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Review Effective use of CORDIC in JPEG

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Abstract: ***As in modern of portable Devices where the power consumption should be limited CORDIC algorithm is a promising technology. The CORDIC algorithm has two modes vectoring mode and rotation mode. The rotation mode can be used for computation of sine and cosine of a function this can be efficiently used for computation of DCT which is used in JPEG image compression. The traditional method of DCT includes look–up table method. This needs more memory and requires multiplication circuit. This project discusses the method of computing DCT using CORDIC, this can eliminate the multiplication, as CORDIC uses only adders and shifters. This project also proposes a comparative study of computing DCT using variants of CORDIC algorithm like Bi-rotation CORDIC, Cascaded CORDIC etc***

Keywords: CORDIC, DCT, JPEG, image compression

1. Introduction

The CORDIC (COordinate Rotation DIgital Computer) was proposed by Jack E Volder in 1959 for the use in airborne system by using simple adders and shifters which reduces the cost of implementation and reduces power consumption. The application of CORDIC varies from Image processing, Robotics, Satellite communication etc. The kinematics of robotics involves the calculation of sine values and cosine values. In Image compression (processing) the CORDIC can be used for computation of DCT. JPEG image compression is gaining popularity because of its efficiency. DCT is a main module in the JPEG process and the DCT is computed using Lookup-table method i.e the pre computed value of DCT matrix is stored in a look up table and is addressed when needed, or by Taylor series(polynomial approximation) method which needs heavy hardware for its computation. Here a novel method for the computation of the DCT matrix using CORDIC algorithm which reduces the silicon area and power consumption is proposed, and its efficient use in JPEG image process is also proposed

Since the number of transistors increases according to Moore's law new algorithms should be developed to reduce the power consumption.In CORDIC there exist two methods for the calculation of trigonometric and other functions and they are rotation mode and vectoring mode. Fast Fourier Transform (FFT) is an important and very common term coming in the DSP applications FFT twiddle factor is an another important term and it consists of mainly sine and cosine terms, so by using CORDIC algorithm for the generation of trigonometric functions we can calculate sine and cosine values and we can calculate the twiddle factor.Thus the area optimization is possible in FFT also. Further we can use this FFT in OFDM system and as aresult the total system area is optimized for the OFDM system. Due to the simplicity and hardware efficiency, the CORDIC algorithm is most suitable for VLSI implementation.

2. Literature Survey

Paula Aguilera[7] compared various image compression technique like PNG,TIFF,JPEG,JPEG2000 etc and concluded that among these the JPEG 2000 provides the highest compression ratio and quality but it is based on discrete wavelet transform. the PNG (portable network format) and TIFF(tagged image file format) is lossless image compression and presently not widely used in the field image processing. The JPEG 2000 is a very efficient image compression technique compared to Vinay Jeengar, S.N. Omkar [8],have compared DCT Method and DWT method of image compression and have found out that DWT method is far better than DCT method at the expense of number of computations ie if DCT requires n operation DWT need n^2 operations , but DWT have limited application in image processing. And also though the DWT provides the highest compression ratio it the complexity involved is high involved is very high.

Pravin B. Pokle and N. G. Bawane (2012)[6] details about the JPEG (Joint Photographic Experts Group) process which is an lossy image compression technique which uses the DCT(discrete cosine transform), explains one dimensional DCT and also two dimensional DCT where the two dimensional DCT is a variation of one dimensional DCT applied twice ie in X direction and in Y direction also the process of JPEG compression. Starting from dividing 8×8 blocks, as the pixel value ranges from 0 to 255 but the next process that is DCT works only with pixel value that ranges from -128 to 127 so we need to subtract 128 from every block to get value between -128 to 127,The next step in JPEG image compression process is quantization where very high energy levels are discarded and only the relevant energy levels are passed to the next process that is scanning. The next process is scanning where any suitable scanning process is done and Huffman coding is done for further compressing of the image

Ken cabeen and Peter Gent (2005)[5] discussed about the DCT which is done to convert the time domain into frequency domain as the time domain computation is complex. The DCT equation and also how it is used in image compression process, also provides the standard DCT matrix for an 8×8 block of image a and the quantization matrix based on the fact on the sensitivity of our eyes and also for optimum image compression ratio, human eyes are sensitive to low frequency signals and the accordingly the quantization matrix is selected. The quantization matrix

varies from Q_1 to Q_{100} While Q_1 provides the highest compression ratio it gives the poor image quality while Q_{100} provides the best image quality but gives less image compression. Considering above facts, we choose an optimum quantization matrix based on image compression ratio and image quality and which is suitable for our design we take quantization matrix as Q_{16}.

