Low Bit Rate Video Coding Implementation on Low Cost Low Performance DSP Processor

Swapna D. Pahade
Assistant. Professor
Department of Electronics &
Communication Engg.
Sinhgad college Of
Engineering,
Vadgaon(BK), Off Sinhgad
road,Pune-411002.

Ajay D. Jadhav, Ph.D.
Prof. & Head PG Programs,
Department of Electronics &
Communication Engg.
Sinhgad college Of
Engineering,
Vadgaon(BK), Off Sinhgad
road,Pune-411002.

Poorva Waingankar
Associate professor
Department of Electronics
engg.
Thakur College of Engineering
& Technology, Mumbai

ABSTRACT

Compression is useful in reduction of the cost of transmission bandwidth and storage of larger size images. One of advanced form of compression is based on wavelet compression. DWT can be used to reduce the image size without losing much of the resolutions computed. It reduces the amount of memory required to represent given image [1].

This paper covers a review of the fundamentals of image compression based on wavelet and also presents wavelet based low bit rate video coding technique. Wavelet based image compression has been illustrated using DSP Processor platform. The implementation of DWT compression algorithm using embedded approach has been tried with DSP processor TMS320C6713. DWT algorithm is implemented using C language. The Code Composer Studio (CCS) software is used to simulate the code written in C language to successful display the compression result on TI's digital signal processing board TMS320C6713. DSP simulation results are verified using MATLAB simulation results. Compression ratio for the image compressed by DSP simulation is obtained as 1.0124. Compression ratio by MATLAB simulation is obtained same as 1.0124. This work shows that average simulation time of the system is 21 milliseconds and memory used is 2.5Kbyte. The coefficients of compressed image which are the results of MATLAB software and C language using Code Composer Studio (CCS), IDE Environment are closely matched.

General Terms

compression, bandwidth, algorithm, embedded, simulation, resolution, performance.

Keywords

Discrete wavelet transform (DWT), DSP processor, Code Composer Studio (CCS) software, MATLAB simulation, low bit rate video coding, compression ratio, IDE Environment.

1. INTRODUCTION

A typical 'still image' contains a large amount of spatial redundancy in plain areas where adjacent picture elements i.e. the pixels have almost the same values. It means that the picture elements are highly correlated. The redundancy can be removed to achieve compression of the image data i.e., the fundamental components of compression are redundancy and irrelevancy reduction. The basic measure of the performance of a compression algorithm is the compression ratio, which is defined as the ratio of original data size to the compressed data size. Higher compression ratios will produce lower image quality and the vice versa is also true [2].

The next version of the JPEG standard i.e. JPEG 2000 which incorporate wavelet based compression techniques. In a wavelet compression system, the entire image is transformed and compressed as a single data object rather than block by block as in a DCT-based compression system. It allows a uniform distribution of compression error across the entire image. It can provide better image quality than DCT, especially on a higher compression ratio [3].

1.1 Discrete Wavelet Transform (DWT)

As per [1], The EPWT (Easy Path Wavelet Transform) is a locally adaptive wavelet transform. It works along pathways through the array of function values and exploits the local correlations of the given data in a simple appropriate manner. The experimental results show that PSNR-value obtained by applying a 9/7 tensor product wavelet transform to the original image is 24.61 dB. The EPWT provides very good approximation results but produces a non-negligible amount of extra costs due to the adaptivity of the method.

In paper [2], an algorithm is presented which is based on a hybrid technique implementing a combination of the discrete wavelet transform and the discrete cosine transform Wavelet transform enables to decorrelate the spatial correlation of pixels without the limitation of the block-based DCT. Hence, undesirable blocking artifacts in the reconstructed image, typical to DCT-based compression techniques, are avoided. DWT employs two sets of functions, called scaling functions and wavelet functions, which are associated with low-pass and high-pass filters, respectively. After each filtering step, half of the samples can be eliminated according to the Nyquist's rule. Experimental results shows that the DCT-DWT hybrid compression technique provides higher PSNR values of about 2–5 dB than the MPEG-based technique.

In [4], different image compression standards are illustrated. Out of which JPEG2000 is recent and new standard uses discrete wavelet transform. The wavelet transform can be performed with reversible filters, which provide for lossless coding, or non – reversible filters, which provide for higher coding efficiency without the possibility to do lossless..

According to [6], image compression algorithms aim to remove redundancy in data in a way which makes image reconstruction possible. This basically means that image compression algorithms try to exploit redundancies in the data; they calculate which data needs to be kept in order to

reconstruct the original image and therefore which data can be 'thrown away'. By removing the redundant data, the image can be represented in a smaller number of bits, and hence can be compressed.

