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Hybrid Technique for Image Compression Using SPIHT and BCH Codes

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ABSTRACT: Due to the rapid development of multimedia and digital imaging, a high quantity of data is required to represent the modern imagery. This requires lots of disk space and long time for transmission. The objective of this paper is to implement hybrid techniques for image compression by combining SPIHT algorithm with Huffman and BCH coding techniques. SPIHT (set partitioning in hierarchical trees) is computationally very fast and best algorithm that is based on the idea of coding groups of wavelet coefficients as zero trees. Huffman coding is an entropy coding technique which is used for further compression and BCH coding technique is error detection and correction algorithm which is used for lossless compression. In this, we implemented SPIHT algorithm, SPIHT combined with Huffman coding and SPIHT combined with BCH coding separately on different images. This shows that combining SPIHT with either Huffman or BCH coding improves the efficiency of SPIHT algorithm. Results shows that combination of SPIHT and BCH coding results in lossless compression by achieving high PSNR values at extremely lower bitrates compared to classical SPIHT and SPIHT combined with Huffman coding.

KEYWORDS: Hybrid technique; image compression; SPIHT; Huffman coding; BCH codes; high PSNR

I. INTRODUCTION

Digital image compression addresses the problem of reducing the total number of bits required for an image. Usually, images contain pixels with various types of redundancies and compression can be achieved by eliminating the redundancies. In general three types of redundancies exist in digital images that fallow,

Psycho-visual redundancy: corresponds to different sensitivities to all signals by human eyes
Inter-pixel redundancy: corresponds to statistical dependencies among neighbouring pixels
Coding redundancy: uses some variable length coding techniques to achieve compression

Image compression techniques can be classified as Lossy and Lossless, in lossless compression the reconstructed image after compression is identical to the original image. Whereas in lossy compression, the reconstructed image losses the significant data compared to the original image. However lossless compression only achieves a modest amount of compression and lossy compression is capable of achieving much higher compression. A typical compression system consists of source encoder, quantizer and entropy encoder, compression is accomplished by applying a linear transform to decorrelate the image data, quantizing the resulting transform coefficients, and entropy coding the transformed values. The transform used in the compression technique is wavelet transform as it is mostly concentrate onth signals that had abrupt changes compared to the fourier transform. One of the most important characteristics of Discrete wavelet transform(DWT) is wavelet decomposition. Any image that is decomposed by wavelet transform can be reconstructed with desired resolution. In compression the original image is first transformed in to wavelet domain using the pyramidal decomposition up to certain level. In this technique SPIHT(set partitioning in hierarchical trees) is used for compression in which the image undergo pyramidal decomposition using Wavelet transform before the SPIHT coding stage.

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II. RELATED WORK

It is known that image compression includes some major stages which are transforming the image and entropy encoding to reduce the irrelevant data[1]. So, to achieve the lossless compression by combining two techniques it is necessary to choose best techniques among already existed techniques[2]. Many techniques have been studied and their advantages and drawbacks are analysed[6]. Since transforming the image is the major stage in compression all the transforms like DFT, DCT and DWT are studied. Among all the discrete transforms, it is found that Discrete wavelet transform (DWT) has got unique features and it is best for compression[3]. So wavelet based image compression techniques like EZW and SPIHT are studied and analysed[8]. Compared to EZW, SPIHT has more advantages and it can be used for lossless compression[1]. Thus SPIHT[7] is selected as one of the techniques in the implemented hybrid technique[7].

For further compression SPIHT is to be combined with any other technique[4]. For this entropy coding techniques like Huffman coding, runlength coding and LZW coding have been studied and it is found that these techniques further compresses the image which undergoes SPIHT compression and losses the significant data and results in the lossy compression[5]. BCH coding is an error correcting and detecting algorithm that never losses the significant data and it can be used for further compression. Thus BCH coding is combined with SPIHT compression technique to implement a hybrid technique.

