Lossy Compression of Biometric Images Implemented Using Floating Point DSP Processor

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Abstract. In this paper, several numbers of biometric images are compressed in order to reduce the number of bits needed in representing an image with conservation of image quality. Biometric images compression is important to solve the problem of efficiently transmitting data and storing large number of biometric images in low capacity of memory device. Biometric images are compressed using two techniques which are DCT and Quantization. The compression algorithm is implemented on general purpose computer and DSP processor in order to compare between both of them in terms processing time and evaluate the performance of this technique by measuring the difference between the original image and reconstructed image using PSNR, SSIM and MSE. Experimental results show DCT algorithm produces a high quality for reconstructed images with acceptable compression rate in terms of quality level is more than 50%. Furthermore, implementing the proposed algorithm using DSP board achieves better performance in terms of processing time compared with PC based.

1 Introduction

Image compression is the technique that is used to properly code digital images in order to minimize the number of bits needed in displaying an image. Advancement in digital technology has enhanced the communication media in which representation of visual information poses a vital role. High definition TV, videoconferencing, medical imaging, video wireless transmission, virtual reality, video telephony and video server are the emerging application of image compression [1]. If the number of users is large, the video signal and original biometric digital image often contains many information, hence, requires a large channel and storage capacity. The cost of implementation increases exponentially with the required capacity despite the improvement of the communication channels and storage capacity technology. However, compression techniques are important to overcome the shortcomings of the channel or storage capacity, which in turn reduce the data rate and retaining the quality of the image or video signal decoded.

Image compression techniques can reduce data to the extent where it is almost not obvious to the human eye and the utilization of statistical redundancies in the data [2]. Spatial and spectral redundancies are the two types of redundancies that ensue in images. The correlation that joins neighbouring pixels together causes spatial redundancy while spectral redundancy occur according to the correlation relating different color planes [3]. In the compression theory both spatial and spectral redundancies can be eliminated by utilizing transform coding or subband coding (Discrete Cosine Transform). Another type of redundancy called temporal redundancy which is due to the correlation of different frames in an array of images such as in video conferencing applications or broadcast images. Inter-frame coding also called motion compensated predictive coding MCPC can be used to remove temporal redundancies [4].

Several compression algorithms have been developed for image and video compression and some of these algorithms have become standards accepted for compressions such as MPEGs, JPEG, H.263 and H.261. These algorithms are computationally expensive to run in a standard processor because their execution is a block based method [5]. Discrete cosine transform DCT and Huffman coding are labelled the two most computational intensive functions or components and they are often employed using digital hardware to implement particular functions in the algorithm.

The implementation of video and image compression algorithms through the hardware posits a lower speed and density but performance is not flexible. However, recent technological improvements in software and semiconductor technology have enhanced the performance and lower the cost of floating point digital signal processor. Presently, digital signal processing DSP processor becomes an appealing resolution for executing video and image compression algorithm most particularly for low to medium video frame rate

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applications. DSP processor has been largely used in graphic card and sound card most of the signal processing product. Speed rate, programmability and fast development cycle are the main benefit of using DSP processor. Compression can be implemented using high level programming language such as C and assembly language handles critical coding to further increase speed of execution.

Fixed point DSP and floating point DSP processor are the two types of programmable DSP available in the market. Fixed point DSP is of lower cost, high speed execution and large volume production. However, conversion of the algorithms into fixed point in order for adequate data scaling at every arithmetic step to avoid overflows and maintain accuracy can be very challenging. Floating point DSP is of higher cost in terms of price with the advantage in the algorithms mapping is reasonably simple and direct enabling a closer design cycle [6].

1.1 Biometric Image Compression

Image compression achieves reliable transmission and good image storage systems. The need to store, manage and transfer digitized biometric image, have increased tremendously especially for the 2D biometric data and video signal. The size of the image stored can be really high and take large part of the storage device. An ideal color image with 640 x 480 pixels resolution contains nearly a million elements meanwhile a 512x512 gray image may have 262144 components available for storage. It is also a time consuming process to transfer all the records from the biometric sensor to the running internet servers that classifies the process [7].

