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FPGA Implementation for Video Processing

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Abstract:
Intelligent video surveillance for security purposes requires real-time performance. Video compression is used in many current and emerging products. It is at the heart of digital television set-top boxes, HDTV decoders, DVD players, video conferencing, Internet video, and other applications. These applications benefit from video compression in the fact that they may require less storage space for archived video information, less bandwidth for the transmission of the video information from one point to another or a combination of both. Besides the fact that it works well in a wide variety of applications, a large part of its popularity is that it is defined in two finalized international standards, with a third standard currently in the definition process. The advancement of Field Programmable Gate Array (FPGA) enables development and implementation of a system with reconfiguration capability. Besides, it also offers competitive cost in comparison to an Application Specific Integrated Circuit (ASIC) deployment of the system. In recent years there is an increase research in the effort to implement video surveillance and processing system using FPGA.

Keywords: *HDTV Decoders, DVD Players, FPGA, ASIC, video processing*

1. Introduction

With the advancement of technology, image and video processing techniques are widely adopted and used in application such as video surveillance and security, facial recognition etc. such application may demand for real-time performance. The data of images to be process can also be huge with the adoption of high-definition format. This requirement would translate into a large amount of computing resource for CPU processing, memory and data bandwidth as well as storage space. On the other hand, system for application such as video surveillance may be deployed using an embedded system environment where there is very limited amount of processing power, memory bandwidth and storage.

On the other hand, Field Programmable Gate Array (FPGA) emerges as an alternative solution to implement system with large logic requirement at a lower cost than Integrated Circuit (lC) design. Besides, FPGA also allows for system reconfiguration with shorter time-to-market in comparison to Application Specific IC (ASIC) designed system. Such benefits attract a researcher to develop and implement digital processing systems using FPGA. FPGA provides an ideal platform to implement a hardware form of image and video processing engine while providing the performance close to a custom IC environment. This is in-line with the definition of hardware accelerator where specific processing or calculation is implemented using custom hardware setup.

Nevertheless, majority of these researches focused on the development of stand-alone hardware accelerator to accelerate a specific task or algorithm of video processing. The developed hardware accelerator will requires modification before it is able to be adopted by different system and take advantage of the acceleration provided. This reduces the reusability of the developed hardware accelerator system to help improves the performance of image and video processing system, especially in the embedded environment.

2. Methodology

2.1. DWT for Video Processing

The Wavelet Transform (WT) is a way to represent a signal in the time-frequency form. Wavelet transform are based on small waves, called wavelets, of varying frequency and limited duration Wavelet Transform uses multiple resolutions where different frequencies are analyzed with different resolutions. This provides a more detailed picture of the signal being analyzed.

A transform can be thought of as a re-mapping of a signal that provides more information than the original. The Fourier transform fits this definition quite well because the frequency information it provides often leads to new insights about the original signal. However, the inability of the Fourier transforms to describe both time and frequency characteristics of the waveform led to a number of different approaches. None of these approaches was able to completely solve the time–frequency problem. The wavelet transform can be used as yet another way to describe the properties of a waveform that changes over time, but in this case the waveform is divided not into sections of time, but segments of scale.
The DWT represents the signal in dynamic sub-band decomposition. Generation of the DWT in a wavelet packet allows sub-band analysis without the constraint of dynamic decomposition. The discrete wavelet packet transform (DWPT) performs an adaptive decomposition of the frequency axis. The specific decomposition will be selected according to an optimization criterion.

2.1.1. Proposed DWT Algorithm

- The following is a general overview of the MPEG process.
- The video is converted into frames, which is nothing but the image format.
- The image is broken into 8x8 blocks of pixels.
- Working from left to right, top to bottom, the DWT is applied to each block.
- Each block is compressed through quantization.
- The array of compressed blocks that constitute the image is stored in a drastically reduced amount of space.
- When desired, the image is reconstructed through decompression, a process that uses the inverse Discrete Wavelet Transform (IDWT).

