Poster Presentation on "The Compression Effects of the Binary Tree Overlapping Method on Digital Imagery "

Mayank Patidar

Department of Electronics and communication engineering, IIITN

Abstract

This poster describes a new method of digital image compression called binary tree overlapping. With this method, an image is divided into bit planes that are transformed into a binary tree representation in which initial identical portions of different lines in the bit planes are transmitted as one path in the tree. To increase compression, distortion can be introduced by considering two lines which differ in less than a preset number of bit positions to be identical. A time efficient method of implementing binary tree overlapping based on a communication technique called content-induced transaction overlap is outlined.

Introduction

An efficient image compression technique is essential for data storage and transmission. Binary Tree Overlapping (BTO) harnesses the power of binary trees. Binary tree is a hierarchical structures with at most two children per node. BTO strike the balance between image quality and data reduction by reducing data redundancy. An image is divided into bit planes, each of which contains horizontal lines of bits. It can be applied to a sequence of video images as well as one still image.

Binary Tree Representation and Distortion Technique

The idea is to represent a collection of frame lines by a binary tree in which each frame line to be transmitted is a path from the root to a leaf. A left branch in the tree can represent a 0 in the line and a right branch can represent a 1. The portion of a line which is transmitted is called a fragment. An image is restored from the binary tree by reconstructing the lines based on the paths from the root to a leaf. The time required to perform binary tree overlapping with mismatch tolerance on a computer is proportional to $l \cdot n^2$, where l is the line length and n is the number of lines. It is much faster when implemented with a special purpose device which performs a process similar to content-induced transaction overlap (CITO), an approach to multiaccess communications in which control is induced by the messages' contents.

Lines with Tags

011011 00
011000 01
011011 10
011001 11

Binary Tree Representation

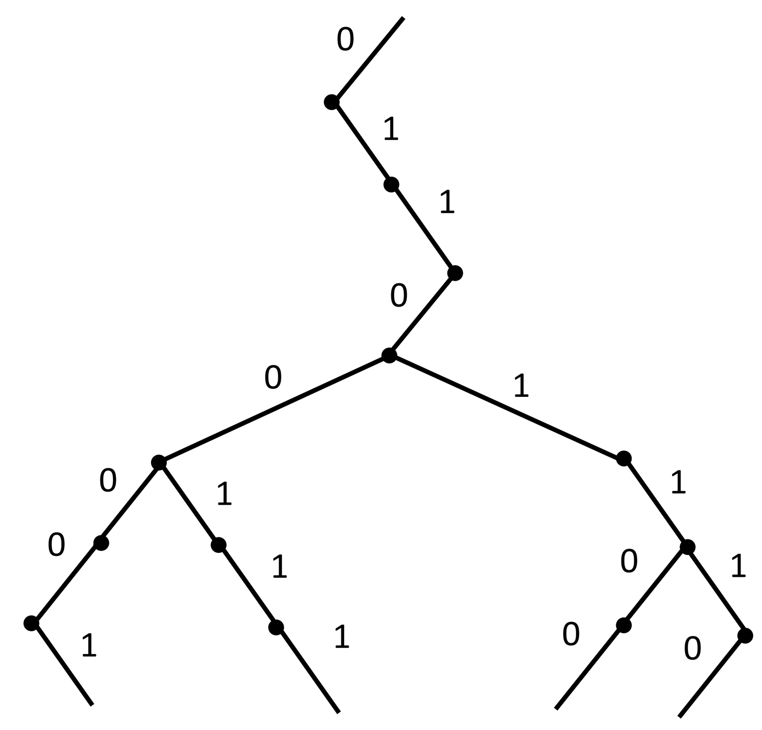

Figure 1. Example of binary tree representation and transformation.

Sent

01100001 010 11 011 100 001 0
bc bc bc

Reconstructed

$$\begin{matrix} 0&1&1&0&0&0&0&1 \\ 0&1&1&0&0&1'&1&1 \\ 0&1&1&0&1'&1&0&0 \\ 0&1&1&0&1&1&1'&0 \end{matrix}$$

(1 ' is nol transmitled because there must be a 1 afler a bifurcation point.)