Biometrics image is the measurement and statistical analysis of people's physical attribute. It mainly identifies and get control to access any individuals or object of interest that are under surveillance. Biometric authentication usually authenticate with unique parameters of any individual’s inherent physical traits. For example, if any government is launching program to gather the biometric grouping features particularly fingerprint, iris and facial patterns for its residents. Managing the large system storage can be challenging including database transmission over internet or designing a portable sensor device to carry. This forms an underlying reason to investigate the compression algorithm for several biometrics image based on JPEG compression techniques. It is also important to measure the compression performance of compressed biometric image using several measurement standards. Image generally dominates the major share of the communication bandwidth. Hence, efficient image compression technique is essential. The most focal objective of image compression is to eliminate redundancy and exclude irrelevancy. Redundancy helps to remove redundancy from the signal source and irrelevancy omits pixel values which are not noticeable by the human eye.

2 Propose Compression Method

There is a compression method based on a frequency transform that is able to compress biometric image which is Discrete Cosine Transform (DCT). This transform (DCT) contains unique features which allow for the creation of an efficient image compression. The main advantage of image transformation using DCT is the elimination of redundancy between neighbour pixels. Efficiency or performance of the transformation scheme can be directly measured by its ability to array input data into as few coefficients as possible [8]. Image compression can be implemented in both software and hardware. However, the use of hardware implementations will achieve faster processing than software implementation which is due to highly parallel algorithms that exist in specific hardware such as DSP processor.

In designing any compression algorithm, two most contrasting problems are reducing data rate and increasing processing time along with conservation of image quality. In this paper, DCT compression algorithm is implemented using floating point DSP processor in order to increase the processing time with preservation of image quality. In the implementation approach floating point DSP processor is used, because it has a special purpose internal module designed for highly extensive mathematical operation exist in the compression algorithm. It has a dedicated hardware to perform multiply and accumulate (MAC) operation and a floating point arithmetic unit which is able to speed up the processing time compare to general purpose computer.

2.1 Discrete Cosine Transform Algorithm

JPEG is a modern lossy/lossless compression technique for colour or grey scale static images. In a case where there is neighbouring similar coloured pixel, this compression works well on continuous tone images. JPEG utilizes many parameters to in order to enable the users to manipulate the amount of information lost (and in this way likewise the compression ratio) over a very wide range. In JPEG some visual information are permanently lost compared to other formats like GIF (Graphics Interchange Format), PPM (Predict, Probability Model) and PGM, It is however called a lossy compression technique. Knowing the data to dispose is the main requirement of JPEG. The JPEG encoder and decoder block diagram is given in figure 1.

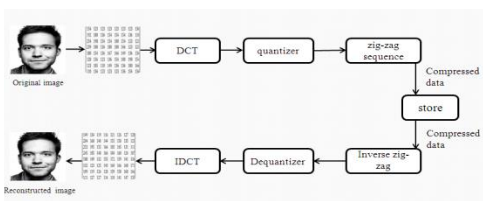

Fig. 1. JPEG encoder and decoder block diagram.

The original image as shown in figure 1 is usually divided into hundreds or even thousands of 8x8 blocks in JPEG compression technique. The pixels of each colour component are organized in groups of 8x8 pixels called data units. If the number of image rows or columns is not a multiple of 8, the bottom row and the rightmost column are duplicated as many time as necessary. The discrete cosine transform (DCT) is executed on every information unit to make 8x8 maps of frequency components. They are represented to the normal pixel value and progressive higher-frequency changes inside the gathering and each of the 64 frequency components in a data unit is reduced by a different number called its Quantization Coefficient (QC), and after that adjusted to a whole number. Quantization step size is calculated by the satisfactory visual quality of image. After quantization, the coefficients are organized as the frequency increases. For each non-zero DCT coefficients, JPEG reports all the zeros that precede the amount of bits desired to represent the largeness of the number. To consolidate the runs of zero, JPEG processes DCT coefficients in the zigzag pattern. The coefficient at the top left side are called DC coefficient while the other 63 coefficients are known as AC coefficients [9]. Entropy coding is used to code DC coefficients from previous block while AC coefficients are coded by entropy coding. JPEG committee delivers a standard table to be utilized for entropy coding.