According to [7], DWT offers adaptive spatial-frequency resolution (better spatial resolution at high frequencies and better frequency resolution at low frequencies).In present scene, much of the research works in image compression have been done on the Discrete Wavelet Transform. DWT now becomes a standard tool in image compression applications because of their data reduction capabilities. The basis of Discrete Wavelet Transform (DWT) is wavelet function that satisfies requirement of multi-resolution analysis. Discrete wavelet transform have certain properties that makes it better choice for image compression. It is especially suitable for images having higher resolution. DWT represents image on different resolution level i.e., it possesses the property of Multi-resolution. Since, DWT can provide higher compression ratios with better image quality due to higher de-correlation property. Therefore, DWT has potentiality for good representation of image with fewer coefficients

2. PROCESSOR BASED IMPLEMENTATION ASPECTS

For experimentation, here Daubechies4 wavelet is used. Important properties of wavelet functions in image compression are compact support (lead to efficient implementation), symmetry (useful in avoiding dephasing in imageprocessing), orthogonality (allow fast algorithm), regularity and degree of smoothness (related to filter order or filter length). Daubechies wavelets are families of orthogonal wavelets that are compactly supported. Compactly supported wavelets correspond to finite-impulse response (FIR) filters and, thus, lead to efficient implementation.[7]

To implement DWT based algorithm on a DSP Processor platform is a challenge. An embedded environment constraint the energy consumption, the memory space, and the execution time of an application. On the other hand, the complexity of the applications running on DSP processor platform keeps increasing. The important consideration for designing an embedded system are reliability, performance, low power consumption, low cost, small size, limited user interface and capability to upgrade software in the field. a number of criteria useful for choosing a DSP: arithmetic format, data width, speed, memory organization, ease of development, multiprocessor support, power consumption, and cost.[8].

Looking forward to new era of image processing where modernized and fastest ways are used to compress the images by using DWT technique as used in JPEG2000, world is definitely in the need of an embedded approach. In the work presented here, DSP processor like TMS320C6713 is used. Moreover selecting best wavelet for compression results in low number of average bits per pixel which ultimately results in low bit rate transmission of video. For experimentation, image file is stored in computer and then its image coefficients are read by MATLAB software. These image coefficients are used as input image on DSP processor based platform. Apply lossy DWT algorithm on these coefficients and finally gets the coefficients of compressed image which can be again read by MATLAB software and compressed image can be seen in the same simulation software.
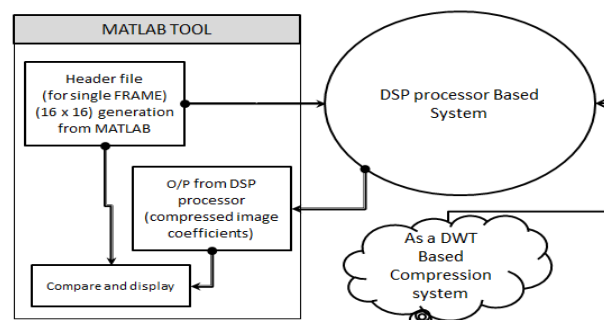

Fig. 1 Block Diagram of the flow of Experimentation

The basic DWT algorithm is used for implementation. The DWT algorithm is implemented using C language. The Code Composer Studio software is used to implement the code written in C language to successful display the compression result on TI's digital signal processing board TMS320C6713.DSP simulation results are verified using MATLAB simulation results.

3. EXPERIMENTATION

This part describes the experimentation and related concepts carried out in the work. The presented system and related specifications are also discussed.

Embedded approach:
Code composer studio which provides an integrated development environment (IDE) and DSP starter kit (DSK), with the TMS320C6713 floating point processor onboard.

Objective:
The objective of this work is to design simple, low cost DWT based compression system using low cost DSP processor using standard algorithm procedure.

System Requirements:
1) *Software Environment*: CCS (code composer studio) which provide the necessary software support. CCS provides an integrated development environment (IDE), bringing together the C compiler, assembler, linker, debugger and so on for writing code in C language. MATLAB platform to compare, evaluate and validate the results with C code results.
2) *Hardware Environment:* The hardware environment is based on DSP starter kit (DSK) with TMS320C6713 floating point processor onboard.

3.1 Experimental Work

The DSP Processor based system accepts image coefficients generated by MATLAB as an input/source file. The image is stored in MATLAB work file and then it is read. The coefficients are directly used as source file in C code. The system work flow diagram is as shown in fig.2 which helps to carry out procedural steps.