Original length $= 24$

Compressed length $= 23$

Compression ralio $= 1.04$

Theoratical expression for compressed ratio

A simple approximated compression ratio expression is given by:

$$k = \frac{l}{a + \log l} \tag{1}$$

Where: k = compression ratio, a = average fragment length and l = length of tag

Maximum compression is achieved if a approaches zero and is given by:

$$k_{\text{max}} = \frac{l}{\log l} \tag{2}$$

For example, for a 256 by 256 image, $k_{\text{max}} \approx 30$.

Hardware Implementation of BTO

Hardware implementation of BTO is based on the content-induced transaction overlap (CITO) communications technique.

- **Loading Frames**: Describes loading frame into special memory (bit serial associative memory) that can look at one piece at a time.

- **Super Quick**: This implementation is a specific type of associative processor and has an advantage of fast operation.

- **CITO Device**: Introduces a device called CITO with two parts for pictures and tracking.

- **Finding the Right Spot**: Explains how the device finds the right places in pictures to prevent mix-ups.

- **Sorting Out Problems**: Describes how the device fixes mix-ups and keeps track of them.

- **Starting Over**: Discusses the device's ability to begin fresh and keep track of new pictures.

The time T required for this algorithm is:

$$T = (n + l)a + (n - l)b \approx n(a + \log(l + \log n)) \tag{3}$$

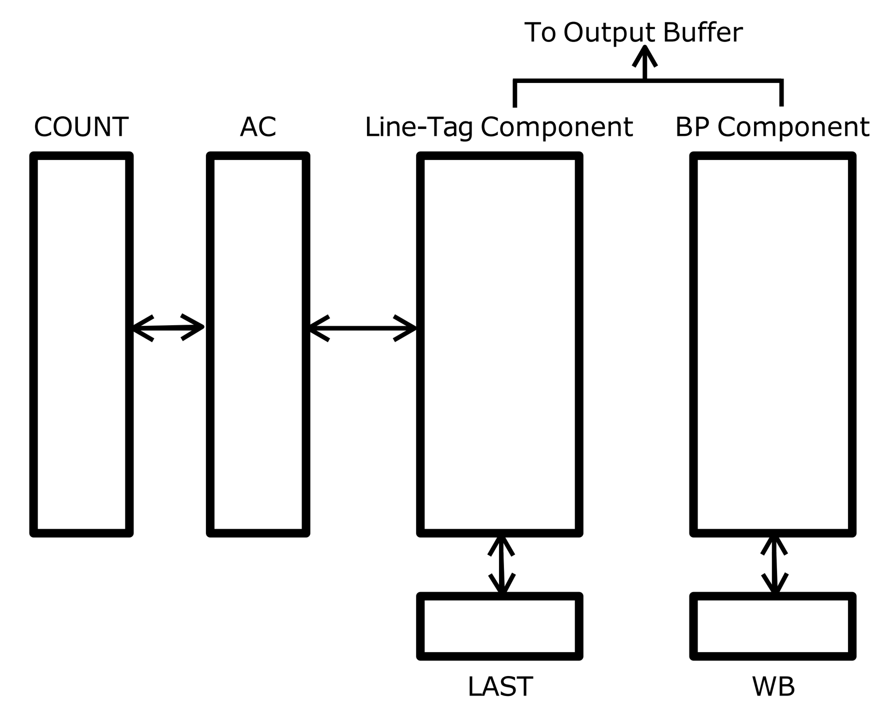

Figure 2. An individual CITO device.

Error control

If a bit changes from 0 to 1 or vice versa in a fragment, this bit will be incorrect in all lines which are constructed from fragments that bifurcate from the same path after the error.

- Error Types: - Two types of errors: fragment and bit competition errors.
- Fragment Error: - Alters pixel values in a portion of the image due to bit changes within a fragment.
- Bit Competition Error: - Can disrupt synchronization and alignment of subsequent fragments.
- Error Control: - Three techniques: run length encoding, error control coding, and forced updating.
- Synchronization: - Special codes manage synchronization and indicate the end of the tree.
- Run-Length Coding: - Shifts lines in the image but is corrected by forced updating.

Important Point

Scan QR code for Research Paper

Simulation Studies

While BTO is distortionless, compression can be increased by introducing mismatch tolerance. Simulation studies show that substantial compression without excessive distortion can be achieved by varying the level of mismatch tolerance with bit plane. Bit plane analysis was also performed to determine the effects of each bit plane on compression. An excellent quality image is produced with a compression ratio of 2, a good image with a ratio of about 3 and a fair image with the ratio of about 4. In terms of its implementation and compression efficiencies, BTO is comparable to first-order DPCM.