The two dimensional DCT of image *f(x,y)* can be obtained from the to one dimensional DCT as expressed below.

$$F(u,v) = \frac{4}{N^2}\alpha(u)\alpha(v)\sum_{x=0}^{N-1}\sum_{y=0}^{N-1} f(x,y)\cdot\cos\left[\frac{(2x+1)u\pi}{2N}\right]\cdot\cos\left[\frac{(2y+1)v\pi}{2N}\right]$$

The two dimensional inverse DCT is given by

$$f(x,y) = \sum_{u=0}^{N-1}\sum_{v=0}^{N-1}\alpha(u)\alpha(v)F(u,v)\cdot\cos\left[\frac{(2x+1)u\pi}{2N}\right]\cdot\cos\left[\frac{(2y+1)v\pi}{2N}\right]$$

where

$$\alpha(u),\alpha(v) = \begin{cases} 1/\sqrt{2} & \text{for } u,v=0 \\ 1 & \text{for } u,v=1,2,\ldots,N-1 \end{cases}$$

where u and v are coordinates in the transform domain. The sequential zeros that occurs within each and every block are exploited with zigzag pattern. It normally starts increasing from low-frequency to high frequency terms and the quantization will probably remove high frequency term in the quantization stage. This process will generally produce a more compressed output by positioning entropy for more order. The lower frequency components depict the steady luminance variations and are essential to the human visual system than the high frequency changes since human eye cannot note changes in higher frequency components. More zeros are expected to run after the quantization process where the important coefficients in the order of 8x8 block can be expected towards the end of the 8x8 block to enable more compression in the entropy [10]. The zigzag pattern is shown in figure 2. Data of 64 coefficients are rearranged in a zigzag pattern.

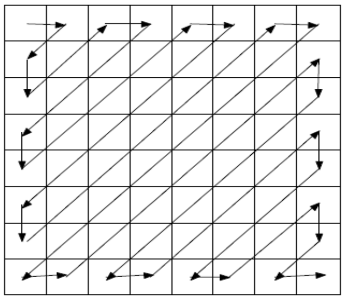

Fig. 2. Zigzag-sequence

2.2 Implementation of algorithm

After we have validated our design using simulation of C program, we will transfer our algorithm to floating point DSP processor using Code Composer Studio IDE development software. The algorithm is written in C, compile and load into DSP development board. Several biometric images for different traits and the DCT algorithm are implemented on this board. The coding part of the algorithm is done in the Code Composer Studio IDE which is done in the visual studio. Details of CCS development tool are given in figure 3 and figure 4.

The TMS320C6713 DSK board is connected to personal computer through a USB to debug and run the out file of the C code, as shown in figure 5. Communication with on-chip emulation support happens over the JTAG to monitor and control program execution. The C6713 DSK board also has JTAG interface through the USB port. Code composer studio can be used with a simulator (PC) or can be connected to a real DSP system and test the software on a real processor board (DSP).

3 Performance Analyses

The DCT image compression algorithm was developed using C program and implemented in DSP board running with floating point DSP processor. The performance is measured based on the several quality assessment of the reconstruct image.

