some results of the slope threshold method (implemented digitally) are shown in Figures 3a-f; Figure 3a is uncompressed. The order of the figures is that of increasing RMS error. Various schemes exist to transmit the timing information n_m; a penalty of approximately 50% in gross compression ratio can be achieved by an efficient run-length coding scheme for $n_{m+1}-n_m$. Picture #26 in Figure 3c has a gross compression ratio of 3.65 to 1. No difference is apparent to an untrained observer between Figures 3a and 3c. Picture #25 in Figure 3d has a gross compression ratio of 5.95 to 1. Only a slight difference can be observed between Figures 3a and 3d.

Because of the ease of implementation both at transmitter and receiver, the slope threshold method is ideal for TV compression.

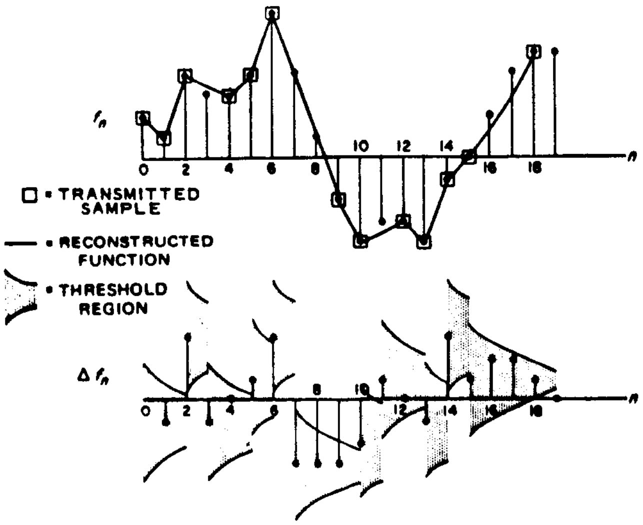
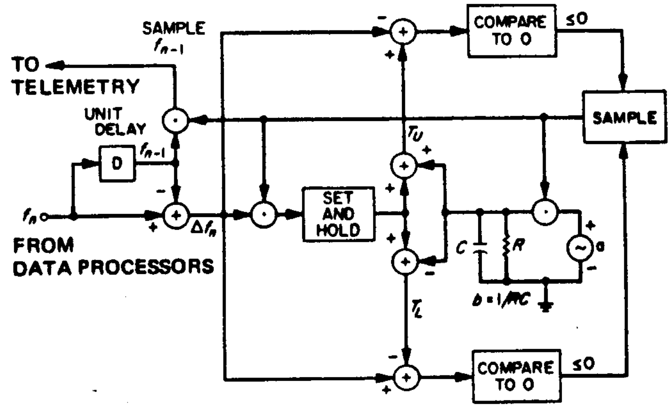


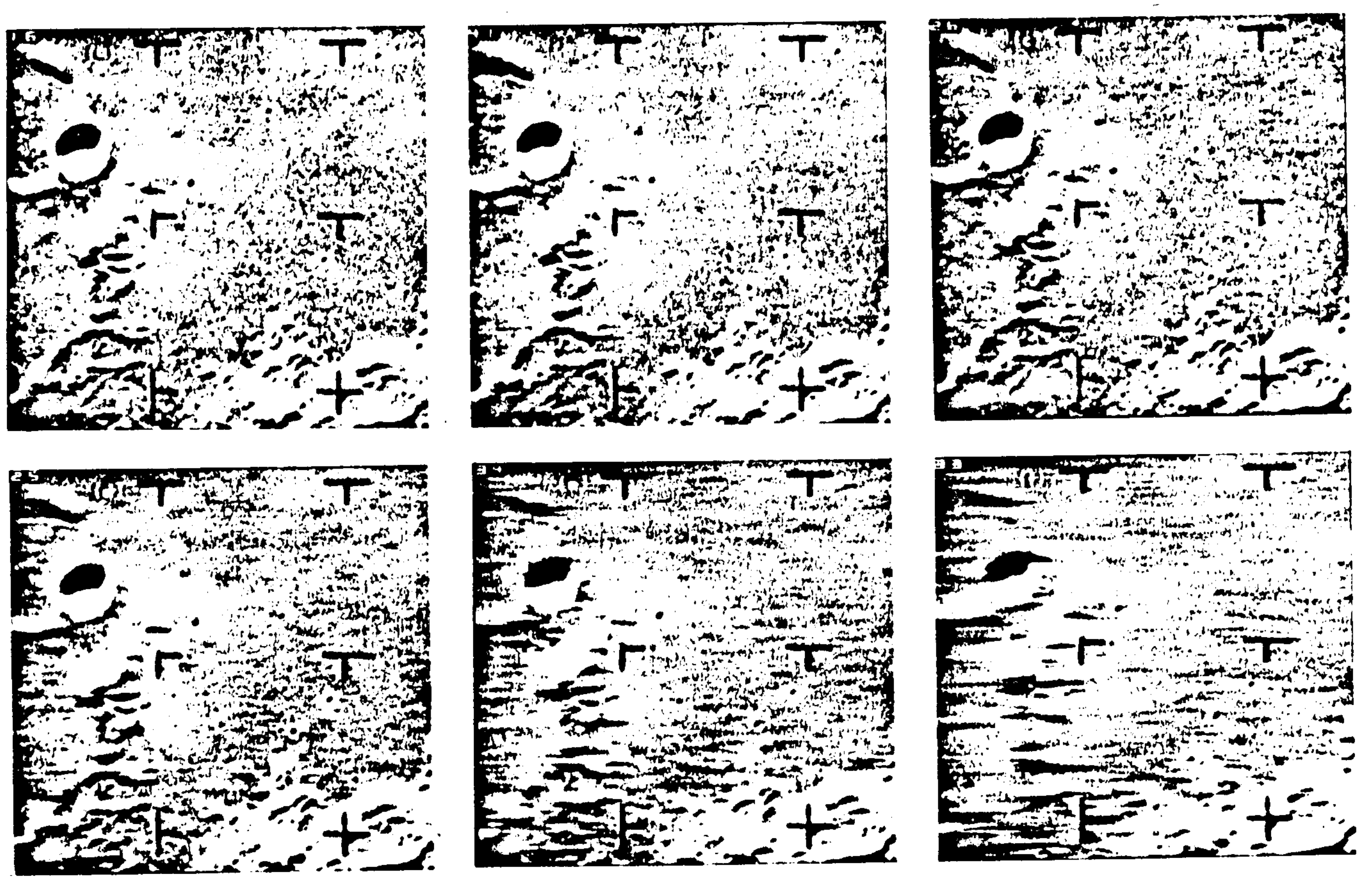
Illustration of the Slope Threshold Method for Data Compression

FIGURE 1



Proposed Implementation of Slope Threshold Method

FIGURE 2



Progression of Increasing RMS Error (a) raw data, picture 16, (b) picture 41, (c) picture 26, (d) picture 25, (e) picture 34, (f) picture 33

FIGURE 3

Picture No.	a	b	RMS error	Gross compression ratio
16	1	0.05	0	1
41	4	0.05	1.139	2.54
26	6	0.1	1.555	3.65
25	9	0.1	2.230	5.95
34	10	0.05	2.909	8.5
33	15	0.05	3.78	13.18