Hybrid Design of Image Processing Techniques for Multiple Biomedical Applications in MATLAB and FPGA

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Abstract: The Computer Vision has become an essential component in the fields of biomedical applications and laboratory research in which images are processed and analyzed. The aim of the current research is to propose a hybrid design by using watershed algorithm and morphological filters for multiple biomedical applications like detection of brain tumor, lung cancer, gall bladder stone and cataract. The watershed algorithm is first implemented in MATLAB and then FPGA. Co-simulation is also done using HDL Coder. The paper compares the three implementations for watershed algorithm and also detects cataract by morphological filters.

Keywords: *Biomedical, Image Processing, Watershed, Morphological filters, Co-simulation, FPGA*

I. Introduction

Biomedical imaging has been evolving since the discovery of X-ray beams in 1895. Bio-medical imaging may help in capturing the internal parts of the body but bio-medical image processing with the help of computerized algorithms helps in automatic identification and analyzing of what might not be visible to human eyes. Nowadays, image processing algorithms are widely used in various biomedical applications for easy detection.

In order to analyze the huge amount of biomedical images from medical instruments, intelligent high speed real-time systems which may process the images have become essential. Image processing can be applied to FPGAs due to the parallel architectures, logic density and large memory capacity. Hardware implementation of image processing has become very convenient because of the advances in very large scale integration (VLSI) technologies.

In this paper, we have used MATLAB to detect brain tumor [1], lung cancer [2,3], gall bladder stone [4] using watershed algorithm and to detect cataract [5] using morphological filters [6]. Thus, a design of hybrid image processing techniques is proposed which can detect 4 diseases. We have to select any one of the four options and give necessary input image to obtain the desired output. It is cost-effective as with a single device we can detect multiple diseases.

After that, co-simulation with FPGA using HDL coder and simulation in XILINX along with implementation in FPGA is done for watershed algorithm. The latency of the watershed algorithm on 3 different platforms are compared.

Brain tumor is abnormal growth of cell within the brain. It can be of two types: malignant(cancerous) and benign. Malignant tumor is more common than benign and its easy

and timely detection can save many lives. Lung cancer which is uncontrolled cell growth in tissues of lungs is the number one cause of cancer deaths. Gall bladder stones are pieces of solid materials that form in the gallbladder, a small organ located under the liver. Cataract is layer of proteins built up in the lens of the eye and causes blurry vision.
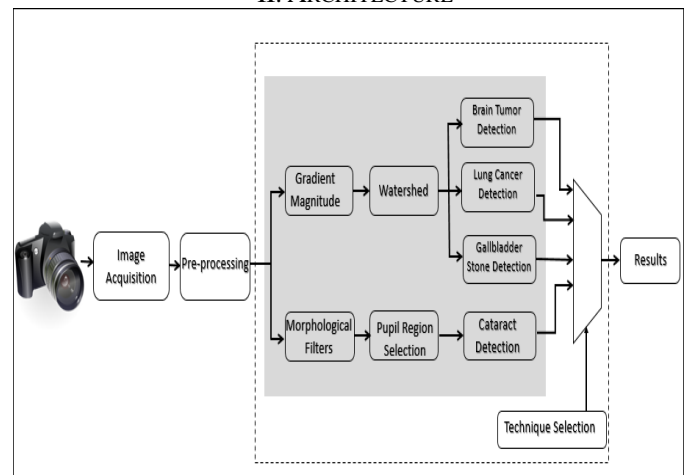
II. Architecture

Fig. 1: Block diagram of the proposed hybrid image processing algorithm

The proposed hybrid design as shown in Fig. 1 can detect any of the four diseases depending on the user-
- Brain Tumor Detection.
- Lung Cancer Detection.
- Gallbladder Stone Detection.
- Cataract Detection.

A. Brain Tumor/Lung Cancer/Gall Bladder Detection using Watershed Algorithm

Applying watershed algorithm in MATLAB includes the following steps:
- Image acquisition of MRI/USG/CT scan report is done by camera.
- Image is sent for pre-processing to remove the noise.
- Edge detection of the image is done by gradient magnitude which basically gives direction of the image.
- Segment the tumor/cancer/stone by applying watershed algorithm. An image can be denoted by peaks and valleys depending on the intensity of the gray level. High intensities are denoted by peaks and low intensities by valleys. In geographical term, watershed refers to a ridge

that divides areas drained by different river systems. Similarly, watershed algorithm segments the image so that we can find the tumor/cancer/stone distinctively.

1. Co-simulation of MATLAB watershed with FPGA

The MATLAB code for watershed segmentation is co-simulated [7,8] with FPGA by converting it to Verilog code using HDL coder as shown in Fig.2.
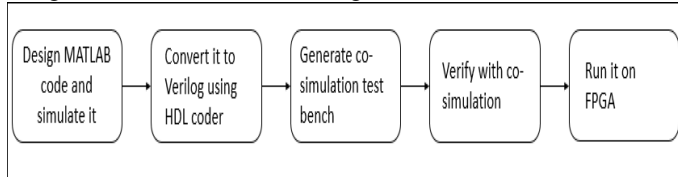

Fig. 2: Co-simulation steps

2. Implementation of watershed on FPGA

Implementation of the watershed algorithm [9,10] in Verilog includes the following steps:
* Sorting of the image grey levels.
* Extraction of the coordinates of all the pixels for each level.
* Processing of the image level by level in the following way: For each pixel, if it has a labeled neighbor, it inherits this label, otherwise a new label is assigned and the pixel takes the new label. If two neighbors are labeled differently, then the pixel is considered as a watershed and so on until processing the entire image.