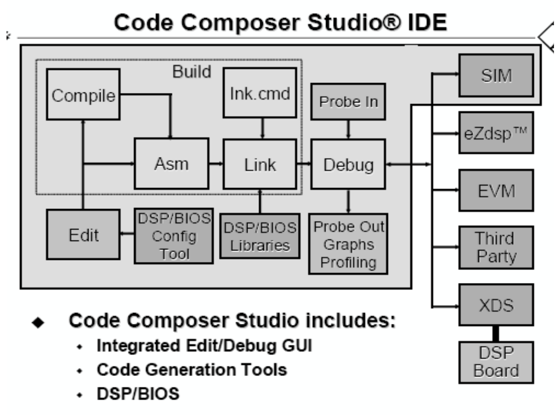

Fig. 3. Code Composer Studio Architecture

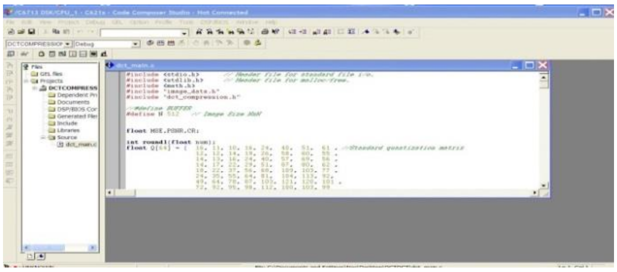

Fig. 4. Code Composer Studio design entry

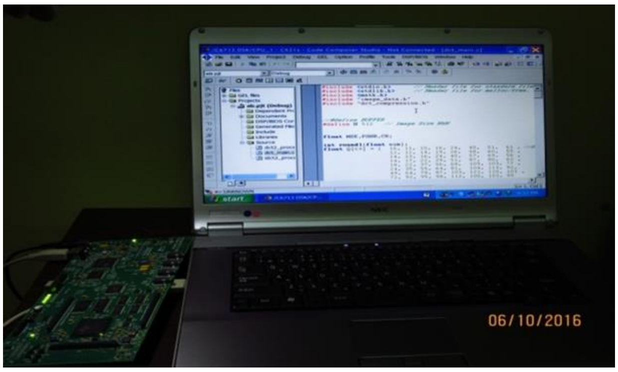

Fig. 5. Physical Connection of TMS320C6713 DSK board and PC through USB Cable

The performance in terms of speed also has been measure to show the advantage of DSP processor to perform compression algorithm. The DCT image compression algorithm was tested on several biometric images such as: facial, fingerprint, and palmprint to see how it operates on different types of biometric images. Biometric images were tested over five quality levels 90, 70, 50, 30, and 10. The results for the set of tested biometric images can be found in Table 1-3.The results are made in terms of Peak signal-to-noise ratio (PSNR), mean squared error (MSE), Bit Per Pixel (BBP), correlation (CORR) and Structural Similarity Index Metric (SSIM). Details of this analysis are shown as follows.

$$PSNR = 20log_{10}\frac{255}{RMSE}$$

$$MSE = \frac{1}{NM}\sum_{i=1}^{N}\sum_{j=1}^{M}\left(I_{ori}(i,j) - I_{rec}(i,j)\right)^2$$

$$CORR = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}(Ai,j - A^{-})(Bi,j - B^{-})}{\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}(Ai,j - A^{-})^2\sum_{i=1}^{M}\sum_{j=1}^{N}(Bi,j - B^{-})^2}}$$

$$\mathrm{SSIM}(x,y) = \frac{(2\times\bar{x}\bar{y} + C1)(2\times\sigma_{xy} + C2)}{(\sigma_x^2 + \sigma_y^2 + C2)\times((\bar{x})^2 + (\bar{y})^2 + C1)}$$

$$BBP = \frac{total\ number\ of\ bit\ in\ the\ compressed\ image}{number\ of\ pixel}$$

In this experiment, table 1 shows the result of applying DCT compression algorithm on biometric face image with five quality levels which are 10, 30, 50, 70, and 90. The results are evaluated in terms of PSNR, SSIM, MSE, CORR and BBP. The best performance can be achieved with quality level 90. Fig. 6a illustrates original face image with reconstructed face images with qualities level 90 is shown in Fig. 6f.

In the second analysis, DCT compression algorithm is conducted on biometric fingerprint and palmprint image with different quality levels. These quality levels are from 10 to 90 scales. PSNR, SSIM, MSE, CORR and BBP are used to evaluate the difference between the original image and reconstructed image as shown in table 2 and table 3. Table 4 shows the performance analysis in term of processing speed. DSP processor offer better processing speeds compare to PC based method.

