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Real Time VHDL Design of High Speed Gabor Filter for Disease Detection

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Abstract—In current scenario there are number of skin related diseases such as tonsillitis, cancer etc which can be detected in its early-state and can be cured. For this a new idea is proposed in this paper which uses an efficient Gabor filter design and pipelined architecture for input. The hardware implementation of this technique attains a reasonably fast output rate (i.e. several images/second) for a better resolution than in the most recent VLSI implementations. We first present a hardware efficient FPGA-based shift-add CORDIC algorithm which implements a Gabor-type filter and improves data transfer rate, provide efficient noise reduction, less power consumption and reduced memory usage. The code for Gabor filter will be developed in VHDL using Modelsim and then implemented on SPARTAN-3E FPGA kit for detecting the early stages of disease using textural properties of anatomical structures. The fine-pipeline based architecture improves of the accuracy, performance of the system and extremely fast processing of large amounts of image data).

Keywords—Include at least 5 keywords or phrases Segmentation, Real time Medical image, CORDIC algorithm, Gabor algorithm, FPGA, Do File.

I. INTRODUCTION

Image segmentation [1] is the process of partitioning a digital image into multiple segments i.e. sets of pixels. The segmentation of image by considering the textural property of anatomical structures and regions of interest plays crucial role in most medical imaging applications. Texture refers to properties that represent the surface or structure of an object. Feature extractions, Texture discrimination, Texture classification, Shape from texture are the major issues in texture analysis. The segmented image is more meaningful and easier to analyse.

Medical imaging is the technique and process used to create images of the human body for clinical purposes (diagnose or examine disease). In reality, these images are rich in color and texture. It is difficult to identify image regions containing color-texture patterns. Color is that attribute of light-energy which is related to the wavelength. It is well known that color carries a very important part of information regarding objects of interest in an image. This concept is used in color-based segmentation [9] of images. For medical image segmentation gray level alone may not be sufficient, as many soft tissues have overlapping gray level ranges. In order to discriminate between disease area and rest of the images initially a set of features is found using the cell counting system. Thus the use of the textural properties of the anatomical structures could be useful.

In real time application motion estimation in image sequences is a fundamental issue in many applications. Many techniques are in existence but we are particularly interested in methods using Gabor filters, which are known to provide quality results but usually require intensive calculation. A new, fast energy-based method is presented here which uses shift-add CORDIC algorithm for Gabor filter design. An implementation of this technique on a general purpose Digital Signal Processor (DSP) board is advantageous as compared with Very Large Scale Integration (VLSI) and parallel machine approaches. Our hardware implementation will attain a reasonably fast output rate (several images/second) for a better resolution than in the most recent VLSI implementations.

A customized 2D Gabor Filter for RGB color image [7] segmentation is proved to be an effective segmentation tool with improved data transfer rate, efficient noise reduction, less power consumption and reduced memory usage. CORDIC algorithm plays main role for implementation of trigonometric functions which are the rotation based vectors because of two major factors as: Their capability to achieve optimal uncertainty in both space and frequency, and their similarity with primary visual cortex of mammals. Gabor function [4] locates the texture features in the spatial domain

Here we focus on detecting main features of disease capturing the real time image of patient from a video camera and create a resulting image showing percentage of disease affected area on MATLAB. The Gabor Filter for color image segmentation will be coded using VHDL in Modelsim and will be implemented in SPARTAN-3E FPGA. Field Programmable Gate Array (FPGA) technology [12] has become a viable target for the implementation of hardware efficient algorithms suited to image processing applications. Finally the result will be observed in matrix form on MATLAB showing how much percent the disease is present in input image.

To speed up the processing scheme, the digital image processing techniques prefers the hardware implementation. Among all the types of hardware implementation (i.e. ASIC, DSP and FPG), FPGA is used as it is reconfigurable device. It only allows the pipeline architecture and parallelism whereas DSP won't allow this type of architecture. It has low computational time and low cost. This type of chips simplifies the debugging and verification of complex algorithm.

