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Design and FPGA Implementation of DWT, Image Text Extraction Technique

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Abstract

In digital image processing, detection and extraction of text from a documentary image is found a challenging task, especially for inclined, vertical and circular text. In the extraction method, the image is segmental in text regions from a compound image. There are many techniques to segment the image but HAAR DWT is one of the popular and fastest methods, because its coefficients are either 1 or -1. HAAR DWT detects 3 kinds of edges for colour images and removes non texted regions. The paper focuses on the design, modeling and simulation of the proposed method with the help of VHDL programming language. The design will be compared with the existing methods, and the speed and existing hardware is optimized in terms of memory and time parameters. The design is developed in Xilinx 14.2 ISE software and is synthesized on Virtex -5 FPGA.

Keywords: Image Extraction, HAAR Discrete Wavelet Transform (DWT), Field Programmable Gate Array (FPGA)

1. Introduction

An image [1, 7, 8] is a 2D array of values representing light intensity. In the Digital Image Processing, the term image refers to a digital image and its manipulation by means of processor. An image is said to be the function of the light intensity, f(x,y) where f is the brightness of the point (x, y) and x and y represent the spatial coordinates of a picture element, or pixel. With the help of convention, spatial reference of the pixel with the coordinates (0, 0) is located at the top, left corner of the image. Fig. 1 shows the pixel, in which the value of x increases moving from left to right side, and the intensity of y increases from top to bottom. A digital image composed of several picture elements called pixels. The sample and the brightness at one point of an image is represented by the pixel. A digital

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image is a two dimensional discrete signals with N x N array of elements. Each element is the array is a number which represents the intensity of a sampled signal. The conversion of an image into digital is done using camera or scanner. Digital images can be read directly on a computer screen. For example a 4 x 4 image in matrix format and its 3D view is shown in fig. 2

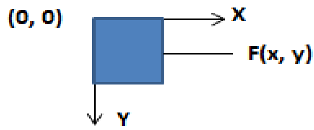

Fig.1 Special reference of the (0, 0) pixel[7]

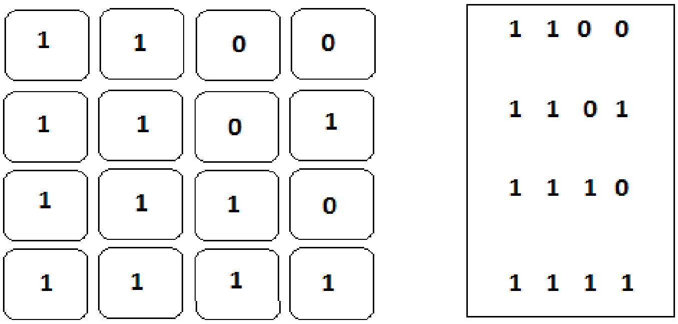

Fig. 2 Digital image representation [8]

Recent development and advancement in the research areas of image processing have much interest in content retrieval and derived in the perceptual and semantic content as characters and text with colour images. The human behavior and perceptual includes text, color, shape, pixel intensity semantic includes events objects, interrupts and their relations. Image contents can be described using text and their analysis, that can be used easily and clearly to describe the features of an image. Characters and text data can be embedded into an image. Up to now, all have been extracted using two basic techniques. These techniques are edge detection and component connection based technique. The system used for text receives an input in the form of discrete values from an image or a sequence of images. Text recognition [4, 5] and decoding problem can be divided into the following parts. (i) Detection of input text (ii) localization of input text, (iii) tracking on encoded text (iv) Extraction or decoding and enhancement of text, and (v) recognition of decoded text. The meaning of and text detection is to detect the text which are presences in image or embedded key in the encoding process. In the extraction method, present threshold values of images are needed for scene based change detection because the portion occupied by a text region relative to the entire image is usually small. Text extraction is based on the difference between two consecutive frames and then used this scene change information for text detection. Edge-based methods are based on edge detection and contrast between the text and the background. Text boundary has edges, which are identified and merged with the help of a particular transform. Thresholding operation of an image is applied with the help of differential filters to an input image and finds vertical edges and smoothing operation used to eliminate small edges. The colour image RGB components [4] of an input image are combining to give an intensity image Y as follows:

$$Y = 0.299R + 0.587G + 0.114B \quad (1)$$

Where, R, G and B are red, green and blue components of a colour image. The canny operators are used to detect edges of an image. The watermark text encryption and decryption [9] is also based on the text localization. The methods of text localization are divided into two types: region based and texture based method. Regions based defined methods are using the properties of the color or gray scale in a text region or their differences with the corresponding properties of the background.

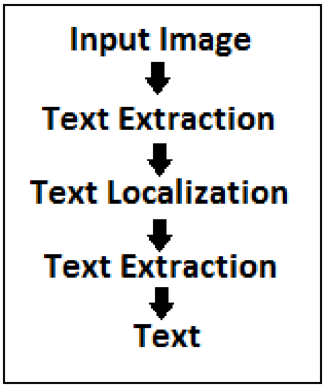

Fig. 3 Steps in text extraction

The organization of the paper is as follows. Section-1 presents the introduction; section -2 related works, section-3 DWT and methodology. Results are presented in section 4 and conclusion is followed in section 5.

2. Related Work

A number of methods have been proposed already for text and character extraction. Binarisation is one of the most processes used in the extraction of the text. Arnab *et al* [1] proposed that natural texture synthesis is an important problem in Image processing and computer vision. Synthesis models used for texture analysis can be broadly classified within two domains, spatial and transformed domains respectively. The spatial-domain models are also classified in two basic categories; Linear Model and non- linear models. A. Kejariwal, *et at* [2] explained proxy based portioning method to extract the watermark for mobile devices. Bin Cheng *et at* [3] proposed a process to build the directed graph, in which the vertices involve all the samples and the ingoing edge weights to each vertex describe it-norm driven reconstruction from the remaining samples and the noise. After it, a series of new algorithms for various matches in learning tasks are derived upon the graphs e.g., data clustering, sub space learning, and semi supervised learning. Chung-Wei Liang *et at* [4] paper presents an efficient yet simple method to extract text regions from static images or video sequences in which Haar DWT operates the fastest among all wavelets because its coefficients are either 1 or -1. This is one of the reasons to employ Haar DWT to detect edges of candidate text regions and the detailed sub bands as component contain both text edges and non-text edges. The intensity of the text edges is different from that of the non-text edges, and texture analysis is possible. Moreover, it is possible to apply thresholding to preliminary remove the non-text edges. The regions of texture are composed of vertical edges, horizontal edges and diagonal edges. Mathematical morphological dilation operators are applied to connect isolated text edges of each detail component sub-band in a transformed binary image. With the help of experiment results, the real components of text regions are the overlapped portion of three kinds of dilated edges. So, we can apply morphological AND operator to three kinds of dilated edges and obtain the final text regions correctly. Dr. N. Krishnan *et at* [5] A method of text extraction from images is proposed using the Haar Discrete Wavelet Transform, the Sobel edge detector, the weighted OR operator, thresholding and the morphological dilation operator. These mathematical tools are integrated to detect the text regions from the complicated images. According to the experimental results, the proposed method is proved to be efficient for extracting the text regions from the images. Haar DWT detects three kinds of edges of the original image. 2D Haar DWT decomposes an input image into 4 sub-bands, one average component (LL) and 3 detailed components (LH, HL, HH).The illumination components are transformed to the wavelet domain using Haar wavelet. This stage results are in the four bands LL, LH, HL, and HH sub image coefficients. Jian-Xia Wang et *at* [6] focused on the vehicle plate recognition based on grey projection segmentation approach. It is two stage segmentation approaches consist of coarse and accurate segmentation, helpful for good segmentation and increased speed in recognition process of text and characters. Saraju P et *at* [9] presented an FPGA based implementation of an invisible spatial domain watermarking encoder. The watermarking encoder consists of a watermark generator, watermark insertion module, and a controller. Most of the invisible watermarking algorithms available in the literature and also the algorithm implemented in this paper insert pseudorandom numbers to host data. Therefore, we focus on the structural