Steps involved here are as listed below.
1) First step include all header files of DSP processor TMS320C6713.
2) Include the input image (16x16) coefficients as a header file of DSP processor TMS320C6713.
3) CCS provides an integrated development environment (IDE), to watch change of output of DWT compression system.

4) As per algorithm main part of work focuses on Discrete Wavelet Transform that involves computational complexity in calculating coefficients from filter bank.

5) Verification of results and successfully display the compressed image using MATLAB software.

6) Analysis of algorithm using MATLAB.

System Specification:

a) DSP Processor =TMS320C6713

b) Crystal frequency for DSP processor=225MHz

c) Wavelet used for compression= Daubechies 4 wavelet

d) Image size= 16x16 matrix

e) Software IDE Platform=Code Composer Studio(CCS) /MATLAB
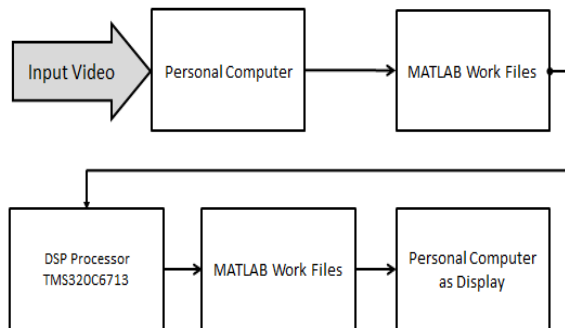
f) Simulator=Device cycle accurate simulator

Fig. 2 System Work Flow Diagram

4. SIMULATION RESULTS

This includes simulation model for DWT based video coding. Simulation model shows wavelet based low bit rate video coding. Video coding is performed by using successive adding difference (SAD) algorithm [15]. Compression results of simulation model in terms of visual quality and bit rate for wavelet families are discussed using MATLAB simulation software. This analysis presents image compression and video coding using DWT.

4.1 Video coding

Image compression techniques try to exploit the spatial correlation that exists in a still image. When we want to compress video or sequence of images, an added dimension namely, the temporal dimension has to be exploited. Generally, there is little or very little change in the spatial arrangement of objects between two or more consecutive frames in a video. Therefore, it is advantageous to send or store the differences between consecutive frames rather than sending or storing each frame. The difference frame is called the residual or differential frame and may contain far less details than the actual frame itself. Due to this reduction in the details in the differential frames, compression is achieved.

The successive adding difference method of video coding involves the following steps [15].

1) Generate a differential frame by subtracting two temporally adjacent intensity image frames,

2) Quantizes the differential frame, and

3) Reconstructs original frame by adding quantized differential frame to the other frame

4.2 Simulation Results for Video Coding using DWT

Results are presented in MATLAB simulation model for video coding using successive added difference method. This analysis presents compression using DWT.

Tthe original video 'rhinos.avi' has been taken for video coding using DWT. Input video 'rhinos.avi' has 240x320 resolution, 15fps (frames per second) and having 114 total number of frames. Applying successive added difference method and DWT compression on input video it results in highly compressed video as shown in fig3(c). Average bit rate calculation for input as well as output video is done by using average bit rate formula used by video coding standards. Average bit rate of multimedia file is the ratio of multimedia file size to the playback time of same file multiplied by eight which is as per standard definition used by video standards. The simulation results for video are as follows.

1) Calculated average bit rate for original video =27005kbps

2) Calculated average bit rate for first level compressed video from simulation model = 6868kbps

3) Calculated average bit rate for second level compressed video from simulation model =1807kbps

