# FPGABased Blood Sample Characterization

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*Abstract:* Blood grouping is the first and foremost essentiality for many of the major medical procedures. Microscopy has intermittently proved inefficient since it is time consuming ,the results are difficult to reproduce and also there is a need of an expert. Traditional ways of detecting blood group have remained analogue in this era of digitization and are therefore susceptible to human fallibility. Due to these reasons, automation of evaluation process is of high importance. It would be very efficient and arguably a lifesaving approach if the process of detecting blood can be completed successfully in a cost- effective way with the technologies at hand and without the plausibility of man-made error. This proposition is expected to evaluate the group of a sample blood with its computed image. The whole process excludes a major probability of human error while detecting the agglutination from the traditional method and it would get the task done within a fairly insignificant amount of time. An FPGA implementation and parallel processing algorithms are used in conjugation with image processing techniques to make this system reliable for the characterization of large numbers of blood samples. The program was developed using Matlab software then transferred and implemented on Arty 7000 Zync FPGA from Xilinx employing Vivado software. FPGA's have the advantages of speed and re-configurability which is required for image processing applications. Hardware implementation of the proposed algorithm on FPGA demonstrates a power consumption of 890 mW from a 2.5 V power supply. Blood group characterization using our FPGA implementation requires only 5.6 s, while a desktop computer-based algorithm with Matlab implementation on a Intel core i5 processor with 8 GB RAM and 1.60 GHz clock takes 16.113 s. The presented device is faster, more portable, less expensive, and consumes less power than conventional instruments. The proposed hardware solution achieved accuracy of 99% when tested with over 100 different blood samples.

***IndexTerms*–ABO system, agglutination, Blood samples, BRAM, Camera, Canny edge Image Processing.**

## I. INTRODUCTION

According to a study conducted by the Accident Research Centre (ARC) of BUET, road accidents claim on average 12,000 lives annually and lead to about 35,000 injuries. In these accidents it is often necessary to perform urgent blood transfusion where it is essential to determine blood group of the victim rapidly. Besides, there are some other use cases where blood typing may be needed at the point-of-care such as public health centers, battle field, schools, veterinary care centers and forensic sites. Perhaps, the most telling need is in rural areas of developing countries where access to labs and trained technicians is simply not present. Unfortunately, Detection of blood group in disaster or remote areas where expertise is unavailable is challenge. As a result, Transfusions between blood groups can be catastrophic. Therefore, knowing the blood type of donors and recipients is of the utmost importance. The conventional system of blood typing may prove life taking due to lack of trained technician. In real time, the health technicians, in these situations, must decide quickly what procedures they must apply, in order to guarantee the best treatment for the patient. In the mentioned emergency situations, where there is no time for human blood typing, the universal donor blood is administrated. As a result, some reactions mayoccur, risking the patient's life [19,20] and stock levels of blood from universal donor blood type decreases.

Blood group is the classification of blood based on the presence or absence of inherited antigenic substances on the surface of red blood cells (RBCs). These antigens may be proteins, carbohydrates, glycoproteins, or glycolipids depending on the blood group system. Blood groups are identified by antigens and antibodies in the blood. Antigens are any substance that stimulates the immune system to produce antibodies. Antigens can be bacteria, viruses or fungi that cause infection and disease. Antibodies, also called immunoglobulin, are proteins manufactured by the body that help fight against foreign substances called antigens. When antigens enter the body, it stimulates the immune system to produce antibodies. The role of antibodies is to bind with antigens and inactivate them so other bodily processes can take over, destroy and remove the foreign substances from the body. As of 2008, the International Society of Blood Transfusion (ISBT) had recognized a total number of 30 human blood group systems, with ABO and Rh as the two most common groups [1].

### 1.1. ABO System

The ABO blood system is the most important blood group system in human blood transfusion. The associated anti-A, anti-B antibodies are usually immunoglobin M, abbreviated as IgM antibodies. ABO blood system determines whether the person belongs to blood A or B or AB or O.

There are four major blood groups determined by the presence or absence of two antigens A and B on the surface of red blood cells:

- Group A – has only the A antigen on red cells
- Group B – has only the B antigen on red cells
- Group AB – has both A and B antigens on red cells
- Group O – has no antigens on red cells

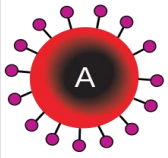
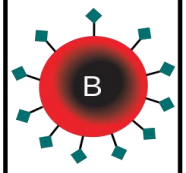
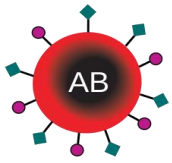
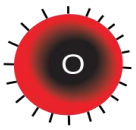
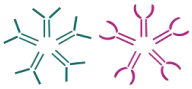
| | Group A | Group B | Group AB | Group O |
|---|---|---|---|---|
| Red blood cell type |   |   |   |   |
| Antibodies in Plasma |  Anti-B |  Anti-A | None |  Anti-A and Anti-B |
| Antigens in Red Blood Cell |  A antigen |  B antigen |  A and B antigens | None |