design aspects of watermarking generator using linear feedback shift register. We synthesized the prototype watermarking encoder chip using Xilinx FPGA. Both encryption and digital watermarking techniques need to be incorporated in a digital rights management framework to address different aspects of content management. The synthesis of the chip is carried out using Synplify ProTM tool targeting Xilinx Virtex - 2 technology with XCV50-BG256-6 target device. Sunil Kumar et *at* [10] proposed a novel scheme for the extraction of textual areas of an image using globally matched wavelet filters. A technique based on clustering approach has been devised for estimating globally matched wavelet filters using a collection of ground truth images. In the paper it is extended the text extraction scheme for the segmentation of document images into texture analysis, background, and picture components which include graphics and continuous tone images. In the method, multiple classifiers, two class fisher classifiers have been used for this purpose. It is also exploited contextual information by using a Markov random field formulation based pixel labeling scheme for refining of the segmentation results. The papers consist of the approaches called M-bad, fisher classifier and cluster based approach and simulation results are examined in MATLAB. Xiaoqing Liu et *at* [11] obtained experimental results recorded based on criteria such as invariance with respect to lighting conditions, rotation, color, and distance from the camera (scale) as well as horizontal and/or vertical alignment of text in an image. Several experiments have also been conducted for images containing 8 different font styles and text characters belonging to language types other than English. Yuichi Tanaka et *at* [12] used direction determining methods for the adaptive directional WT (Wavelet transforms) have been discussed. Wavelet Transforms are regarded as pre filtering steps by the 2-D filter bank or the directional WT for fixed directions. The obtained sub bands are used as reference frames for the direction calculation of the adaptive directional WT. The proposed framework requires fewer filtering operations than the conventional FS-WTs. In image and video processing using wavelet transform (WT) [12], multi resolution decomposition is one of the most important features. It represents an image by several. Traditionally, 2-D WT is based on 1-D filtering along horizontal and vertical directions. Four sub bands LL, LH, HL, and HH are obtained from the first level 2 DWT by extracting edges, i.e., regions containing high-frequency, along horizontal, vertical or diagonal orientation from the original image.

3. Discrete Wavelet Transform (DWT)

The two-dimensional extension of DWT [4, 12] is essential for transformation of two-dimensional signals, such as a digital image. A two-dimensional digital signal can be represented by a two-dimensional array $X[M, N]$ with M rows and N columns, where M and N are nonnegative integers of 2D image array. The simple approach for two-dimensional implementation of the DWT is to perform the one-dimensional DWT row-wise to produce an intermediate result and then perform the same one-dimensional DWT column-wise on this intermediate result to produce the final result. This is shown in Fig. 4. This is possible because the two-dimensional scaling functions can be expressed as separable functions which is the product of two-dimensional scaling function such as $\Phi_2(x, y) = \Phi_1(x)\,\Phi_1(y)$. The same is true for the wavelet function $\Psi(x, y)$ as well. Applying the one-dimensional transform in each row of image, two sub-bands are produced in each row. When the low-frequency sub-bands of all the rows (L) are put together, it looks like a thin version (of size $M \times \frac{N}{2}$ of the input signal). Similarly put together the high-frequency sub-bands of all the rows to produce the H sub-band of size $M = \frac{N}{2}$, which contains mainly the high-frequency information around discontinuities in the input signal as edges. So that, applying a one dimensional DWT column-wise on these intermediate results L and H sub-bands four sub-bands LL, LH, HL, and HH [4, 8] of size $\frac{M}{2} \times \frac{N}{2}$ are generated. LL is a coarser version of the original input signal. LH, HL, and HH are the high frequency sub-band containing the detail information of the image. It is also possible to apply one-dimensional DWT column-wise first and then row-wise to achieve the same result.