Pseudo Code-

```
1:  Input : f , Output : l
2:  v[p] ← 0, l[p] ← 0, New label ← 0, Scan_Step2
    ← 1, Scan_Step3 ← 1 // Initialization
3:  Scan from top left to bottom right : step1(p)
4:  while Scan_Step2 = 1 do
5:      Scan image from top left to bottom right :
        step2(p)
6:      if v[p] is not changed then
7:          Scan_Step2←0
8:      else
9:          Scan image from bottom right to top left :
            step2(p)
10:         if v[p] is not changed then
11:             Scan_Step2←0
12:         end if
13:     end if
14: end while
15: while Scan_Step3 = 1 do
16:     Scan image from top left to bottom right :
        step3(p)
17:     if l[p] is not changed then
18:         Scan_Step3←0
19:     else
20:         Scan image from bottom right to top left :
            step3(p)
21:         if l[p] is not changed then
22:             Scan_Step3←0
23:         end if
24:     end if
25: end while
26: function step1(p)
27:     if v[p] ≠ 1 then
28:         for each n of p // n is neighbor pixel of p
29:         if f[n] < f(p) then v[p] ←1
30:         end if
31:     end if
32: end function

33: function step2(p)
34:     if v[p]≠ 1 then
            min← VMAX, for each n of p // n is neighbor
            pixel of p
            if f(n) = f(p) and v[n] > 0 and v[n] < min then
            min← v[n]
37:         end if
38:         if min ≠ VMAX and v[p] =6 (min+1) then
            v[p] ←min+1
39:         end if
40:     end if
41: end function
42: function step3(p)
43:     lmin←LMAX, fmin←f(p)
44:     if v[p] = 0 then
45:         for each n of p
46:         if f(n) = f(p) and l[n] > 0 and l[n] <
            lmin then lmin←1[n]
47:         end if
48:         if lmin = LMAX and l[p] = 0 then lmin←
            New label + 1
49:         end if
50:     else if v[p] = 1 then
51:         for each n of p
52:         if f(n) < fmin then fmin←f[n]
53:         end if
54:         for each n of p
55:         if f(n) = fmin and l[n] > 0 and l[n] < lmin
            then lmin←1[n]
56:         end if
57:     else
58:         for each n of p
59:         if f(n) = f(p) and v[n] = v[p] -1 and l[n] >
            0 and l[n] < lmin then
60:             lmin ←  l[n]
61:         end if
62:     end if
63:     if lmin≠ LMAX and l(n) ≠lmin then l[p] ←1min
64:     end if
65: end function
```

B. *Cataract Detection using Morphological Filter*

Cataract detection in MATLAB includes the following steps:
* Image acquisition of eye is done by camera.

- Image is sent for pre-processing to remove the noise.
- Apply morphological filters like open() and close() in MATLAB which are basically series of erosion and dilation. This helps in detecting the pupil of the eye.
- White colour in pupil denotes presence of cataract. Image inversion is performed and in the output, cataract affected eyes are seen as black in the centre marked by a red circle. In normal eyes no red circle is marked and is white in the centre.

III.RESULTS AND DISCUSSION

The camera used is iball usb camera with 30fps and 640x480 resolution.

A. Brain Tumor/Lung Cancer/Gall Bladder Detection using Watershed Algorithm

The images are resized to 256×256 8-bit and then sent for MATLAB, co-simulation and implementation on FPGA. Output images are also of size 256×256.

a. Brain Tumor

Brain tumor cell can be seen distinctively after applying watershed algorithm to the MRI scan image. The step by step images are shown in Fig. 3.
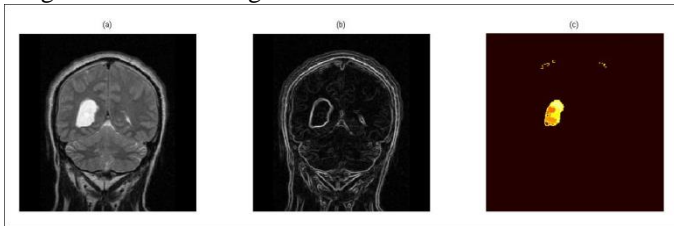

Fig. 3: (a) MRI Scan Image of Brain Tumor (b) Gradient magnitude of the input image (c) Segmentation of the image by watershed algorithm

b.Lung Cancer

Lung cancer cell can be seen distinctively after applying watershed algorithm to the MRI scan image. The step by step images are shown in Fig. 4.
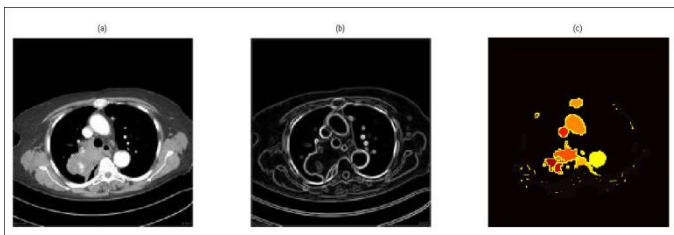

Fig. 4: (a) MRI Scan Image of Lung Cancer (b) Gradient magnitude of the input image (c) Segmentation of the image by watershed algorithm

c. Gall bladder stone

Gall bladder stone can be seen distinctively after applying watershed algorithm to the USG image.The step by step images are shown in Fig. 5.