Thus this method results in the low bit rate video coding since bit rate of compressed video has been lowered to great extent.
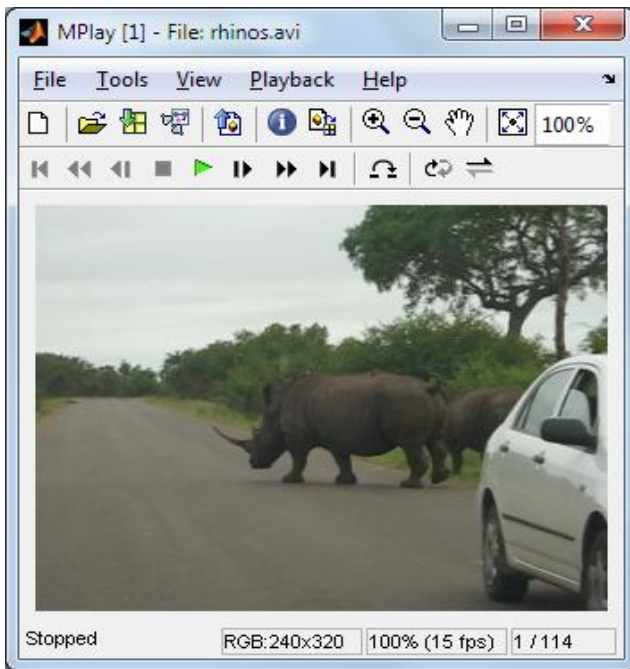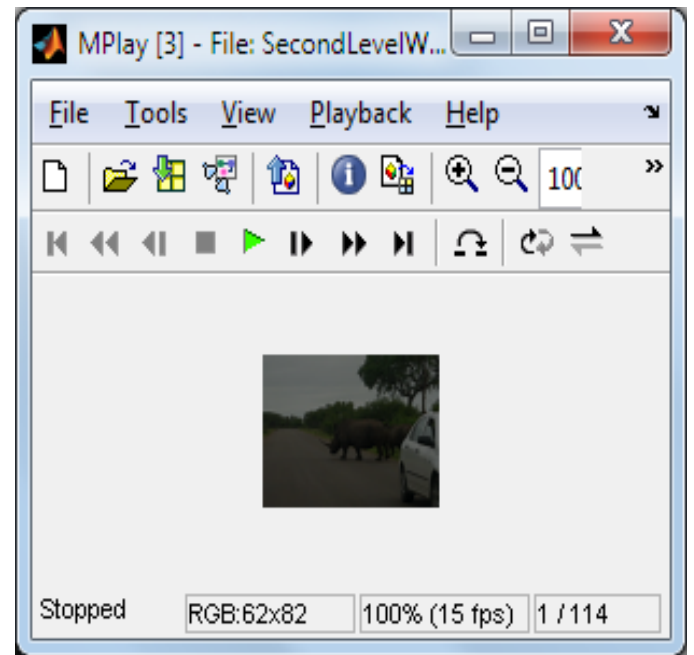
Fig.3 (a)   Original Video 'rhinos.avi

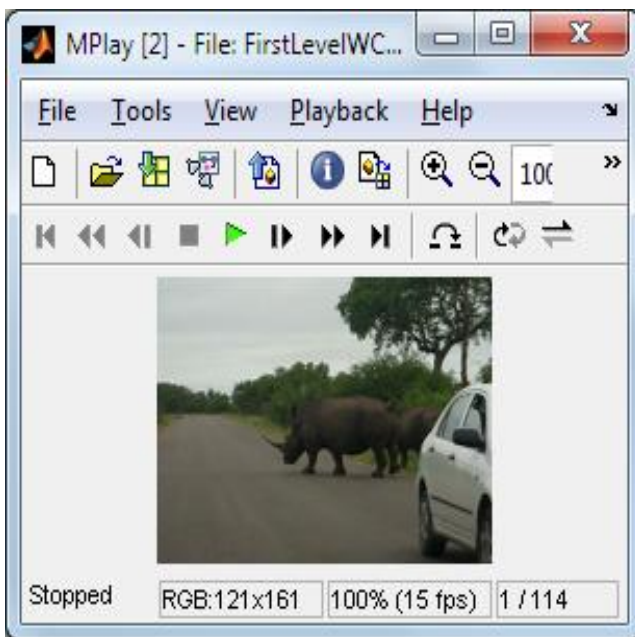**Fig.3 (c)   Second Level Compressed Video 'rhinos.avi**

5. RESULT COMPARISON

Following steps are followed for implementation of image compression using DWT algorithm.

- ➢ Store 16x16 grayscale image in work file of MATLAB software.

- ➢ Gray scale image coefficients are directly used as source file input in C code for CCS.

- ➢ Once the image coefficients are stored in Code Composer IDE, the compressed image coefficients are computed by using DWT lossy algorithm.

- ➢ The compressed image coefficients are stored in MATLAB work file. MATLAB tool is used for successful display of compressed image and verification is done with the same software tool.

Fig.3 (b)   First Level Compressed Video 'rhinos.avi

5.1 Results of Experiment

The results of experiment are as discussed below.