The multi-resolution decomposition approach [8] in the two-dimensional signal is demonstrated in Fig. 4 After the first level of decomposition, it generates four sub-bands LL_1, HL_1, LH_1, and HH_1. Considering the input signal is an image, the LL_1 sub-band can be considered as a 2:1 sub-sampled (both horizontally and vertically) version of image. The other three sub-bands HL_1, LH_1, and HH_1 [8, 12] contain higher frequency detail information. These spatially oriented (horizontal, vertical or diagonal) sub-bands mostly contain information of local discontinuities in the image and the bulk of the energy in each of these three sub-bands is concentrated in the vicinity of areas corresponding to edge activities in the original image. In discrete wavelet transform six major steps of image compression. These encoding processes are following step-by-step. The encoding and decoding scheme of the DWT is listed step by step applied for the division of sub bands of images.

Fig. 4 Extension of DWT in 2D signals [8]

Encoding Process

The steps of encoding8 process are given below.
Step1: first the original image passed through a combination of filter, such as low-pass and high-pass filter. These filters are applying each row.
Step 2: Then output image of the Bothe low-pass and high-pass filter is L_1 and H_1, these are combining into$T_1 = [\, L_1 \; H_1 \,]$.
Step 3: After the filtering the combine output T_1 of these filters are down sampled by the 5.
Step 4**:** Now, again T_1 has been passed through high pass filter and low filter by applying on each column.
Step 5: Let suppose the output of the step 4 is L_2 and H_5. Then H_2 and L_2 combine into $T_3 = \begin{bmatrix} L_2 \\ H_2 \end{bmatrix}$
Step 6: After the filtering the combine output T_3 of these filters are down sampled by the 5. This is compressed image of the processing.

Decoding Process

The decoding process [8] is not exact reverse of the encoding process. The steps of the decoding process are following.
Step 1: First extract low pass filter image and high pass filter image from the compressed image. The low pass filter image is taking by upper half rectangle matrix and high pass filter image is taking by down half rectangle matrix.
Step 2**:** These images are up sampled by 5.
Step 3: Then the summation of both images take into one image is called R_1.
Step 4**:** Then again extract low pass filter image and high pass filter image by simply dividing vertically part of the image. First half is low pass filtered image part. And second half is high pass filter image.
Step 5**:** After then above process take summation of both images. It is the output of reconstructed image.

So, in the DWT we get very high extraction ratio, and also lose minimum amount of information. But if more than one level then get more extraction ratio but the reconstructed image is not identical to original image. The discrete wavelet transform is a very useful tool for signal processing and image analysis especially in multi-resolution representation. In DWT method, signals are decomposed into different components in the frequency domain. 1D DWT decomposes an input sequence into two components the average component and the detail component by calculations with a low-pass filter and a high-pass filter [9].

LL	HL
LH	HH

Fig. 5 DWT decomposition scheme [4, 12]