III. SPIHT ALGORITHM

In this section, we describe the SPIHT algorithm and how it encodes the wavelet coefficients. In general, an image which is wavelet decomposed has non uniform distribution of energy within and across sub bands. This is the motivation for us to partition the pixels that are presented in all sub bands LL,LH,HL and HH into different regions depending on their significance and these regions are assigned with different quantization levels. Thus, SPIHT algorithm finds the significant pixels by partitioning them into different sets. SPIHT algorithm consists of three sets LSP list of significant pixels which consists of significant information in the image, LIP list of insignificant pixels which contains the insignificant information and LIS list of Significant sets which contains the child coefficients of the insignificant pixels. Figure1 show the parent-off spring dependencies in a wavelet decomposed image.

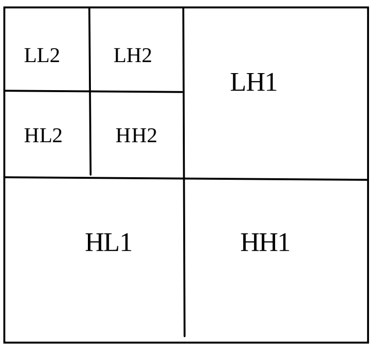

Fig1. Wavelet decomposition

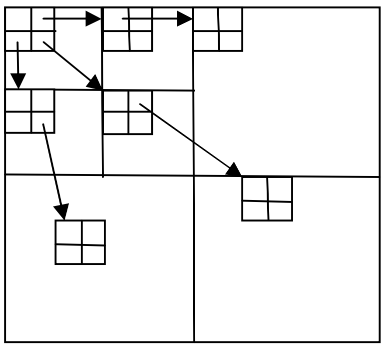

Fig2.parent-offspring dependencies in SOT

64	-34	49	10	7	13	-12	7
-31	23	14	-13	3	4	6	-1
15	14	3	-9	5	-7	3	9
-9	-7	-14	8	4	-2	3	2
-5	9	-1	47	4	6	-2	2
3	0	-3	2	3	-2	0	4
2	-3	6	-4	3	6	3	6
5	11	5	6	0	3	-	4

Fig3.Example 8x8 image

Set partitioning in hierarchical trees (SPIHT) algorithm[7] is an elegant bit plane encoding method and it generates K embedded bit sequence in every stage of quantization. Let $a_{0,}$ $a_{1,}$ ...... a_K denotes the bit sequences of each encoding stage. These sequences are ordered in such a way that the first sequence consists of the most significant bit, second sequence consists of the next most significant bit, and so on. SPIHT algorithm produces a hierarchical quad tree for the wavelet transformed coefficients. A spatial orientation tree (SOT) (see Fig. 2) consists of root nodes and their corresponding decedents. In the spatial orientation tree each node has either no leaves or four offspring coefficients, which are 2 x 2 adjacent pixels as shown in the fig. The LL sub band has pixels with highest

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decomposition level and these are also grouped in 2 x 2 adjacent pixels. However, the upper left pixel in 2 x 2 adjacent pixels (as shown in Fig. 3) has no descendant and the other three pixels has four children.
For the convenience of illustrating the real implementation of SPIHT[7], the following sets of coordinates are defined.

- O(i, j): set of coordinates of all offspring of node (i, j);
- D(i, j): set of coordinates of all descendants of the node (i, j);
- H: set of coordinates of all spatial orientation tree roots (nodes in the highest pyramid level);
- L(i, j)=D(i, j)-O(i, j).

Thus, except at the highest and lowest levels, we have
O(i, j)={(2i, 2j), (2i, 2j+1), (2i+1, 2j), (2i+1, 2j+1)}.
Define the following function,

$$s_n = \begin{cases} 1, & \max\{|C(i,j)|\} \geq 2^n, \\ 0, & \text{otherwise.} \end{cases}$$