Kavya Sharat, Dr.B.V.Uma(2013)[12] have discussed the drawback of several methods of DCT calculation and also detailed about the algorithm for computing DCT by CORDIC algorithm by setting the initial value of x and y . The paper also detailed about the advantages of the algorithm compared to other algorithm and also suggested using radix-4, radix-8 CORDIC to increase the speed of the computation. This paper have suggested the algorithm for computation of the angle by using CORDIC algorithm with initial value of x and y . CORDIC algorithm has become a widely used approach to elementary function evaluation when silicon area is a primary concern. CORDIC is more economical than DSP algorithms both in terms of area and power consumption. This paper presents how to calculate sine and cosine values of the given angle using CORDIC algorithm. A brief description of the theory behind the algorithm is also given in this paper

Jack E Volder (1959)[1] proposed CORDIC algorithm for use in calculation of trigonometric functions in air-borne systems using only adders and shifters avoiding the use of multipliers but the method does not give a perfect result and also result in delay though it is the first paper and done to explore the after this many work have been done exploring the areas of application of CORDIC algorithm and explored the application of the CORDIC algorithm in the area of image processing, bio-medical engineering in space ships and in robotics etc.

Ms. Ankita Sharma , Mrs. Neha Sharma 2014[15]This paper describes the application of the CORDIC Algorithm to find the coordinates of the satellite in the x-y plane. The mathematical and analytical approach for the CORDIC algorithm implementation is presented in this which shows that CORDIC algorithm involves the idea of "rotating" the phase of a complex number, by multiplying it by a succession of constant values. It also presents mathematical and analytical aspects of implementing the CORDIC algorithm for satellite's communication. For sinusoidal angle calculations, this method can provide n-bit accuracy for n iterations. This method is much simpler than the conventional methods as the computations are reduced to only shift and add operations instead of the complex multiplication operations. On the other hand, when a hardware multiplier is available (e.g. in a DSP microprocessor), table-lookup methods and power series are generally faster than CORDIC.

Pramod Kumar Meher, Sang Yoon Park (2013)[9] has suggested various variation in the reference CORDIC like four micro rotation, bi-rotation CORDIC (where the accuracy of the computation decreases but is sufficient for many application like image compression, audio compression etc), pre-Shifted CORDIC, cascaded CORDIC etc for use in angle calculation which speed up the process at the expense of small look up table and also have given the pre-computed table and equation which help in the calculation of the angle in the DCT. Though it provides a faster computation it will again use a considerable use of look up table but the speed of computation can be increased and also the range for calculation of value of an angle also decreases in case of 4-micro rotation CORDIC

Pongyupinpanich Surapong, Faizal Arya Samman[3] Have detailed about the double rotation and triple rotation of the process of the CORDIC which reduces the computation latency and also reduces the error in computation.

A.S.N Mokhtar (2013)[11]discussed how to increase the speed of the conventional CORDIC algorithm by combining third order approximation Taylor series and leading-one-bit detection algorithm which effectively increases the speed of computation in [11] it suggested Taylor series expansion allowed the rotation only in one direction compared to conventional CORDIC and also 3! Was approximated to 2^2. It also provides MSE error in sine and cosine values resulted from the approximation of the factorial was 0.0168% which is insignificant and does not affect the accuracy of the system performance.

Hai Huang and Liyi Xiao 2013[10] Proposes a novel coordinate rotation digital computer (CORDIC)-based fast radix-2 algorithm for computation of discrete cosine transformation (DCT). The proposed algorithm has some distinguish advantages, such as Cooley-Tukey fast Fourier transformation (FFT)-like regular data flow, uniform post-scaling factor, in-place computation and arithmetic-sequence rotation angles. Compared to existing DCT algorithms, this proposed algorithm has lower computational complexity. Furthermore, the proposed algorithm is highly scalable, modular, regular, and suitable for pipelined VLSI implementation.

Pengwei Hao 2001[2] and Ying Chen 2004[4] The DCT explained till now is floating type DCT and simple JPEG ie lossy that is it cannot be decompressed to get back the original image(the reconversion of the JPEG depends on three factors 1.colour 2. DCT 3. Quantization) and also many application requires the decompression of the compressed image, In [2],[4] have proposed a new kind of JPEG called iJPEG which is reversible and it used iDCT instead of DCT to obtain this they explained the use of TERM (Triangular Elementary Reversible Matrix) & SERM (Single Row Elementary Reversible Matrix) matrixes ,and also by varying the quantization level for each blocks. It also compares both the JPEG ie both floating and integer JPEG and found that though both does not make considerable difference but the compression ratio of the iJPEG is less compared to original JPEG.this is due to the fact that iJPEG uses less efficient quantization matrix. From the literature survey though many methods are there for computation of DCT which proves to be efficient in spite of its limitation .Here a new method for the computation of DCT is proposed which is further extended to JPEG process and the variation of CORDIC [9] for computation of various angle is given.

3. Conclusion

Though DWT provides the highest efficiency, but not widely used for image processing compared to DCT. There are many applications for the CORDIC, and DCT is one among them. CORDIC provides an energy efficient and silicon area efficient method for computation of DCT which can be used in JPEG image compression. Still the CORDIC remains a promising technology for DCT computation which reduces the cost of the circuit as it uses only adders and shifters for computations. iJPEG is an variation of normal JPEG which is reversible image compression compared to irreversible provided by JPEG. It uses an integer DCT instead of floating DCT to decompress the original image after compression, with a reduced image compression ratio which accounted by the fact that the iJPEG limited quantization efficiency.

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