II. DESIGN METHEDOLOGY

The design approach consist of main six modules as described below

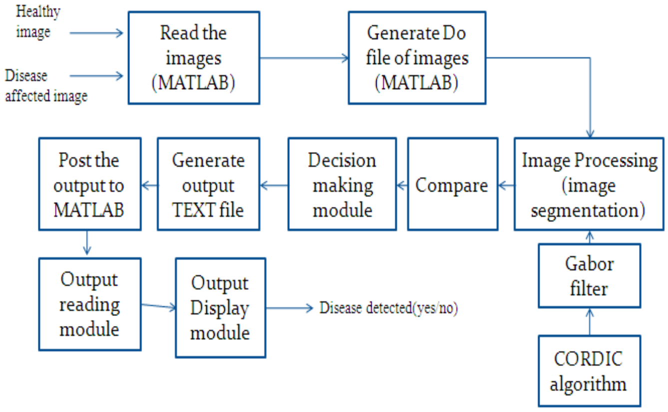

Figure (1): Block diagram of disease detection module

1. MATLAB Image Reading Module

This is a simple image reading and resizing module written in MATLAB. It reads two images from database for comparison. One of which is healthy image and another one having disease features. The comparison will generate a test input file separately for R, G & B as shown in figure (2) which we can use as input to VHDL module

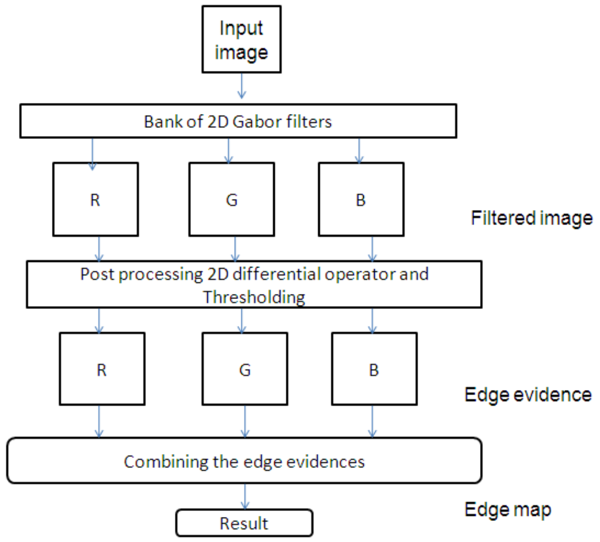

Figure (2): Generation of R G B mask

2. Gabor Filter

Our Gabor-type filter is used as the processing unit in a disease detection module. Gabor Filters have received considerable attention because the characteristics of certain cells in the visual cortex of some mammals can be approximated by these filters. In addition these filters have been shown to posses optimal localization properties in both spatial and frequency domain and thus are well suited for texture segmentation problems.

A Gabor filter can be viewed as a sinusoidal plane of particular frequency and orientation, modulated by a Gaussian envelope. It can be written as:

$$h(x, y) = s(x, y)\, g(x, y) \quad \text{........(1)}$$

where s(x, y) is a complex sinusoid, known as a carrier and g(x, y) is a 2-D Gaussian shaped function, known as envelope. These are defined as follows

$$s(x, y) = e^{j(w_x x + w_y y)} \quad \text{..........(2)}$$

$$g(x, y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x2+y2}{2\pi\sigma^2}} \quad \text{.........(3)}$$

Thus the 2-D Gabor filter equation can be written as:

$$g(x, y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x2+y2}{2\pi\sigma^2}} e^{j(w_x x + w_y y)} \quad \ldots..(4)$$

This Gabor algorithm discussed above, will be use to implement a Gabor Filter in VHDL.

2.1. CORDIC Algorithm

CORDIC is a Coordinate Rotation Digital Computer algorithm the set of shift-add algorithm collectively known as CORDIC algorithm for computing a wide range of functions including trigonometric, hyperbolic, logarithmic and linear functions.

As we observe the Gabor Filter equation, the implementation is quite complex as the complex exponential term is present there. This term is divided in two kernels. Even kernel is cosine modulated and the odd kernel is sine modulated and hence two filers are 90 degrees out of phase. These trigonometric functions which are based on vector rotations are implemented using Iterative shift & add operation. No Multiplication is required and hence Delay/Hardware cost is reduced comparable to division or square rooting. It is a Hardware Efficient Algorithm. The data format consists of two 16-bit words which are used for the even and odd kernels of equation 1. The 16-bit words consist of a 4-bit integer part and 12-bit fractional part. The image pixels are represented by an 8-bit number. It is a shift and add algorithm uses only right shifts and additions, minimizing the computation time

3. Image Segmentation Module

This is the segmentation modules that applies the Gabor filter to the input image, and provide a segmented output in the form of a 2D array.

4. Disease detection module

Depending upon the output of image segmentation module i.e. (1) the value in matrix showing total size of disease affected area and (2) color of disease, this module [6] [7] will detect if disease (Tonsillitis/Tumor) is present in the input image or not, and provide an output depicting the same. With this we can also able to identify the stage of disease by observing the intensity value of pixel in each segment.

5. VHDL output module

The output from disease detection module would be stored in a text file format and an output file would be generated. This would contain the values showing 1 (i.e. 256) for disease affected area and 0 for the rest as shown in figure (6).