5.1.1 Source Image File

Still image file is first stored in MATLAB work folder. The source image is shown in fig.4 (a). This is 16x16 image file having size in .bmp format. The compressed image from DSP simulation software is shown in fig.4 (b).Verification of compressed image has been done using MATLAB software. Same image compressed using same algorithm in Matlab simulation is shown in fig.4(c).The coefficients of images compressed in DSP simulation and MATLAB simulation are shown in table1 and table2 respectively.
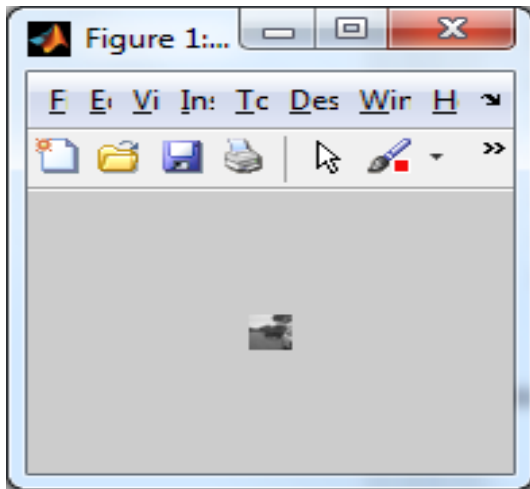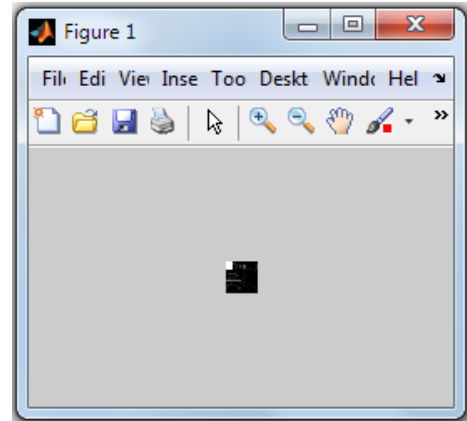

Fig. 4(b) Compressed image from DSP simulation side

Fig. 4(a) Original Input image
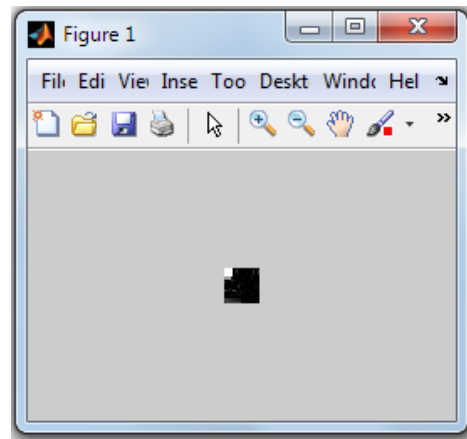

Fig. 4(c) Compressed image from MATLAB simulation

255	255	255	255	0	0	18	0	2	0	1	0	0	0	9	0
255	255	255	255	0	60	0	0	0	4	0	0	0	51	0	58
255	255	255	255	2	0	16	0	1	0	17	5	4	42	0	47
255	255	255	255	4	6	3	0	3	0	0	0	23	2	0	7
154	156	175	28	0	1	6	0	6	1	0	0	14	3	0	0
0	0	0	61	20	0	0	0	0	1	2	0	1	0	4	3
42	0	0	0	0	0	4	2	0	3	0	0	0	3	3	3
0	0	0	0	0	0	0	32	5	0	0	4	0	2	0	0
1	0	0	0	0	0	50	0	0	0	1	0	1	0	11	9
0	0	58	0	0	3	0	0	0	13	0	0	0	7	6	8
79	34	0	17	76	0	0	11	9	0	0	11	3	0	0	18
0	0	0	0	0	15	4	19	3	9	0	0	16	3	1	0
7	5	11	20	12	2	9	13	4	0	5	3	0	2	0	0
0	1	2	1	3	2	0	0	0	0	0	0	0	0	4	4
55	60	53	43	36	25	27	25	0	4	0	3	0	1	1	5
49	74	65	64	66	67	67	68	8	2	0	0	1	0	0	0

Table1. Table showing coeff. Of compressed image from DSP simulation side

255	255	255	255	3	0	2	4	3	0	6	0	0	4	0	0
255	255	255	255	55	0	0	0	0	15	0	0	1	0	0	8
255	255	255	255	4	47	0	78	0	84	0	1	0	0	4	40
255	255	255	255	14	10	6	0	0	43	17	0	31	6	3	24
0	0	0	0	2	0	6	0	0	0	5	0	0	0	21	0
0	0	0	0	0	17	2	3	0	0	2	0	0	0	7	2
0	41	78	31	61	0	2	0	0	18	0	0	0	0	0	2
0	0	0	0	0	72	13	0	0	1	0	1	0	1	0	2
0	20	24	20	15	6	0	0	0	11	0	2	0	3	0	0
107	98	114	98	97	97	97	107	8	0	4	1	0	0	0	0
0	3	0	0	0	0	3	22	0	23	0	0	0	0	0	4
0	0	25	53	4	2	6	0	18	4	0	20	0	0	2	0
16	47	0	0	13	31	0	0	0	22	8	0	0	15	0	1
18	0	0	0	0	0	38	23	9	0	3	7	0	0	18	2
0	0	0	11	9	2	0	3	0	0	1	0	3	2	0	2
6	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

