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A Survey on FPGA Implementation of SPIHT Algorithm for Image Compression

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***Abstract*— Set partitioning in hierarchal trees (SPIHT) is a very widely used compression algorithm for wavelet transformed images. A better attention has received by SPIHT algorithm ever since its introduction in 1996 for image compression among most algorithms. Though SPIHT is much efficient and simpler than many existing compression techniques as it's a fully embedded codec, provides high PSNR, good image quality, efficient combination with error protection, sort information on demand, optimized for progressive image transmission and so requirement of powerful error correction decreases from beginning to end but still it has some drawbacks which need to be removed for its better use so since its evolution it has undergone many changes in its original version. This paper presents a survey on SPIHT and implementation of SPIHT algorithm.**

***Index Terms*- Image Compression, SPIHT, DWT, EZW.**

I. INTRODUCTION

A 'Set Partitioning in Hierarchical Trees' (SPIHT) algorithm as a throughput efficient FPGA implementation for images compression. The SPIHT suited for both colour images and gray images. The basic SPIHT was modified in two ways by FPGA implementation, one by interchanging the refinement passes and the other by using static mappings. As SPIHT algorithm is wavelet based, the discrete wavelet transform plays an important role in this algorithm. [1] Amir Said et al proposed an alternative to computationally simple and most effective technique for compression of image because of this an excellent performance can be achieved. [2] The aim was partial ordering by magnitude with set partitioning, profiteering of self-similarity within an image wavelet transform and apply for bit plane transmission. Also proposed different and new implementation based on SPIHT, which can give excellent throughput than EZW and other compression processes. This implementation is latest one and provides higher performance than EZW coding.

T. Vijayakumar et al proposed high speed DWT and pipelined SPIHT technique, implemented on FPGA that fulfil the trade-off between area and speed complexity of image compression techniques. [3] The pipelined architecture of SPIHT algorithm and DWT computation using matrix multiplication is performed. The DWT overcomes area and pipelined SPIHT provides higher performance and speed. On the Virtex-5 FPGA, SPIHT along with DWT requires less than 5% of resources. Alvin W. Y. SU proposed straight forward modified SPIHT coding procedure that requires no tables, Because of this SPIHT becomes perfect algorithm for high performance, low cost hardware implementation. [4] The modified SPIHT include easy process for coefficient scanning, 1-D addressing method rather than the 2-D wavelet coefficient, also rather than use of dynamic memory allocation it uses fixed memory allocation. This modification facilitates an extremely high performance and simple hardware implementation on the cost of slightly higher distortion. In this modified SPIHT rate control is easy also no need of look-up table. Well suitable for many embedded applications. Miranda Mathews proposed a real time image compression using SPIHT algorithm by VLSI architecture with arithmetic coder. [5] The proposed work described SPIHT without list for VLSI implementation which uses breadth first search method (BFS). A high speed arithmetic coder architecture design with SPIHT was used to gain high performance. For verifying the result matlab simulation is used. The higher PSNR achieved by the use of SPIHT along with arithmetic coder, also decreases the time requirement, and provides a more efficiency.

II. DISCRETE WAVELET TRANSFORM

In functional analysis and numerical analysis, a discrete wavelet transform (DWT) is wavelet transform for which the wavelets are discretely sampled. As with other wavelet transforms, a main advantage of this transform has over Fourier transforms is temporal resolution: it captures both location information and frequency. The SPIHT encoding techniques and wavelet filters used in medical compression images. [6] The hardware realization for medical image compression with trade-off in area, power and time, requires quantizing of wavelet coefficients and analysis of its effect on reconstruction process. This modified algorithm is implemented along with HDL, 1D and 2D DWT processor on FPGA. The realization decreases the number of computation to half by exploiting the similar properties as the DWT processor implemented using a modified algorithm. The result presents that the hardware design and software model are perfectly matches so that there is no any loss and hence well suited for loss less compression in medical image. The basic idea of the wavelet transform is to represent any arbitrary function as a superposition of a set of such wavelets as basis function. These basis functions are baby wavelets and resulted from a single prototype wavelet called the mother wavelet, by dilations and translations (shifts) or contractions (scaling). Calculating wavelet coefficients at every possible scale is a fair amount of work, and it generates a dreadful lot of data. If the positions and scales are chosen based on powers of two, hence called as dyadic scales and positions, so calculation of wavelet coefficients are accurate and efficient just as. And this is obtained from discrete wavelet transform (DWT), [1] as shown in Fig. 1.