A detailed description of the SPIHT coding algorithm is given as follows,
Initially, T(0) is set to be 2^{M-1} , where M is such that, the largest coefficient magnitude in the image, say C_{max} , satisfies $2^{M-1} \leq C_{max} < 2^M$. The encoding is progressive in coefficient magnitude for successively using a sequence of thresholds T(*n*)= $2^{(M-1)-n}$, n=0,1...,M-1. Here, the encoding method is regarded as "bit plane" encoding of the wavelet coefficients because the thresholds are a power of two. At stage n, all coefficients with magnitudes between T(n) and 2T(n) are identified as "significant," and their positions and sign bits are encoded. This process is called as sorting pass. Then, every coefficient with magnitude at least 2T(n) is "refined" by encoding the nth most significant bit. This is called as refinement pass. The encoding of significant coefficient position and the scanning of the significant coefficients for refinement are efficiently accomplished through using the following three lists: the list of significant pixels (LSP), the list of insignificant pixels (LIP) and the list of insignificant set (LIS). Each entry in the LIP and LSP represents an individual pixel which is identified by coordinates (i, j). While in the LIS, each entry represents either the set D(i, j) or L(i, j). An LIS entry is regarded as of type A if it represents D(i, j) and of type B if it represents L(i, j).
The fallowing represents the coding algorithm of SPIHT and is referred from[7].

SPIHT coding algorithm [7]
Step 1: (Initialization)

Output n= $\log_2\{\max(|C_{(i,j)}|)\}$
set the LSP as an empty list,
add the coordinates (i,j) to the LIP,
add the coordinates (i,j) with descendants to the list LIS, as type A entries,

Step 2: (Sorting Pass)

2.1) for each entry (i, j) in the LIP do:
2.1.1) output S_n(i, j);
2.1.2) if S_n (i, j)=1 then move (i, j) to the LSP
and output the sign of $C_{(i,j)}$;
2.2) for each entry (i, j) in the LIS do:
2.2.1) if the entry is of type A then
output S_n(D(i, j)),
if S_n(D(i, j)) = 1 then
for each (k,l) ∈ O(i,j) do:
output S_n(k, l);
if S_n(k, l) = 1 then add (k, l) to the LSP
and output the sign of $C_{(k,l)}$;
if S_n(k, l)=0 then add (k, l) to the end of the LIP;
if L(i,j)≠ 0 then move (i, j) to the

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end of the LIS, as an entry of type B, and go to Step 2.2.2);
otherwise remove entry (i, j) from the LIS;
2.2.2) if the entry is of type B then
output S_n(L(i, j));
if S_n(L(i, j)) = 1 then
add each (k,l) ∈ O(i,j) to the end of
the LIS as an entry of type A;
remove (i,j) from the LIS;

Step 3: (Refinement Pass)
For each entry (i, j) in the LSP, except those included in the last sorting pass (i.e., with the same n),output the nth most significant bit of | ci,j |;

Step 4: (Quantization Step Update)
Decrement n by 1 and go to Step 2.

IV. PROPOSED ALGORITHM

A. SPIHT Combined with BCH or Huffman Coding

Our proposed method is SPIHT combined with BCH coding which can be implemented by using the fallowing block diagram. This represents the implementation of hybrid technique using SPIHT and either Huffman or BCH coding.