Table2. Table showing coeff. of compressed image from Matlab side

5.1.2 Step wise results

The image file is read using MATLAB and its image coefficients are as shown in CCS window in fig. 5. All image coefficients values are in the range from 0 to 255. It should be noted that pixel value for gray image range from 0 to 255. Where pure black is represented by 0 and pure white by 255.[5]
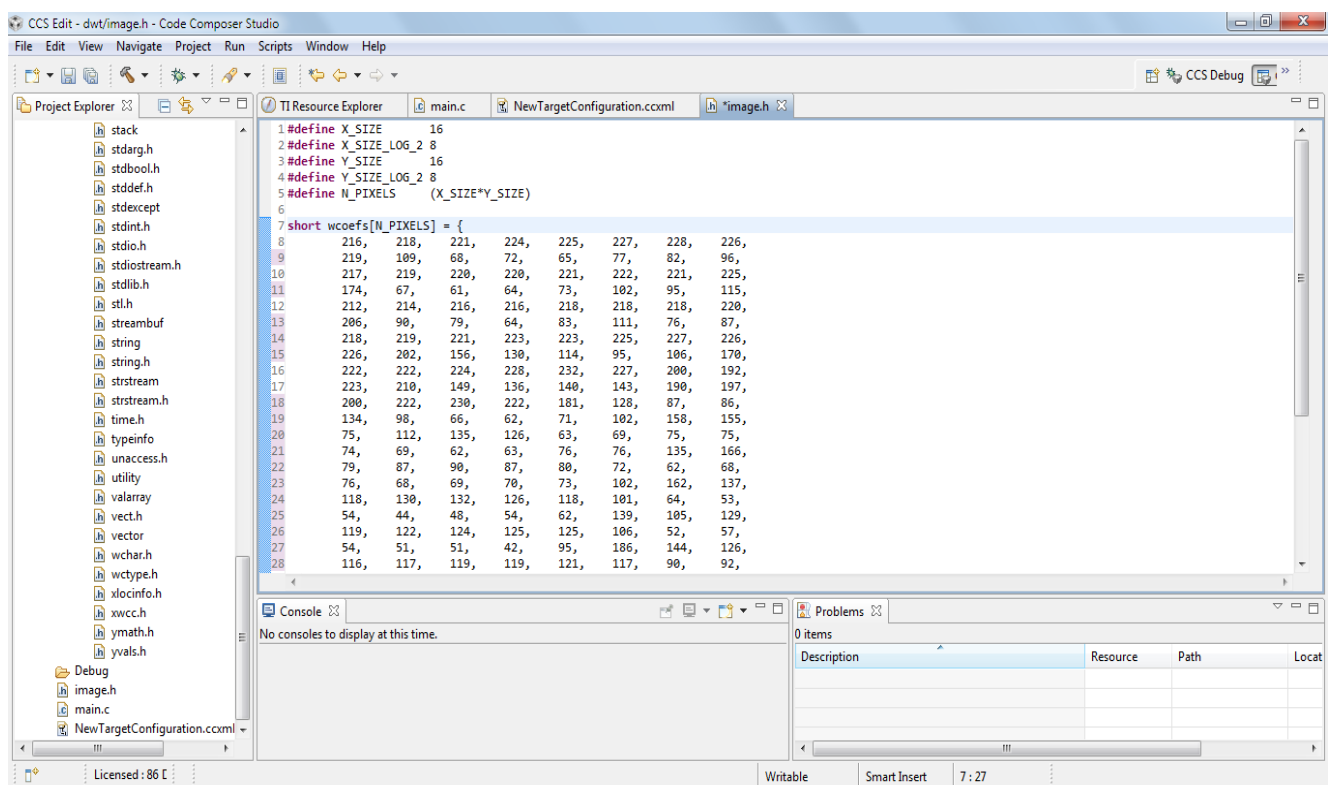

Fig.5 CCS window showing "image.h" for input 16x16 image

From fig.6, the CCS window shows the declaration of input image (16x16). This image is taken from MATLAB Work File. All these 256 coefficients of input image are stored and declared as header file of CCS IDE Environment by image.h .