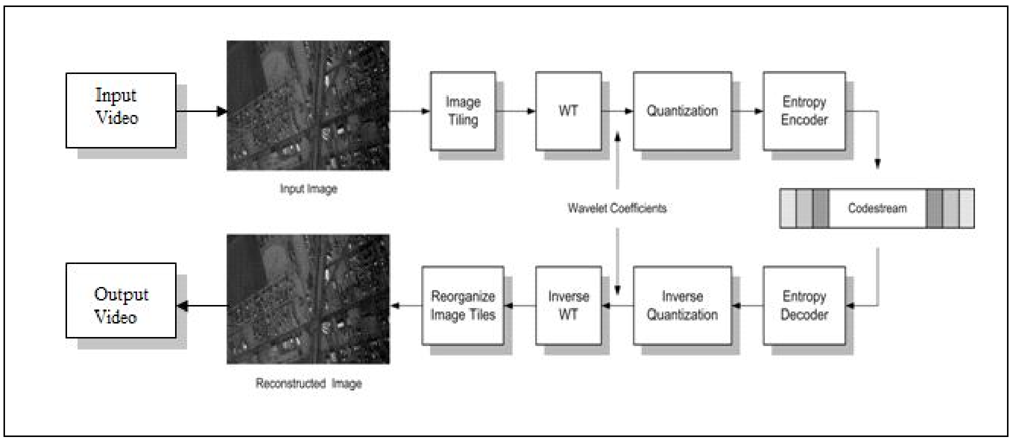

Figure 1: block diagram of Image processing

The Discrete Wavelet Transform (DWT), based on time-scale representation, provides efficient multi-resolution sub-band decomposition of signals. It has become a powerful tool for signal processing and finds numerous applications in various fields such as audio compression, pattern recognition, texture discrimination, computer graphics, etc. Specifically the 2-D DWT and its counterpart 2- D Inverse DWT (IDWT) play a significant role in many image/video coding applications.

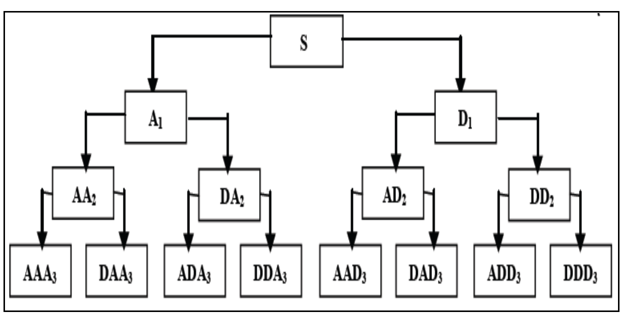

Figure 2: DWT Decomposition

The DWT architecture, the input image is decomposed into high pass and low pass components using HPF and LPF filters giving rise to the first level of hierarchy. The process is continued until multiple hierarchies are obtained. A1 and D1 are the approximation and detail filters.
The barbera image is first decomposed into four sub bands of LL, LH, HL and HH. Further the LL sub band is decomposed into four more sub bands as shown in the figure. The LL component has the maximum information content as shown. the other higher order sub bands contain the edges in the vertical, horizontal and diagonal directions. An image of size N X N is decomposed to N/2 X N/2 of

four sub bands. Choosing the LL sub band and rejecting the other sub bands at the first level compresses the image by 75%. Thus DWT assists in compression. Further encoding increases compression ratio.

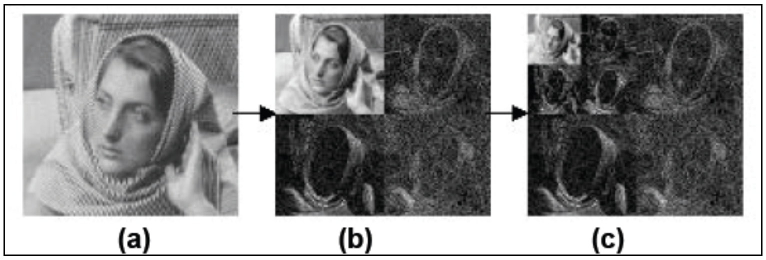

Figure 3: DWT Decomposition of barbera image
(a). input image
(b). after one level 2D-DWT Decomposition
(c). after two level 2D-DWT Decomposition