Table 1. Compression Results for Different Bitplanes

bitplane	entropy	simple compression ratio	compression ratio using r.l.e.
1	.970	.967	.568
2	.990	.966	.523
3	.987	.967	.547
4	.946	.947	.643
5	.808	1.000	.870
6	.590	.1.123	1.350
7	.319	1.514	2.349
8	.137	2.904	4.454

The graph demonstrating the efficiency of Binary Tree Overlapping (BTO) in achieving high compression rates while retaining image quality, as indicated by low Normalized Mean Square Error (NMSE) values. This observation positions BTO as an optimal choice for applications where efficient data compression is essential without compromising image quality.

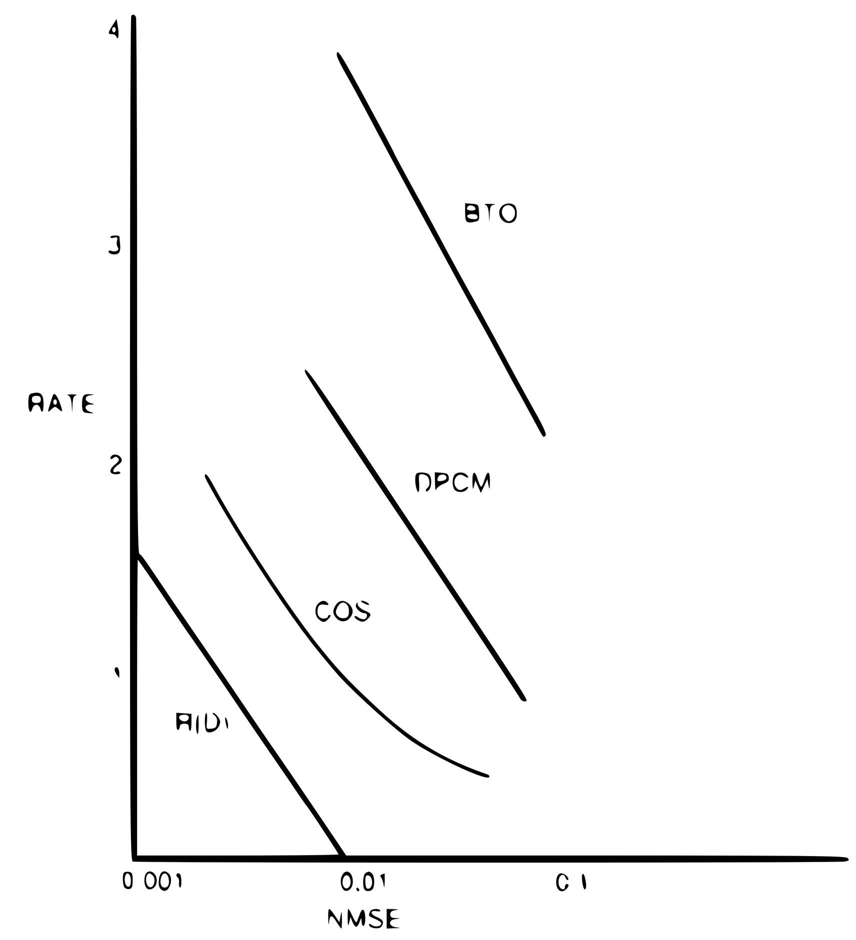

Figure 3. Bit rate versus normalized mean square error.

Conclusions

Binary tree overlapping using the CITO associative processing technique is time efficient: only logical operations are required and the number of operations is proportional to the number of bits in the compressed image. The hardware consists of a bit-serial associative processor and an output buffer. Error control techniques can effectively be used to decrease the chance of error and arrest its propagation without substantially reducing compression.

Acknowledgments

The author is extremely grateful to Dr. Tapan Jain and the department of ECE, IIITN for sharing their knowledge, valuables ideas, and guidance which are immensely helpful in various stages of this work.

References

L.J. Dimento and S.Y. Berkovich, "The Compression Effects of the Binary Tree Overlapping Method on Digital Imagery," in IEEE Transactions on Communications, vol. 38, no. 8, August 1990.