Fig. 5: (a) USG image of gallbladder stone (b) Gradient magnitude of the input image (c) Segmentation of the image by watershed algorithm.

Co-simulation

The hex file of the image is generated by MATLAB and then watershed algorithm in MATLAB is converted into Verilog by HDL Coder to co-simulate the program with FPGA. The latencies in milliseconds(ms) of MATLAB simulation, co-simulation and FPGA implementation on XILINX are shown in Fig. 6.
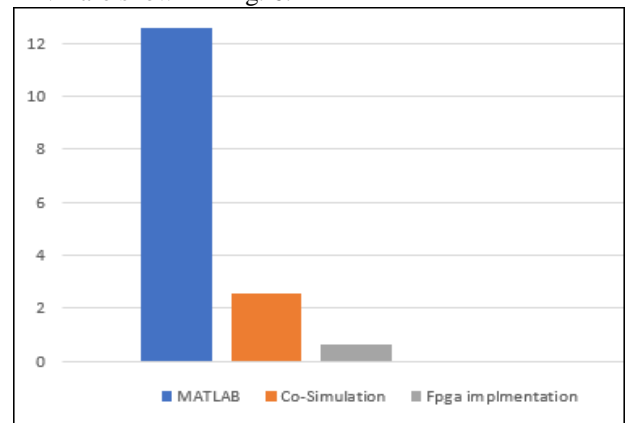

Fig. 6: Latency comparison of watershed algorithm Implementation on FPGA

The watershed algorithm is written in XILINX using Verilog and implemented on Spartan 3E XC3S500E. The resource allocation for the implementation is shown in TABLE I. The hex file of the MRI/USG scan is fed into the Verilog program of watershed algorithm and we get the output hex file.

Table 1: Resource allocation for FPGA implementation

Logic	Used	Available	Utilization(%)
Slices Registers	30	3104	1
Slice LUTs	8	1552	0.05
Bonded IOBs	19	232	8
Flip Flops	9	NA	NA
BUFGMUXs	1	24	4

Comparison of implementation of watershed algorithm on FPGA by different authors is done in TABLE II.

Table 2: Comparison of watershed algorithm by different authors:

Implementati-on by	Device Used	Image size	Resource Utilization	Clock
Trieu et. al. [11]	FPGA XC 2V6000	512×512	9.8 % of slices	86 MHz
Korbes et. al.[12]	GPU GTX 476	512×512	-	1.2 GHz
Ruparelia et. al. [13]	FPGA XC4VFX60	512×512	1530 Slices	228 MHz
Pradipta et. al. [14]	FPGA XC5VLX 330T	512×512	72 % Total Resource	91.24 MHz
Proposed Design	Spartan 3E XC3S500E	256×256	2.6% Total Resource	0.1 GHz

B. Cataract Detection

1. Image of an eye of a normal person.

Pupil of the eye is detected by morphological filters and circled by a yellow ring as shown in Fig. 7(a). Fig. 7(b) shows a white circle without a red mark. Cataract is not present.
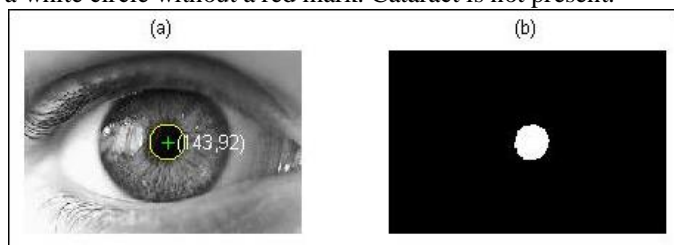

Fig. 7: (a) Normal eye (b) Pupil detection without cataract

1. Image of an eye of a cataract affected person.

Pupil of the eye is detected in Fig.8(a). Fig. 8(b) shows a black circle at centre marked by a red ring. Cataract is present.

Fig. 8: (a) Cataract affected eye (b) Pupil detection with cataract

IV. CONCLUSION AND FUTURE WORK

The paper proposes a hybrid design to detect brain tumor, lung cancer, gallbladder stone and cataract detection with improved speed and better accuracy than previous works. The comparison done in the paper shows that watershed algorithm implemented on FPGA uses only 2.6% of total resources and is faster than MATLAB and co-simulation.

The accuracy of the proposed design depends upon resolution of the camera and clarity of the image. The proposed design can be implemented on hardware in future which can save cost, time and reduce errors made by doctors' naked eyes.

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