DWT Algorithm is implemented on input image and for this Daubechies4 wavelet filter bank is used.

Daubechies4 have scale functions that are orthogonal and have finite vanishing moments that are the compact support. It is used mostly for better reconstruction of image[7]. DWT algorithm using Daubechies 4 filter bank to be implemented on image is in main programme. After run and debug mode, wcoefs as a result of DWT compression on input image is displayed
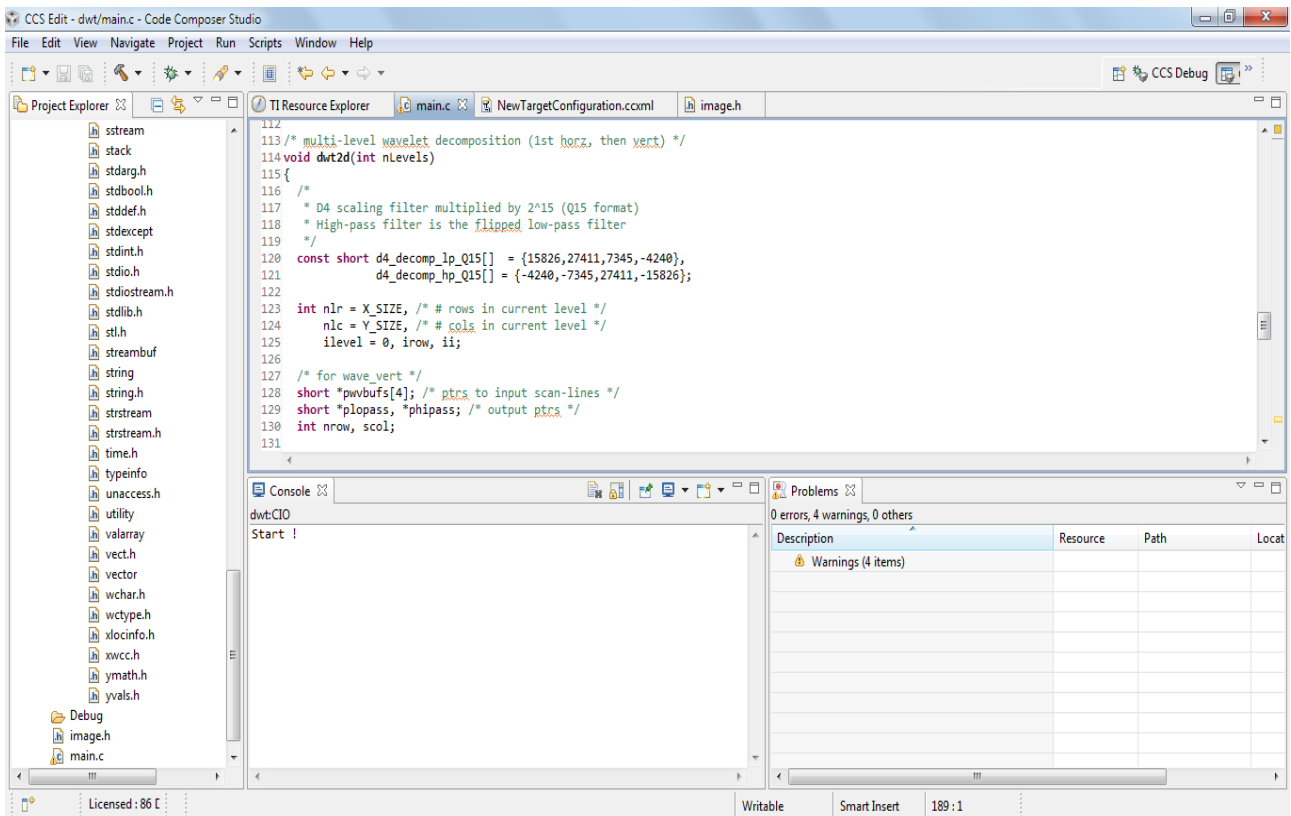