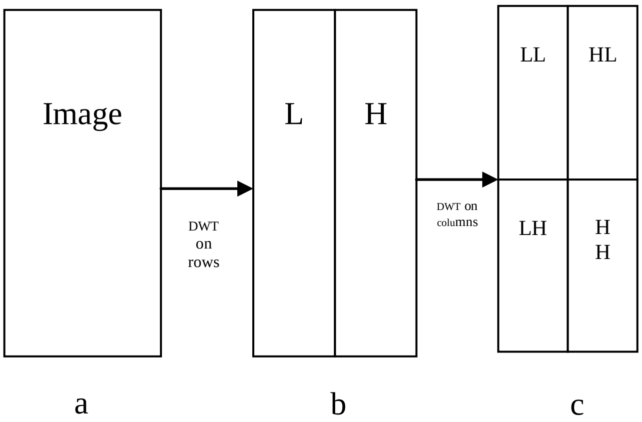

Fig. 1 Block Diagram of DWT (a) Original Image (b) Output image after the 1 -D applied on Row input (c) Output image after the second 1 -D applied on row input

The wavelet transform has gained widespread acceptance in image compression and signal processing. [7] Wavelet transform decomposes a signal as a set of basis functions, and called as wavelets. The DWT has been proposed as a highly flexible and efficient method for sub-band decomposition of signals. The 2D-DWT is nowadays established as a main operation in image processing. In DWT, signal energy concentrates to specific wavelet coefficients. These wavelet coefficients are useful for compressing images. The image converted into a series of wavelets and can be stored more effectively than blocks of pixel. [8]

III. SPIHT ALGORITHM

A. Overview

SPIHT is a very powerful and effective image compression technique proposed in 1996. SPIHT is a totally embedded wavelet coding algorithm that impressively refines the most significant coefficients to achieve the decreasing energy levels. [9] SPIHT is a fully wavelet-based image compression coder. [10] The SPIHT coder first converts the input image into its wavelet transform and produces the wavelet coefficients and then transmits information about them. The decoder uses the received data to reconstruct the wavelet and performs an inverse wavelet transform to get recovered the image. We selected SPIHT because SPIHT predecessor and SPIHT, the embedded zero-tree wavelet coder, were significant breakthroughs in still image compression in that they offered significantly improved quality over vector quantization, training an embedded bit stream, and JPEG, while not requiring producing and wavelets combined with quantization.

The Discrete Wavelet Transform (DWT) runs a low-pass and high-pass filter over the signal in one dimension. The resulted output is a new image comprising of a low-pass and high-pass sub-band. This procedure is then continued in the other dimension till getting one low-pass component, four sub-ands and three high-pass components. A comparative study for image compression of different wavelet families with SPIHT technique is proposed in [11]. Also conducted experiments with different types of wavelet transform. The output image quality is measured in terms of PSNR and CR. According to the research of Shih-Hsuan Yang for still images the SPIHT is very powerful image compression algorithm. [12] The hierarchical wavelet sub-bands are generating by employing SPIHT two dimensional DWT. In this thesis 5-level decomposition is used so that better coding performance can be achieved. The four child nodes generated from the parent node as shown in fig.2. This combination of parent-child node into spatial orientation tree brings the information associated with that orientation and location.