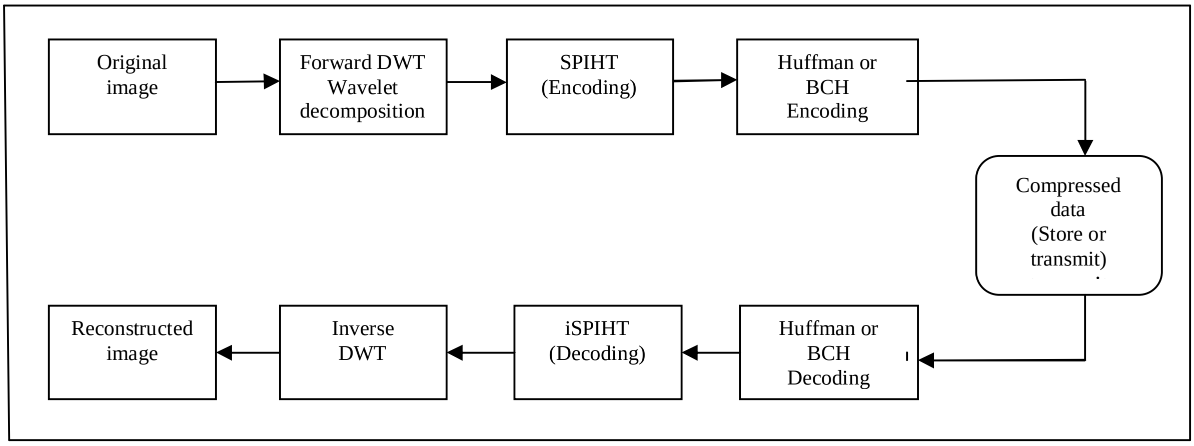

Fig4. Block diagram of proposed method

As shown in the block diagram fig4, the image which is to be compressed is first pre processed and it undergoes wavelet decomposition. After this SPIHT encoding is applied on the image and the coefficients are partitioned into the three lists namely LIS, LIP and LSP. Significant pixels and its corresponding dependencies are found and bit stream will be produced at the output stage of SPIHT. Now, the binary bit stream can be divided into k-bit codes and the codes can be encoded using either Huffman or BCH coding techniques. The encoded data is the compressed data which can be stored or transmitted. The decompression involves the reverse process where the received data is decoded by either Huffman or BCH coding techniques and the codes are obtained. The bit stream will be obtained and the significant coefficients are found using SPIHT decoding and the image will be restored. Here, up to the application of SPIHT on image entire process is same after the SPIHT stage we encode the binary data using Huffman or BCH coding. Let us see how we apply Huffman and BCH coding on SPIHT encoded bit stream separately.

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B. **SPIHT combined with Huffman coding**

As we discussed in the above section, the SPIHT encoded bit stream will be Huffman encoded and can be further compressed. We will understand this with an example illustrated as fallows

Let us take the bit stream obtained from SPIHT stage is
111000111000100000010101100000

Step1:

Bit stream: 111000111001000000010101100000

Step2:

Divide the bit stream into 3-bit binary codes as given below

111 000 111 000 100 000 010 101 100 000

Step3:

The corresponding probability for each code is obtained as,

Since these are 3-bit codes, there will be 8 possibilities and their corresponding probabilities are found.

Step 4:

Probabilities of three bit codes:

3-bit code	Probability
000	0.333
001	0
010	0.111
011	0
100	0.222
101	0.111
110	0
111	0.222

Table1.Probabilities

Step 5:

All 3-bit codes are encoded according to their probabilities in table1, using Huffman encoding,

So that code with high probability will be represented with less number of bits and vice-versa.

Fallowing shows the Huffman encoded bits to the 3-bit codes

3-bit code	Huffman encoded
000	01
001	100000
010	1001
011	100001
100	11
101	101
110	10001
111	00

Table2.Huffman encoded bits

Step6:

Final bit stream after Huffman encoding as shown in table2,S

111 000 111 000 100 000 010 101 100 000 (total 30 bits) is encoded to

00 01 00 01 11 01 1001 101 11 01 (total 23 bits)

Thus we further compressed 30-bit stream to 23 bits using Huffman encoding. Though Huffman encoding further compresses the image and achieves good compression ratio compared to classical SPHIT , this results in lossy compression and the image quality is less compared to the results obtained from the combination of SPIHT and BCH coding that we see in the next section.

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C. HYBRID TECHNIQUE

Algorithm

step1 : Input image (pre processing)
Step2: Forward DWT
(8 –level wavelet decomposition)
Step3: SPIHT algorithm (partitioning of pixels into LSP, LIP and LIS)
Step4: Repeat step3 by decreasing n
Step5: output bit stream is divided into k-bit codes
Step6: Galois field construction
Step7: BCH (n , k) coding

As mentioned above initially the image is preprocessed and forward DWT which is 8-level wavelet decomposition is applied on the original image. In the 3rd step the wavelet decomposed image is subjected to SPIHT encoding. In SPIHT highest coefficient value is taken as 'n' and based on the value of 'n' it partitions the coefficients in to three lists LIS (List of insignificant sets), LIP (List of insignificant pixels) and LSP in which the LSP (list of significant pixels) contains the significant pixels in the wavelet decomposed image. The previous step is repeated by decreasing the value of 'n' so that we may not loss the significant information in the image which results in the lossless compression. This process gives us bit stream which is further subjected to BCH coding.