6. Final image display module

This would be a simple MATLAB code named as post file that posts the text file from VHDL to MATLAB and display how much percent the disease is present.

III. HARDWARE IMPLEMENTATION

This technique converts the video input into sequence of frames. These frames are again converted into text using MATLAB. The resultant is called as Do File [15] which contains the pixel values of image in matrix form. Afterword the simulation is done with the help of Modelsim.

The objective of this proposed system is to achieve a throughput of one pixel per clock cycle and implementation of high-performance parallelization system using FPGA with high resources utilization.

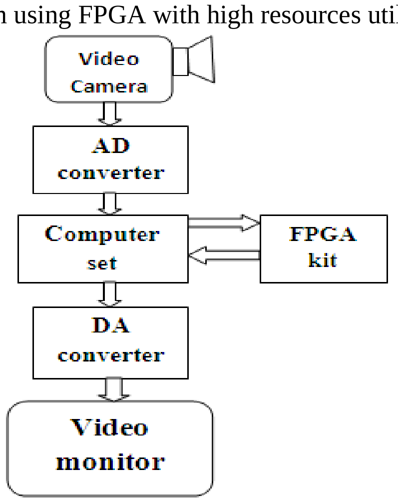

Figure (3): PC board diagram

Figure (3) describes the whole processing structure of this concept. Following are the steps.

Step I: - Take the real time image of patient having tonsils from CCD camera or from database.
Step II: - Read and resize the image module written in MATLAB. It should read reads two images, one from database i.e. healthy image for comparison & another one having disease features. The comparison will generate a test input file which we can use as input to VHDL module for evaluation of disease percentage present in patient.

Preprocessing, this step is to input pixels of an image frame to detect boundaries. The boundaries of disease affected areas are used to check the color and size of tonsil.
Step III:-Generate the Do File. It contains the pixel values of RGB image in matrix form in three frames per pixel of 8×8 size.
Step IV:-Later R, G & B these three frames of every pixel get separately processed by three Gabor filters. The Gabor filter is implemented using shift-add CORDIC algorithm
Step V:-After that there comes Image segmentation module. This is the segmentation modules that applies the Gabor filter to the input image, and provide a segmented output in the form of a 2D array. Feature extraction, the RGB space is found. Then, the green space is used to decide the tonsil area since it is the color that can differentiate the tonsil, which usually has red color, from other parts.
Step VI:-.Depending upon the output of image segmentation module i.e. (1) the value in matrix showing total size of disease affected area and (2) color of disease, this module [6] [7] will detect if disease (Tonsillitis/Tumor) is present in the input image or not, and provide an output depicting the same. With this we can also able to identify the stage of disease by observing the intensity value of pixel in each segment.
Step VII:-Later the output from disease detection module would be stored in a text file format and an output file would be generated showing the disease percentage in patient.

IV. ANALYSIS AND DEVELOPMENT

In developing algorithm some considerations must be taken, such as: properties and constraints. In software base, these properties are: performance (accuracy and speed), complexity, size of code, size of templates, difficulty of development, dependency, and in hardware base these properties are: performance, size of block/modules, and size of templates. And in implementing software algorithm [8] into hardware base some constraints must be taking care, such as: memory, component/block device, module dependency, difficulty of development, interfacing and handshaking, licensing, etc. Initially the work will be simulated using VHDL and then implemented on SPARTAN-3E FPGA.

V. RESULTS AND DISCUSSION

The input image used here is the brain tumor x-ray image as shown in figure (4). The MATLAB simulated output of the image reading module is obtained. The pixel values of the input image are obtained. The image size is fixed to 128 x 128. Thus each input image will be resized and converted to grayscale images .This module generate 128 x 128 x 8 number of lines showing the pixel values in V-Sim format called Do-File shown in figure (5).It generates input suitable to use in Modelsim. These pixel values are further used for implementation in FPGA