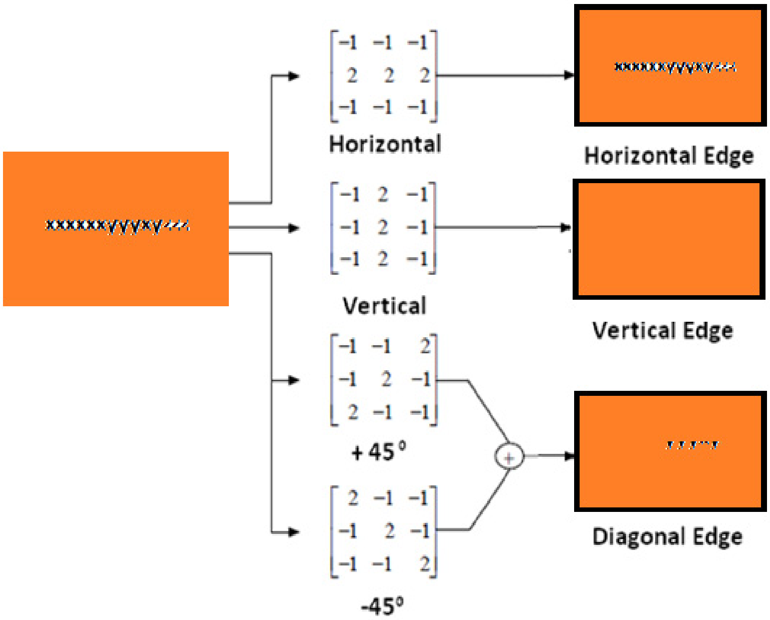

Fig. 6 Edge detection using mask operation [4]

2D DWT decomposes an input image into four sub-bands, one average component (LL) and three detail components (LH, HL, HH) as shown in Fig. 6. In image processing, the multi-resolution of 2D DWT has been employed to detect edges of an original image. In the process of wavelet transform, 2D DWT can detect three kinds of edges at a time while traditional edge detection filters. Three kinds of edges are detected using four kinds of mask operators with the help of traditional edge detection filters. That's what the processing times of the traditional edge detection filters is slower than 2-D DWT. DWT filters decompose the gray image into sub-bands as horizontal, vertical and diagonal edges [4]. In the filtration, three kinds of edges present in the detail component sub-bands but look unobvious. The processing time decreases with the replacement of the 9-7 taps DWT filters with Haar DWT, if the detected edges in image become more obvious. With the help of two ordered 1-D DWT, 2-D DWT is achieved by operations based on row and column values. Row line operation is performed to obtain the result shown in Fig. 8 matrix and column operation is transformed by to get the final resulted 2-D Haar DWT is shown in matrix. 2-D Haar DWT decomposes a gray-level image into one average component sub-band and three detail component sub-bands. The morphological operations like erosion and dilations are used for better approach of refining text region extraction.

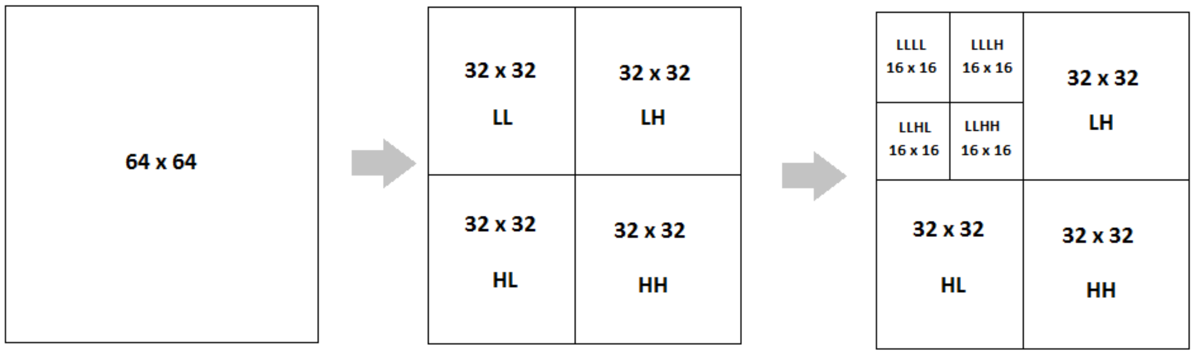

Fig. 7 Decomposition scheme of Haar Transform [8]