2.2. Motion Compensation

Consider the case of a video sequence where nothing is moving in the scene. Each frame of the video should be exactly the same as the previous one. In a digital system, it should be clear that, we only need to send one frame and a repetition count. Consider now, a dog walking across the same scene. The scene is the same throughout the sequence, but only the dog moves. If we could find a way of only sending the motion of the dog, then we can save a lot of storage space. This is an oversimplified case of motion video, but it reveals two of the most difficult problems in motion compensation:

- How can we tell if an image is stationery?
- How do we extract the part of the image that moves?
- We can try to answer these questions by some form of comparison between adjacent frames of the sequence. We can assume that the current and previous frames are available for the comparison. The simple comparison technique is too simple and is like a frame-by-frame DPCM. This has a few problems :
- The pixel compare will rarely produce a zero difference, due to quantisation noise in the system (this can be overcome with a threshold).
- Images are rarely stationery.

Therefore, more sophisticated techniques are needed. This problem is usually addressed by dividing the image into blocks. Each block is examined for motion. If a block is found to contain no motion, a code is sent to the decompresser to leave the block the same as the previous one.

If enough processing power is available, still more powerful techniques may be applied. For examples, blocks may be compared to previous block to see if there is a difference between the two. Only this difference (*motion vector*) is sent.

2.3. Technologies

Image compression techniques are used to reduce redundancy in video data without affecting visual quality. It mostly used in video conference and real time application.

Methods for compression There are two methods for compression

1. Discrete Cosine Transform (DCT)
2. Discrete Wavelet Transform (DWT)

In this paper DCT (Discrete Cosine transform) and DWT (Discrete Wavelet Transform) are used for image compression. Here DWT will perform the adaptive filtering and DCT will use these weighted values as DCT coefficient**.** We apply DCT and DWT techniques are applied to check the performance, based on compression ratio is analyzed.

<u>2.3.1. DCT (Discrete Cosine Transform)</u>

A discrete cosine transform (DCT) express a sequence of many data points in terms of a sum of cosine functions at different frequencies. DCTs are important to lossy compression of audio (e.g. MP3) and images (e.g. JPEG). Disadvantages of DCT.

- Only spatial correlation of the pixels inside the single 2-D block is considered and the correlation from the pixels of the neighboring blocks is neglected.
- Impossible to completely decorrelate the blocks at their boundaries using DCT
- Undesirable blocking artifacts affect the reconstructed images or video frames. (High compression ratios or very low bit rates.
- Poor identification of which data is relevant to human perception
- Less compression ratio.

2.3.2. DWT (Discrete Wavelet Transform)

The Discrete Wavelet Transform (DWT) is an efficient and useful tool for signal and image processing applications and will be adopted in many emerging standards, starting with the new compression standard JPEG2000. This growing "success" is due to the achievements reached in the field of mathematics, to its multiresolution processing capabilities, and also to the wide range of filters that can be provided. These features allow the DWT to be tailored to suit a wide range of applications.

In the early 80s, in the quest for more flexibility and rapid prototyping at low cost, custom logic based re-configurable hardware in the form of Field Programmable Gate Arrays (FPGAs) has been introduced into the IC market. However, although the fact FPGA devices offer an attractive combination of low cost, high performance, and apparent flexibility, their programming model is at the gate level. To allow an FPGA novice signal/image processing developer to benefit from the advantages offered by such devices, high level solutions are desired. It is the aim of this paper to present a framework and the preliminary results of an FPGA-based Discrete Wavelet Transforms system. The proposed environment is a Java-based Graphical User Interface (GUI) combined with both a wavelet database and a parameterized VHDL code generator.

The Discrete Wavelet Transform passing a signal to image, through a pair of filters, a low pass filter and a high pass filter. The low pass filter yields low resolution signal. The high pass filter yields difference signal. The outputs of these filters are down sampled by two. The down sampled outputs have the same number of bits as the input signal. The original signal is reproduced, when the up sampled output of the low pass filter is added to the up sampled output of the high pass filter. The output of the high pass filter is fed into another pair of filters and the process repeated. Haar wavelet transform is the simple example of discrete wavelet transforms . The wavelet transform (WT) has gained widespread acceptance in signal processing and image compression. Because of their inherent multi-resolution nature, wavelet-coding schemes are especially suitable for applications where scalability and tolerable degradation are important. Recently the JPEG committee has released its new image coding standard, JPEG-2000, which has been based upon DWT. Discrete wavelet transform (DWT), which transforms a discrete time signal to a discrete wavelet representation.