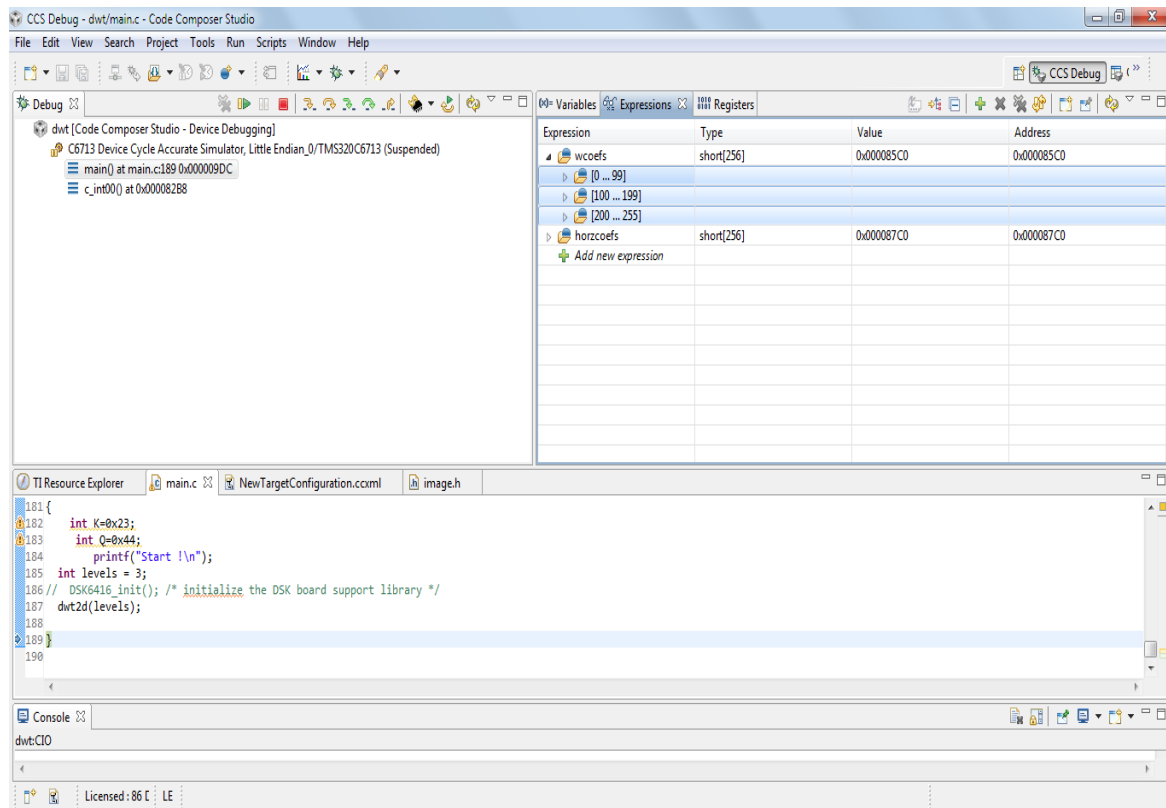**Fig.6 CCS window showing Daubechies 4 code for filtering.**

Fig. 7 CCS output window showing compressed image coefficients

The output wcoef contains 256 coefficients corresponding to compressed image as shown in fig. 7. These compressed image coefficients are to send to MATLAB work file for successful display of compressed image and to verify the results.

5.2 Validation Performance and Limiting factor

DSP simulation results are verified using MATLAB simulation results. Compression ratio for the image compressed by DSP simulation is obtained as 1.0124. Compression ratio by MATLAB simulation is obtained as 1.0124. This work shows that average simulation time of the system is 21 milliseconds and memory used is 2.5Kbyte. The coefficients of compressed image which are the results of MATLAB software and C language using Code Composer Studio (CCS), IDE Environment are closely matched. Due to processor memory limitations only small part of image has compressed.

6. CONCLUSION & FUTURE SCOPE

This paper presented an analysis of Image and Video Compression using DWT. Video coding is done by using successive added difference method for prediction of next frame. In video compression using DWT on 'rhinos.avi' original video,the method results in the low bit rate video coding since bit rate of compressed video has been lowered to great extent.

DSP processor TMS320C6713 based DWT compression system is presented in this paper. This paper include information related with the system work flow used,

implemented and tested procedure using standard development environment such as Code Composer Studio and MATLAB software. In this work, image coefficients are read using MATLAB software. The image coefficients are declared in the 'C' language programme and added as header file to CCS environment. DWT algorithm is performed by DSP processor TMS320C6713 on these coefficients. These compressed image coefficients are stored in MATLAB work file. MATLAB tool is used for successful display of compressed image and verification is done with the same software tool.

The results of MATLAB software and embedded based 'C' language in Code Composer Studio IDE environment are closely matched.

Future Scope

Due to processor memory limitations only small part of image has compressed. The work can be advanced in the direction such that system should able to do real time operation of any image size for gray as well as colour image. Here as part of JPEG 2000 only DWT algorithm is implemented but it can be advanced to do compression of images as per JPEG 2000 standard. Low bit rate video coding concept can be advanced by considering aspect of motion estimation and motion compensation.

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