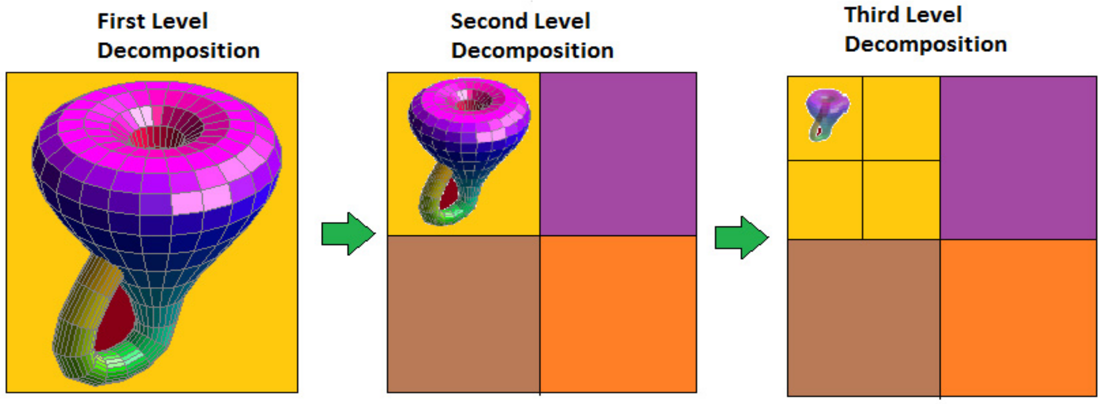

Fig. 8(a) Original image and (b) DWT coefficients (c) DWT sub coefficients [8]

Mathematical morphological operations are very much helpful in the removal of non-texted regions and various types of boundaries distribution as horizontal edge, vertical edge, diagonal etc are clubbed together when they are segregated separately in unwanted non-text regions. The text region of identified images consists of all these boundary and region information can be the area where such types of boundaries will be amalgamated. The edge and boundaries are associated with one other in diversified directions and are normally short. Dilation and erosion help for the text and character extraction deployment for associating separated candidate text boundaries in each detail constituent sub band of the binary image.

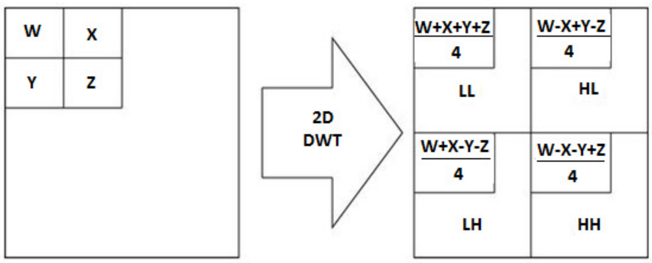

Fig. 9 Image matix with 2D DWT decomosition

4. Results & Discussions

Fig. 10 and 11 show the snapshot results for 2D DWT algorithm and RTL view. The simulation is carried out for 64 x 64 pixels colour images

Step input1: reset =1, clk is applied for synchronization and then run.

Step input 2: reset =0, clk is applied for synchronization,

In the modelsim waveforms, image_in_x_axis and image_in_y_axis, represents the integer value of image at discrete points at X, and Y axis respectively which is a matrix of 64 pixels vales. Sample_x_axis and Sample_y_axis, represents the integer value of image in discrete samples at X and Y axis respectively by which image should be modeled. P_state and n_state are the present state and next state to develop the chip using Finite State Machine (FSM). The RTL view of the developed and synthesized chip is shown in fig. 11 which has the details of the pins of the designed chip. Table 1 list the functionality of the chip.