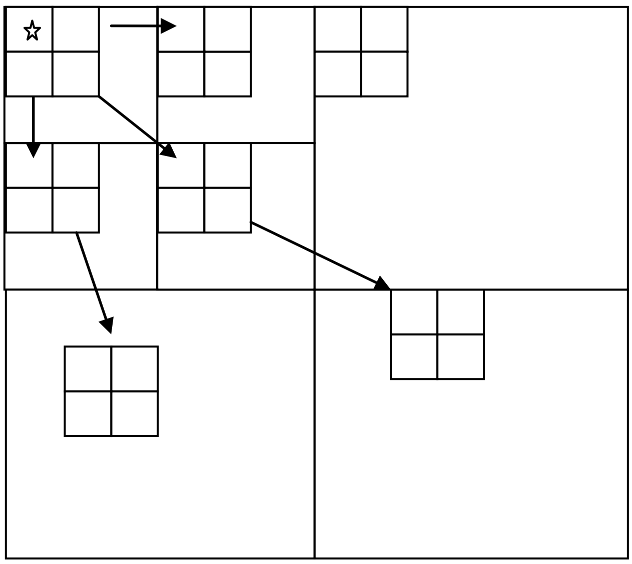

Fig. 2 Data structure used in the SPIHT algorithm

B. SPIHT Algorithm

SPIHT consists of two passes, the ordering pass and the refinement pass. [13] In the ordering pass SPIHT attempts to order the coefficients according to their magnitude. In the refinement pass the quantization of coefficients is refined. The ordering and refining is made relative to a threshold. The threshold is appropriately initialized and then continuously made smaller with each round of the algorithm. SPIHT maintains three lists of coordinates of coefficients in the decomposition. [1] These are the List of Insignificant Pixels (LIP), the List of Significant Pixels (LSP) and the List of Insignificant Sets (LIS). To decide if a coefficient is significant or not SPIHT uses the following definition. A coefficient is deemed significant at a certain threshold if its magnitude is larger than or equal to the threshold. Using the notion of significance the LIP, LIS and LSP can be explained. The LIP contains coordinates of coefficients that are insignificant at the current threshold; The LSP contains the coordinates of coefficients that are significant at the same threshold. The LIS contains coordinates of the roots of the spatial parent-children trees.

SPIHT shows exceptional characteristics over several properties all at once and these are:

1. Fast coding and decoding.
2. Good image quality with a high PSNR.
3. Can be used for lossless compression.
4. May be combined with error protection.
5. Ability to code for exact bit rate or PSNR.
6. A fully progressive bit-stream. [10]

IV. FPGA IMPLEMENTATION

In order to extract an efficient hardware implementation, the processing and communication complexity of the SPIHT algorithm was evaluated in [13] The SPIHT algorithm implementation is simply represented in fig. 3.

The implementation in done in four phase as

1. Header File conversion of input image.
2. Hardware custom logic.
3. FPGA Micro-blaze processor design.
4. Implementation on FPGA.

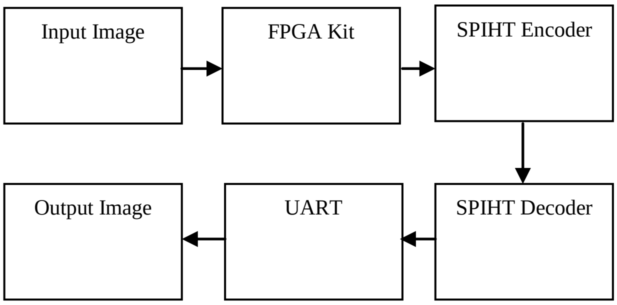

Fig. 3 FPGA Implementation

A. *Header File conversion of input image*

As input is a image data, by the use of Matlab GUI, the input image is converted into header file and use for further processing.

B. *Hardware custom logic*

Using the hardware custom logic, the RTL schematic and net list files are generated for SPIHT as hardware peripherals. Also generate the bit file foe next processing.

C. *FPGA Micro-blaze processor design*

Micro-blaze is a powerful soft processor core that can be implemented into any Virtex architecture. It can efficiently compile the application code and convert it into executable file.

D. *Implementation on FPGA*

The executable file obtained from previous phase and bit file downloaded into the FPGA through parallel interface.

V. CONCLUSION

This paper presents SPIHT image compression technique and its implementation on FPGA. It is seen that the SPIHT image compression algorithm is a really widely used and efficient technique because it offers various advantages as it is a fully embedded codec and very simple with powerful error correction and progressive image transmission techniques. As SPIHT is a completely wavelet based compression, since the discrete wavelet transform plays a vital role in the SPIHT image compression algorithm. This paper also described SPIHT coding algorithm, also introduces a detailed implementation of a efficient and low memory wavelet image coder. The main advantage by making a wavelet coder attractive both in terms of memory needs and speed.

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