High Speed DCT Computation of JPEG: A Review

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Abstract— In this research work, a literature review carried to assess the progress made in the field of DCT computation. The DCT algorithms developed are considered for the review and their application was limited only to JPEG compression. Research carried in the DCT algorithms of a single image (2D) and a series of images from a video (3D). Most of DCT implementations algorithms normally try to avoid multiplications by increasing number of addition operations, Avoiding number of multiplication operations and/or by utilizing a distributed arithmetic based DCT architecture. Avoiding multiplication operations and using addition operations might actually make the architecture slower, since time complexity for addition operations is almost the same as the time complexity for fast multipliers. In this work, we are focusing a DCT architecture based on Vedic mathematics. The review shows high-speed and area-efficient architecture of DCT based on Vedic mathematics.

Key words: DCT, JPEG, Vedic mathematics, FPGA

I. INTRODUCTION

In recent years, multimedia applications got an immense importance. With the rapid growth in technologies, number of processors based on audio, video and image has been developed. Uncompressed audio, video and image files require considerable large storage space and communication bandwidth. Multimedia based web applications not only sustained need to encode signals.

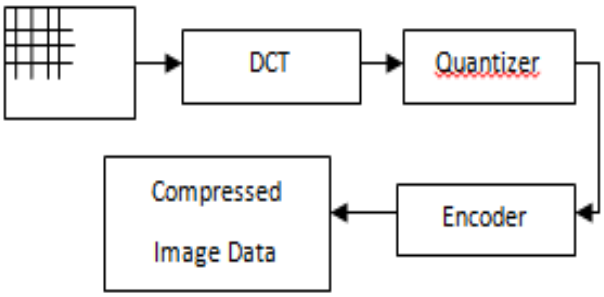

Fig. 1: Block Diagram of Compression

Image compression may be of the type lossy or lossless. Lossless compression technique is suitable for medical imaging, technical drawings. Lossy compression techniques are suitable for natural images such as photographs where minor loss is acceptable. The best quality at a given bit rate is the main goal of image compression.

A. Dct

The JPEG process is a widely used form of lossy image compression that focuses on the Discrete Cosine Transform. IT is a Fourier-like transform, which is widely used in digital signal processing. The DCT works on whole image as by separating images into parts of different frequencies by using a quantization, where fraction of compression essentially occurs, the less essential frequencies are discarded, hence it is called lossy compression. Only the most important frequencies that remain are used to retrieve the image in the decompression process. As a result, reconstruction of images contains image distortion, but these levels of distortion can be adjusted during the various JPEG compression stages. The JPEG method can be used for color and black and-white images, but the focus will be on compression.

B. Vedic Mathematics

Computational unit is key unit of many high performance systems such as microprocessor, DSP processor various Filters. A performance of system is generally determined by multiplier unit. Multiplier unit is normally slowest element of system. Since increasing speed and area optimizing constrain are major design issues. Therefore researchers are constantly developing a new algorithms and hardware designs to implement them. Vedic mathematics is the name given to ancient system of mathematics, which is discovered by shri Bharti Krishna Tirthaji. It is based on 16 sutras and presents a unified and simplified structure of mathematics. Vedic mathematics simplifies complex calculations involved in various topics of mathematics such as basic arithmetic, trigonometry, calculus, geometry. All these methods are very efficient as far as manual calculations are concerned. Following literature review shows different work carried out to speed up computational approach.

II. LITERATURE REVIEW

In this review work, research made in the DCT and algorithms of a single image, and a series images from a video, namely 2dimensional DCT and 3dimensional DCT respectively.

N. Ahmed, T. Natarajan, and K. R. Rao in Discrete Cosine Transform proposed that an huge amount of information is stored, processed and transmitted. Method of compressing the data prior to storage and transmission is of significant practical and commercial interest. Image compression has been considered as an important research work over the last twenty years. This subject has gained as much importance in the fields of pattern recognition, analysis, and biometrics [1-4].

Images are compressed for different applications like storing images in a small memory such as mobile devices or low memory capacity devices, for transmitting the large amount of data, or storing large number of images for research purpose. This is crucial because compressed images occupy less memory and it can be transmitted faster due its small size. Instead of giving importance to standard compression techniques in recognition, researchers have focused in developing special compression algorithms, R. Westwater and B. Furht, in "The algorithm for real-time compression of full-motion video," Real-Time Imaging, a low bit-rate compression of face images [5].

Image compression is the application of compression algorithm on digital images.The important objective is to reduce unuseful amount of data from the

image in order to store or transmit data in an efficient form. Image compression can be of type lossy or lossless [6].

In compression, A Fourier-related transform such as wavelet transform or DCT transforms are applied, followed by quantization and entropy coding [7].

The most popular compression techniques are JPEG and their related transformations are DCT and DWT. It is treated that common image compression standards JPEG 2000 and JPEG have the highest number of applications in real life[8,9].