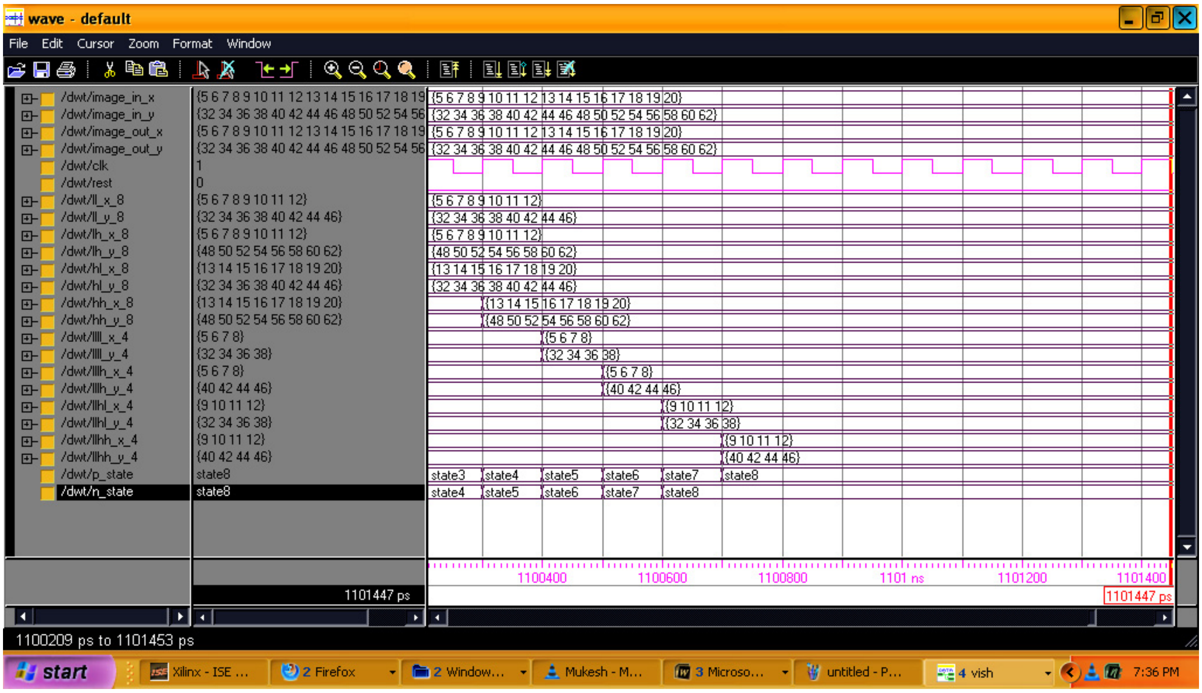

Fig. 10 Modelsim simulation of 2D image

Table 1 Pin details of DWT chip for (64 x 64)

Pins	Functional Description
reset	Used to reset the memory contents zero for synchronization of the components by using clk of std_logic (1 bit)
clk	Default input for sequential logic to work on rising edge of clock pulse of std_logic.(1 bit)
Image_in_x	Input array to the image in the form of pixels intensity value matrix (integer type in x axis)
Image_in_y	Input array to the image in the form of pixels intensity value matrix (integer type in y axis)
Image_out	Output array to the image in the form of pixels intensity value matrix (integer type decomposed in LL, LH, HH and HL subbands)

Fig. 11 RTL view of 2D-DWT

Synthesis Results as Device Utilization and Timing Summary

Device utilization report gives the percentage utilization of device hardware for the chip implementation. Device hardware includes No of slices, No of flip flops, No of input LUTs, No. of bounded IoBs, and No of gated clocks (GCLKs) used in the implementation of design. Timing summary and details provides the information of delay, minimum period, maximum frequency, and minimum input arrival time before clock and maximum output required time after clock. Table 2 and table 3 list the synthesis results as device utilization and timing parameters for 2D DWT chip for text extraction. Total memory utilization required to complete the design is also listed in the table. The target device is: xc5vlx20t-2-ff323 synthesized with Virtex-5 FPGA.