Message	Code vector
0000	0000000
1000	1101000
0100	0110100
1100	1011100
0010	0011010
1010	1110010
0110	0101110
1110	1000110
0001	0001101
1001	1100101
0101	0111001
1101	1010001
0011	0010111
1011	1001011
0111	0100011
1111	1111111

Table3. BCH codes

In this method we apply BCH coding in two ways, in the first method we divide the entire bit stream in to k-bit codes and we directly apply BCH (n,k) encoding to get n bit codes. We can take any value of 'n' and 'k' from standard values and here for simplicity purpose we take (7,4) coding. Here, we encode the 4- bit codes to 7-bit codes as shown in the table3 which contains the encoded 7-bit codes for all the possible 4-bit codes. This method results in lossless compression by maintaining the same compression ratio as classical SPIHT gives.

In the second method we apply BCH decoding in the compression and BCH encoding in the Decompression here also we apply same (7, 4) coding. Here, we divide the bit stream into 7-bit codes and we check each and every code whether it is a valid codeword or not from the above table3. If it is found valid, then we decode the codeword into 4-bit code if not we remain the 7-bit code as it is as shown in fig5. Thus valid code words are decoded to 4-bit codes at the compression stage and it will be encoded to 7-bit code at the decompression stage. This method achieves more compression ratio compared to the classical SPIHT and SPIHT combined with Huffman encoding without losing the significant bits and results in lossless compression.

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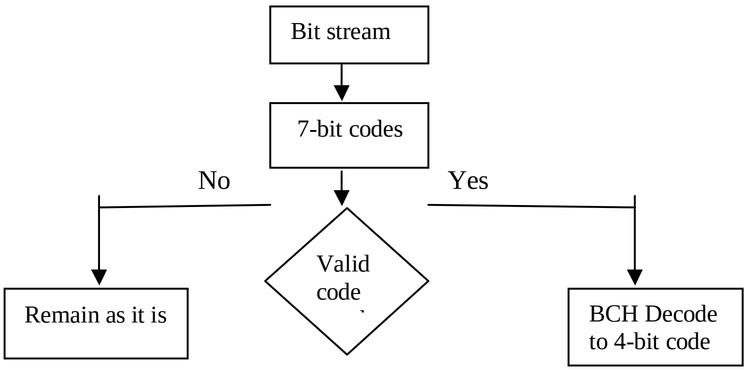

Fig5.BCH coding of SPIHT bit stream

V. Simulation Results

In this section we represent the MATLAB simulation results of the implemented methods. The compression methods SPIHT, SPIHT combined with Huffman and SPIHT combined with BCH coding are applied on a set of three images which are cameraman, Barbara and lena. Each image is subjected to three compression techniques so for the three images, the PSNR values of all the reconstructed images are noted. With the obtained values of PSNR and BPP we represent compression performance (PSNR vs BPP) of the three techniques with a bar diagram. From the obtained results, it is clearly noticed that the reconstructed images using SPIHT are blurred with less PSNR values. The reconstructed images using the combination of SPIHT and Huffman coding improves the quality of the images with high PSNR values. With our proposed method SPIHT combined with BCH coding, the reconstructed images are almost similar to original images and achieved higher PSNR values at lower bit rates compared to the previous methods. A tabular form showing the PSNR values of the images with the three techniques is mentioned below in table4. The comparison of the three techniques is shown in the bar diagram in fig.6. Here we represent the simulation results of the image cameraman in fig.5. As mentioned in the fig.5, first image is the original cameraman image and the rest three are the reconstructed images of SPIHT, SPIHT combined with Huffman and SPIHT combined with BCH(hybrid technique). It is clear from the images that the reconstructed image of hybrid technique is similar to the original image.