The JPEG process is a widely used form of image compression that concentrates the research work around the Discrete Cosine Transform [10].

The DCT separates image into part of differing frequencies. In the quantization step of compression part of compression actually occurs. Less important frequencies are discarded hence it is called lossy compression. Only the useful frequencies are used to retrieve the image in the decompression process [11].

Since the introduction of 1-D DCTs in 1974, it has been applied in a wide range of applications and platforms due to the discrete cosine transform performs statistically close to optimum Karhunen–Loeve transform [2] in compression performance. This has led to the development of a large number of algorithms to calculate the 1-D and two-dimensional (2-D) DCTs. One dimensional and two dimensional algorithms are classified into direct and indirect algorithms. The direct algorithms generally have a common computational structure, which basically reduces the implementation complexity [12][13].

Indirect algorithms are based on the DCTs and other transforms relation. These algorithms include the calculation of the DCT through the Hartley [14], fast Fourier [15], and polynomial transforms [16]. These algorithms normally have irregular structures. Number of algorithms has been developed for fast calculation of the 1-D and 2-D DCTs [12]–[16],

New techniques for the computation of multidimensional discrete cosine transforms (m-D DCT) of three and more dimensions is more challenging and has not been given similar attention. The three-dimensional (3-D) DCT is usually computed using the row-column-frame (RCF) approach. Another way DCT is computed through mapping it to one dimensional and using other transforms [17]–[19].

Instead of using these solutions direct multi dimensional algorithms have a better computational structure. These algorithms can be more efficient than the RCF approach and one dimensional approach and need to be improved. Rapid growth in the three dimensional applications based on the 3-D DCT; there is a greater need to develop fast algorithms for the 3-D DCT for such applications. Due to the improvement in fast algorithms, better software and hardware combination many new applications have been proposed based on the 3D DCTs. These include variable temporal length 3-D DCT coding, hyper-spectral coding systems, video coding algorithms, adaptive video coding, and 3-D compression. Direct and true multidimensional algorithms that have regular design and indexing are preferred [20]–[22].

K. F Blinn, A. Alfalou and M. Elbouz mentioned Discrete Cosine Transform (DCT) most commonly used in image processing applied in many standards such as JPEG and MPEG. It has been widely used in image and speech compression due to its high energy compaction. In Fast algorithm for the 3D DCT paper, new 3-Dimensional vector-radix decimation in frequency (VR DIF) algorithm is developed for fast calculation of 3D DCT. The development in the algorithm shows all the stages of calculation the arithmetic complexity. 3-D DCT VR DIF algorithm requires fewer multiplication operations as compared with the familiar RCF approach [23].

Matrix multiplication is one of the fundamental computations in DCT and reducing this computational time is a major concern. This is where Vedic multiplier comes into picture. Vedic mathematics is mainly based on sixteen principles or word-formulae which are termed as Sutras [24]

Muhammad Rais presented hardware design and implementation of FPGA based parallel architecture for standard and truncated multipliers. The designed multiplier consumes less area as compared to standard conventional multipliers [25].

S Vijayakumar, V Jayaprakasan, V S Kanchana Bhaaskaran has proposed methodology of A 4x4 multiplier based on the Vedic. Conventional methods of multiplier design have been designed using SPICE simulator. Simulation results shows the Vedic design results 29% of reduced average power [26].

Sandesh S. Saokar, R. M. Banakar, Saroja Siddamal proposed a fast multiplier design for signed Q-format multiplications using Urdhava Tiryakbhyam method of Vedic mathematics. For the reason of wide use of Q-format representation in Digital Signal Processors the proposed multiplier can considerably speed up the multiplication operation. They occupy less area and perform operation faster than the booth multipliers. Designed architecture not introduced pipeline stages in the multiplier architecture for maximizing throughput.

Aravind E Vijayan in Efficient Implementation of 8-bit Vedic Multipliers for Image Processing Application proposed architecture is of great significance taking into account the factors of timing efficiency, speed and lesser area utilization. The multiplier proposed can be used to replace traditional multipliers by implementing in arithmetic and logical units[27].

S. Hauck and A. DeHon in Reconfigurable computing: the theory and practice of FPGA-based computation sated that FPGAs are considered as an attractive solution for image processing implementation [28].

III. CONCLUSION

In this review progress made in the field of compression using different algorithms especially 2D and 3D DCT. First the input image is divided into 8x8 block and DCT is applied on each of these block. Review shows most algorithms tries to avoid multiplication resulting complex computational structure. Multiplier designed using Vedic sutras is of great significance taking into account the factors of timing efficiency, speed and area. High speed image compression is possible using Vedic multiplier. DCT algorithm designs based on Vedic Sutras can perform significantly compared to conventional DCT.

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