The synthesis process is carried on Virtex -5 FPGA, in which two 9-pin RS-232 ports [7] assist in the transmission of serial data to and from the FPGA board. In Virtex -5, there is a 50 MHz clock oscillator is the system clock provides the clock signal to the various events taking place within the FPGA and the various programs that require clock for their working. The input switches are given the image_in_x [5:0] and image_in_y [5:0], reset and clock input to the FPGA board, and the results are logged on host computer via an 8-lane PCI Express connection supporting sustained bandwidths of up to 2.38GBytes/sec. The synthesis is carried out simultaneously on 33 images and execution time is noticed. Inbuilt ADC converts the pixels intensity in discrete value, accepted by FPGA and then to integer values with the help of inbuilt DAC. The detailed synthesis process is beyond the scope of the research paper.

Table 2 Device utilization for 2D DWT (64 x 64)

Device Part	**Utilization**	
Number of Slices	249 out of 12480,	2%
Number of Slice Flip Flops	490 out of 12480,	3%
Number of 4 input LUTs	196 out of 493,	20%
Number of bonded IOBs	86 out of 172,	50%
Number of GCLKs	1 out of 32,	3%

Table 3 Timing parameters for 2D DWT (64 x 64)

Timing Parameter	**Utilization**
Minimum period	0.999 ns
Maximum Frequency	400 MHz
Minimum input arrival time before clock	5.190ns
Maximum output required time after clock	3.830ns
Total Memory usage	1059834 kB

The research work is carried with the existing algorithms for the text and character. The methods of text extraction are cluster centre approach, M- band and fisher classifier [10] method. The methods discussed in the research papers are compared with our research proposed method of HAAR transform of DWT based on mathematical morphology. Table 4 shows the average time taken to estimate the response of a document combination of 33 images. The comparative graph for the comparison of all the methods is shown in fig. 12. From the fig, it is clear that HAAR DWT has less execution time, with the integration of hardware chip. The average time for M band is 286 ms, Cluster centre approach 158 sec, Fisher classifier 139 sec and Haar DWT 96 sec simulated on MATLAB image processing tool with the integration of the chip.

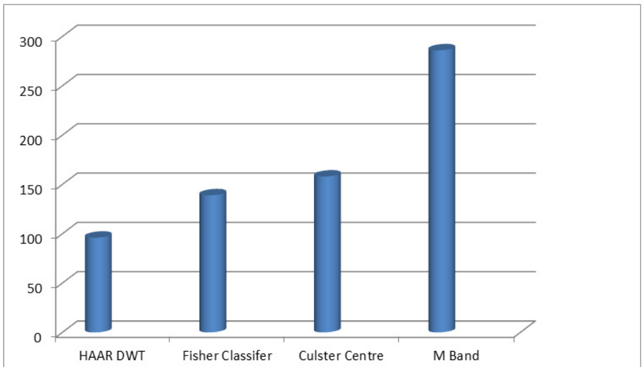

Fig. 12 Comparison chart for different approaches of text extraction

Table 4 Comparison of average time of a document image of 33 images with IEEE ref [10]

Methods	Response time
M- band	286 sec
Cluster centre approach	158 sec
Fisher classifier	139 sec
HAAR DWT	96 sec

5. Conclusions

HAAR DWT has been proved a novel process of text extraction considering multiple cases of image with its textual contents. The chip development and FPGA synthesis is a concept of segmenting the image into different regions to extract the textual information may be in horizontal, vertical, inclined. It also uses the methodology of sliding window for reading sub bands of high frequency. The simulation work is carried out for text regions are refined with the integration of mathematical operations such as dilation, erosion, closing and opening in the developed chip. The synthesis on Virtex-5 FPGA is carried out successfully and results are shown on host computer. The chip integration and methodology is very much successful to extract the textual information from a documentary image. The process the work is compared with the IEEE ref papers and it is found that the extraction is taken in less time in comparison to the ref paper. The setup can be used to recover textual information from surveillance footage, satellite imaging, tollbooth as in a hybrid approach is used to extract textual information form a video scene. In the addition of the future work can be the integration of DWT chip with the extraction of special characters and integration of the concept of cryptographic techniques of encryption and decryption with larger size of block text and key text.

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