Image	**BPP**	**PSNR dB**		
		SPIHT	SPIHT combined with Huffman coding	SPIHT combined with BCH coding
Cameraman	0.25	24.8	32.88	35.58
Lena	0.5	25.72	33.68	36.82
Barbara	0.8	30.62	36.67	38.43

Table4. PSNR values of three techniques

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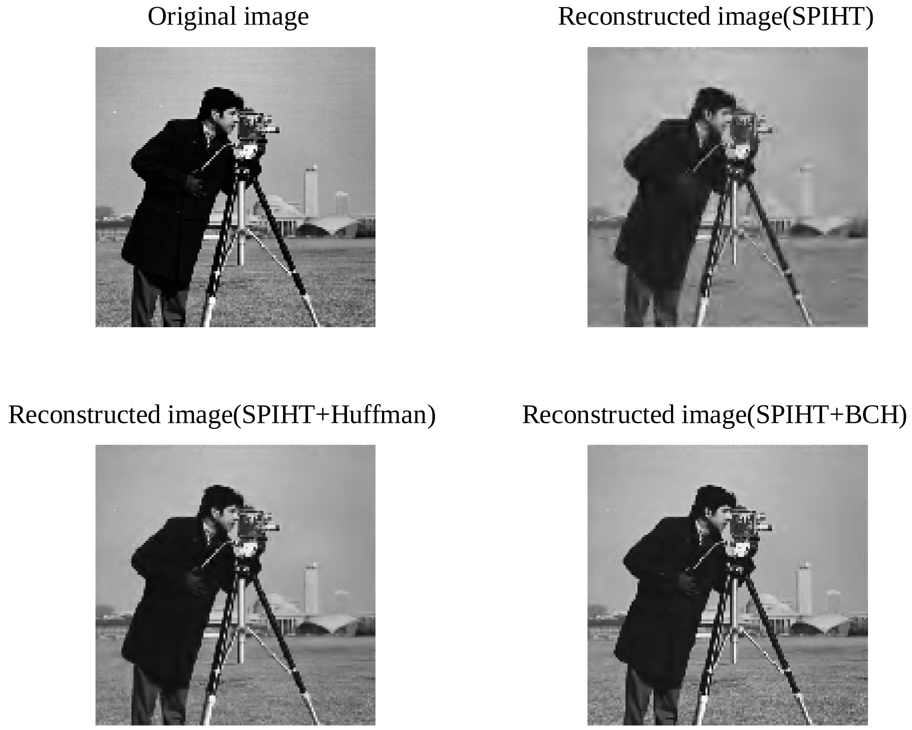

Fig5. simulation results of cameraman image

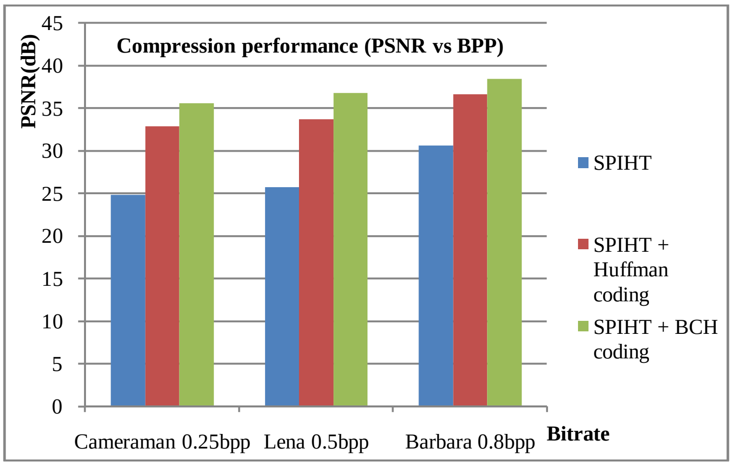

Fig6. Comparison of Compression performance of the three techniques

VI. Conclusion and Future Work

A Hybrid technique for image compression is developed and the combination of SPIHT (set partitioning in hierarchical trees) with different coding techniques namely Huffman and BCH coding is implemented successfully using matlab software. From results, it can be concluded that combining SPIHT with either Huffman or BCH coding improves the efficiency of SPIHT algorithm. Our proposed method SPIHT combined with BCH coding achieves high

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PSNR values at lower bit rates when compared to classical SPIHT and SPIHT compared with Huffman coding. As a future work to this, we can combine SPIHT with joint BCH and Huffman coding i.e, after BCH coding we use Huffman coding for further compression but we should keep compression time in mind or we can change the techniques and combine other techniques with any standard compression technique like SPIHT. These techniques give us better results for images so extending this work to video compression will also be very interesting.

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