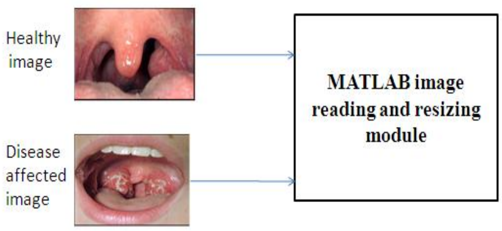

Figure (4): Input image

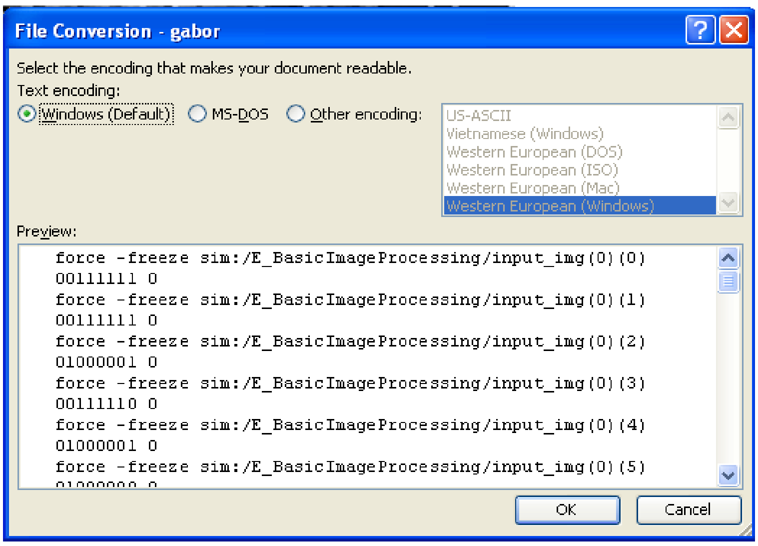

Figure (5): Do-File containing pixels value

The two images which are stored in two buffers are compared and overlapping region between infected area and healthy area is calculated. The difference is compared with threshold level and the decision is taken based on that shown in figure (6). For this experiment the performance of the overall design is evaluated taking tonsil disease. A survey on this clears the ideas about threshold level which is selected less than 30. If the percentage of difference is less than 30, a person will be in safe region. But if it exceeds this limit, disease detected. Here it is 34.73% in figure (7) and hence "Tonsils detected" this statement is generated.

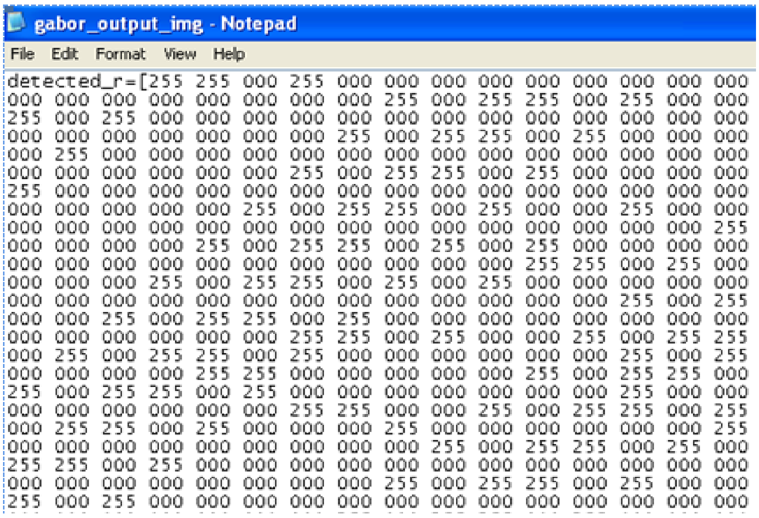

Figure (6): Output of decision making module

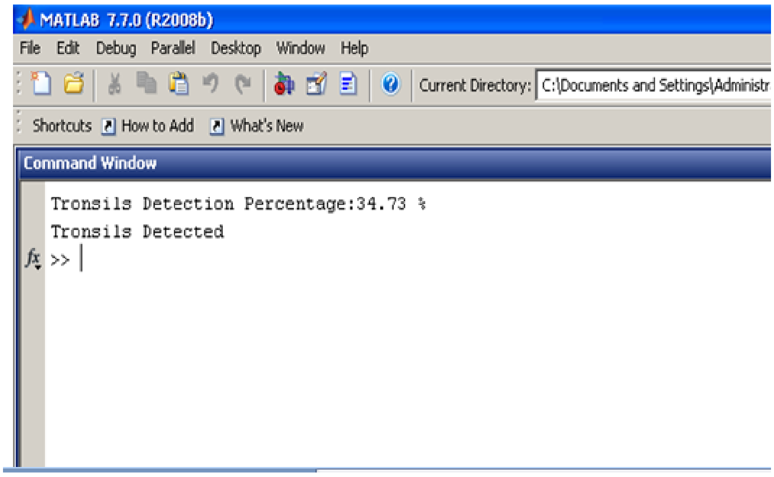

Figure (7): Result showing percent of disease present

VI. CONCLUSION

In this paper, a concept of VLSI architecture for disease detection is proposed. It will improve data transfer rates, provide efficient noise reduction, less power consumption and require less memory storage. The processing time required for simulation is very less as compared to software simulation as pipelined architecture is used thus offers much greater speed than a software implementation. This concept will be helpful in detecting early stage of disease and saving the lives of peoples.

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