3. Hardware Implementation

Xilinx ISE 9.1 was used as a synthesis tool for the IDWT architecture built. Depending on the hugeness of architecture, FPGA of that comparison was to be employed. It thus included the family of Virtex 5 FPGA with XC5VLX50 device, package as FF324 and speed of -3. The RTL Schematic for the discrete wavelet transform is shown as given below.

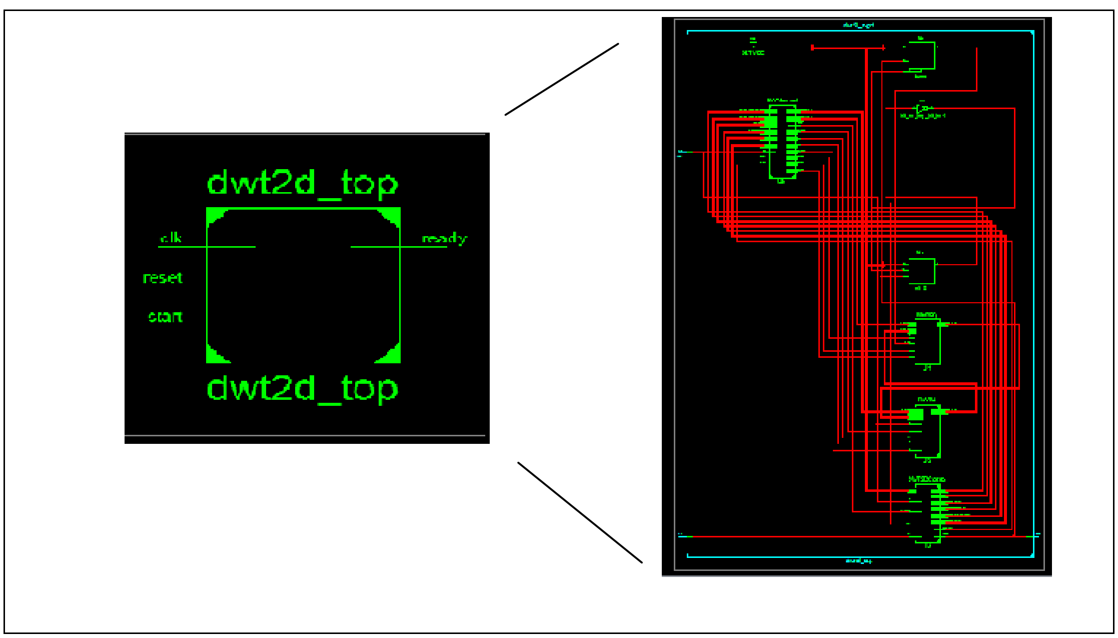

Figure 4: RTL Schematic of DWT-2D

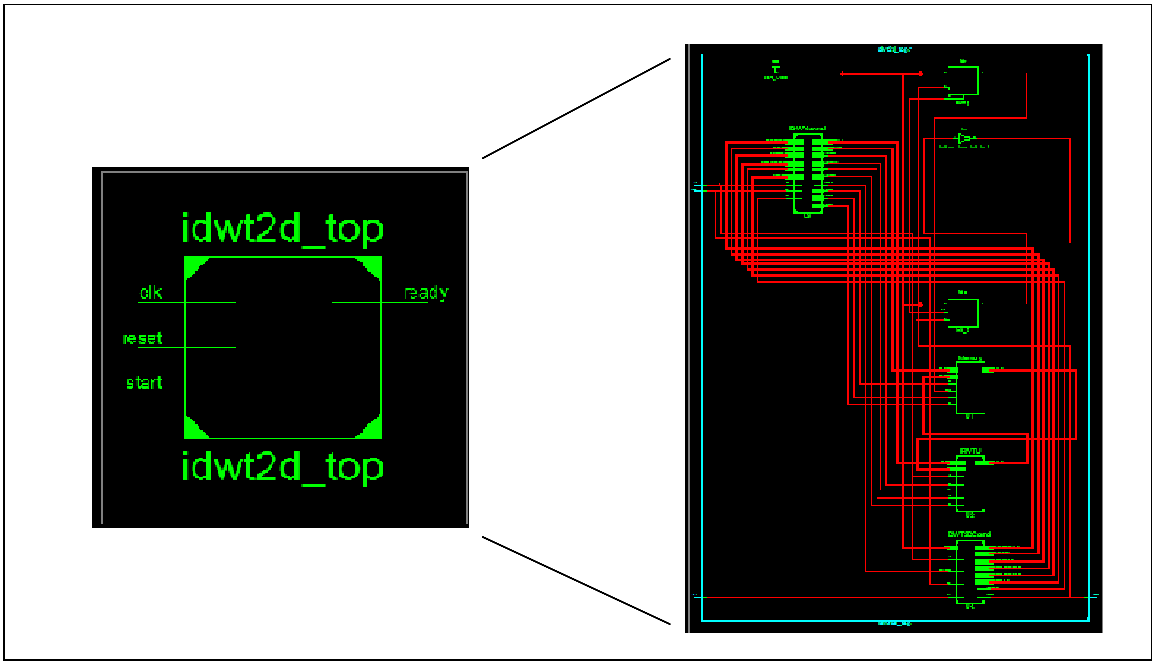

Figure 5: RTL Schemtic of IDWT-2D

4. Matlab Results

Here the video is converted into the frames which are nothing but the image and then they are compressed. Most of the image compression techniques use DWT (Discrete wavelet Transform) based transformation for compression. DWT is used for image decomposition and an N X N image is decomposed using DWT into hierarchical blocks the decomposition is carried out until the sub block is of size 8 x 8. For an image of size 64 x 64, first level decomposition gives rise to 32 x 32 (four sub bands) of sub blocks, further decomposition leads to 16 x 16 (sixteen sub bands), which can further decamped to 8 x 8 at the third hierarchy. The third level of hierarchy, there are 64 sub blocks each of size 8 x 8. Figure 6 shows the decomposition levels of input image of size 64 x 64 using 2D-DWT. The sub bands are further decomposed into four sub bands as shown in Figure 6.

LL	LH	LL	LH	LL	LH	LL	LH
HL	HH	HL	HH	HL	HH	HL	HH
LL	LH	LL	LH	LL	LH	LL	LH
HL	HH	HL	HH	HL	HH	HL	HH
LL	LH	LL	LH	LL	LH	LL	LH
HL	HH	HL	HH	HL	HH	HL	HH
LL	LH	LL	LH	LL	LH	LL	LH
HL	HH	HL	HH	HL	HH	HL	HH

Figure 6: DWT result after two level decomposition

The image compression is done using the DWT. The decompressed image is reconstructed using IDWT.