Table 1. Performance analysis of face image

Face					
Q	PSNR	MSE	SSIM	CORR	BPP
10	33.336	39.825	0.8748	0.99785	2.0335
30	38.805	9.7417	0.9649	0.99945	3.4255
50	41.183	5.5143	0.9795	0.99976	4.0198
70	43.859	2.9098	0.9887	0.99984	4.4965
90	48.956	0.8730	0.9962	0.99995	5.1158

Table 2. Performance analysis of fingerprint image

Fingerprint					
Q	PSNR	MSE	SSIM	CORR	BPP
10	27.879	121.45	0.9437	0.98122	5.9733
30	33.049	33.242	0.9833	0.99484	6.8471
50	35.533	18.618	0.9906	0.99711	7.021
70	38.087	10.582	0.9946	0.99836	7.1344
90	43.619	2.8928	0.998	0.99955	7.3322

Table 3. Performance analysis of palmprint image

Palmprint					
Q	PSNR	MSE	SSIM	CORR	BPP
10	35.983	16.396	0.9293	0.99713	0.6746
30	40.858	5.3368	0.9616	0.99905	1.5324
50	42.643	3.5403	0.9703	0.99937	2.1085
70	44.097	2.5313	0.976	0.99955	2.7718
90	47.082	1.2733	0.9857	0.99977	5.6057

Table 4. Comparison of processing time between DSP processor and PC based method.

	PC based	DSP processor
Face	35s	0.26s
Palmprint	40s	0.35s
Fingerprint	42s	0.46s

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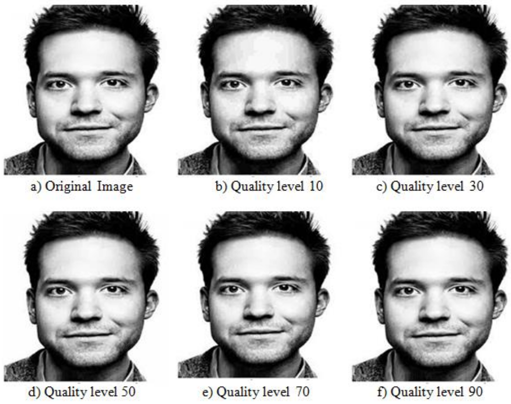

Fig. 6. Face image reconstruction with different quality level.

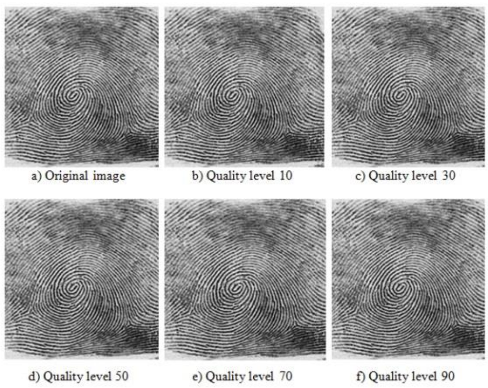

Fig. 7. Fingerprint image reconstruction with different quality level.

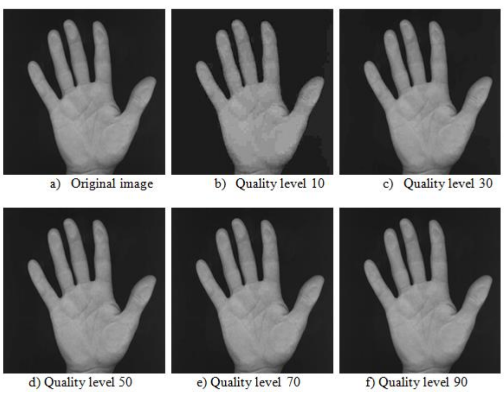

Fig. 8. Palmprint image reconstruction with different quality level.

3 Conclusions

In this paper, we have presented the implementation of DSP processor for 2D-DCT combined with quantization and zigzag process to compress biometric images such as facial, palm print, and fingerprint. In this paper, DCT is used to transform data from spatial domain to frequency domain because DCT is used for lossy compression to compact the most data into a few low frequency components. Several DCT components are discarded by using quantization process especially for high frequency components which do not cause loss in the visual impact and in zigzag process is used to consolidate relatively large runs of zeros. Biometric images compression was performed with five different quality levels namely mean MSE, BPP, PSNR, CORR and SSIM.

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