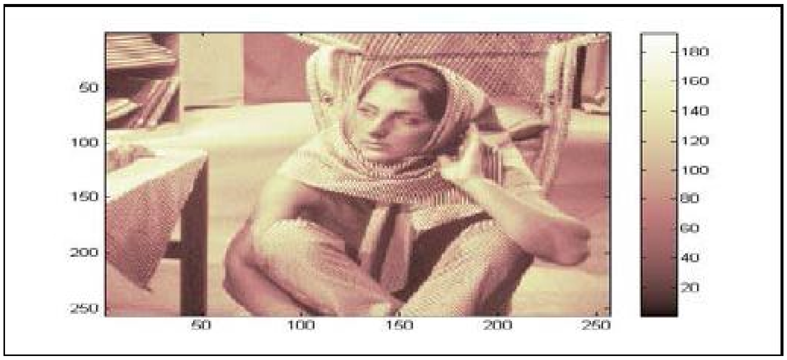

Figure 7

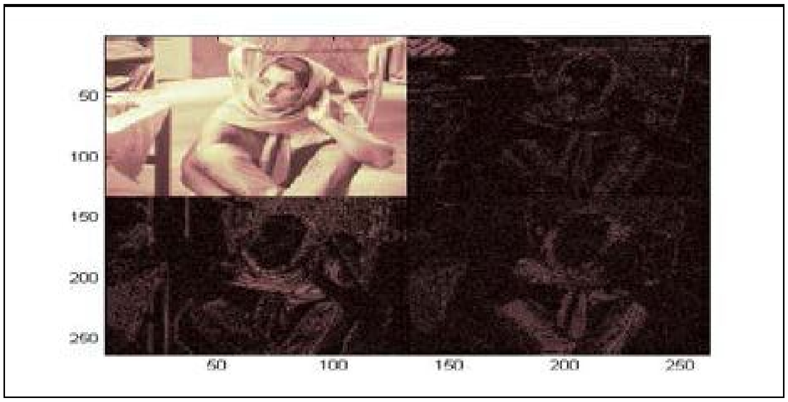

Figure 8

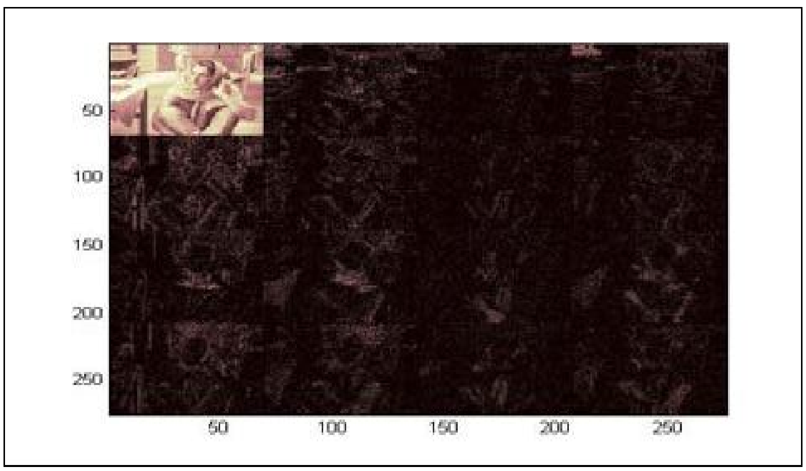

Figure 9

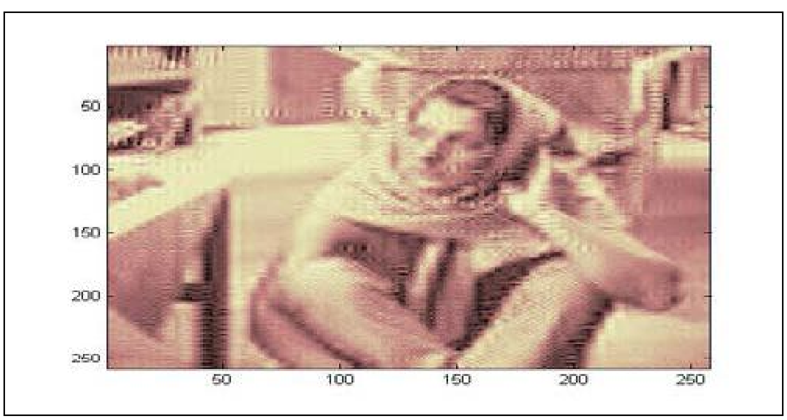

Figure 10: Image compression and decompression using DWT

The input image is decomposed into sub bands using DWT, the input image of size N x N is decomposed into 1-level (Shown in (Figure 8)), further the four sub bands is decomposed into 8 sub bands using DWT (Shown in (Figure 9)), the decomposed sub bands are reorganized into column matrix . The compressed image is further decompressed using the output layer (compressed output and decompressed output are not shown in the figure). The decompressed output from the output layer is rearranged and inverse DWT is performed (shown in (e)), the second level inverse DWT is performed and the final output is reconstructed to obtain the original image. In this proposed architecture, the input image is first decomposed into multiple sub blocks using hierarchical DWT architecture.

4.1. Applications

Some of the major fields in which digital video processing is widely used are mentioned below

- Image sharpening and restoration
- Medical field
- Remote sensing
- Transmission and encoding
- Machine/Robot vision
- Color processing
- Pattern recognition
- Video processing
- Microscopic Imaging
- Others

5. Conclusion

In this paper the methods for optimal computer aided designs of selected DWT based video compression techniques are carried out. The design is simulated in MATLAB and the hardware reference model is verified. The weights and biases obtained using the hardware environment is used in developing VHDL model. The computation complexity of the DWT architecture can be further reduced by designing the subsystems, selection of appropriate data path operators and state machines for data flow logic.

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