Fig1: ABO system

### 1.2. Rhesus (Rh) System

The other blood typing system commonly used is the Rhesus system, also called Rh system, named after the Rhesus monkey in which it was first discovered. In this system, if you have an antigen called the Rh D antigen on the surface of your red blood cells, you are said to be Rhesus positive (Rh+). If you don't, you are said to be Rhesus negative (Rh-). In Australia, about 83% of people are Rh positive. Combining your ABO blood group with Rh system, will identify whether you are Rh+ or Rh- .
Blood can be classified as one of 8 possible types.

| Recipient[1] | Donor[1] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | O− | O+ | A− | A+ | B− | B+ | AB− | AB+ |
| O− | ✓ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ |
| O+ | ✓ | ✓ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ |
| A− | ✓ | ✗ | ✓ | ✗ | ✗ | ✗ | ✗ | ✗ |
| A+ | ✓ | ✓ | ✓ | ✓ | ✗ | ✗ | ✗ | ✗ |
| B− | ✓ | ✗ | ✗ | ✗ | ✓ | ✗ | ✗ | ✗ |
| B+ | ✓ | ✓ | ✗ | ✗ | ✓ | ✓ | ✗ | ✗ |
| AB− | ✓ | ✗ | ✓ | ✗ | ✓ | ✗ | ✓ | ✗ |
| AB+ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

Fig2: Red Blood Compatibility

## II. LITERATURE REVIEW

Bloodisoneofthemostimportantelementofthehumanbodywhichworksasamajorconnective tissue and keeps the circulation of many essential ingredient like oxygen and various nutrients. It is extremely necessary for various medical procedures to be well known about blood type and other features of blood such as the RBC count and CBC [1]. The traditional method of detecting the blood group is usually the plate test and the tube test [2]. Both of which are done by under complete analog procedures with humanobservation.

In the era of digitization, it is not an efficient way to handle such a basic yet essential medical procedure in a full an alog environment. There are also a few techniques such as microplate testing and gelcentrifugation [2,3].These procedures are costly and those need to bed one by people with strong skill set with some particular equipment. In a situation of emergency which might be a difficulty to afford with. Basically, the process of blood group analysis depends on the agglutination of a sample blood. The blood of a patient is mixed with three types of antigens, which are antigen A, antigen B and antigen D. The agglutination in any particular blood sample ensures the positivity of that blood belonging in that correspondent group.

The detection of the composite organisms from a sample blood slide has been done via image processing techniques like threshold morphological operations [4]. Errors can be occurred in these procedures if the detection of agglutinations is solemnly done with human eyes. Wrongly calculated blood group results in extreme situations in case of further diagnostics upon that decision. For determining the correct blood group we need an impeccable operation justified with logical and mathematical calculations and flawless image processing to detect residual errors that evade corrective procedures [5, 6].

Image segmentation is one of the most fundamental techniques of image processing. In segmentation, a bigger image is divided into a number of sub images. While the algorithms run individually on the sub- divided images, the calculations occur more specifically and the result becomes more precise. There are several ways of image segmentation. Otsu method is one of them. Otsu is an automatic threshold selection region based segmentation method [7].

AnotherSignificantandimportantimageprocessingtechniqueisthresholding.Thresholdingdoes Binarization on any image. Some special Thresholding techniques also does Denoising. In some cases, some segmented image becomes cloudy and the important information which is needed to be extracted become complicated to retrieve. In such situations Thresholding is very helpful [8]. So, basically, Thresholding techniques makes an image in black and white and it makes the image much clearer. One automated design was brought up where the researcher suggested [9] the whole testwasdonebasedonslidetestfordeterminingbloodtypesandasoftwaredevelopedusingimage processing techniques. The image was processed by image processing techniques developed withtheIMAQVisionsoftwarefromNationalInstruments[10].Thisparticularresearchintroducedus with the very concept of developing numerical calculation over the processed image since this paper discussed standard deviation with respective mean value to detect the occurrence of agglutinationwhichwasconcludedwiththevalue16.Inthisresearcheverysampleswithstandard deviation value below 16 were found as samples where no agglutination occurred and samples with standard deviation values greater than or equal to 16 are samples classified as agglutination occurred.Whiledevelopingourmethodweintendedtokeepthecalculationareasimplertoensureits intelligibility. Although Ferraz has pursued with his research with blood grouping and image processing this paper led us to one of the crucial computation of our algorithm.

## III.FPGA FOR IMAGE PROCESSING

Application Specific Integrated Circuits (ASICs) represent a technology in which engineers create a fixed hardware design using a variety of tools. Once a design has been programmed onto an ASIC, it cannot be changed. Since these chips represent true, custom hardware, highly optimized, parallel algorithms are possible. However, except in high-volume commercial applications, ASICs are often considered too costly for many designs. In addition, if an error exists in the hardware design and is not discovered before product shipment, it cannot be corrected without a very costly product recall.

Field Programmable Gate Arrays (FPGAs) represent reconfigurable computing technology, which is in some ways ideally suited for video processing. Reconfigurable computers are processors which can be programmed with a design, and then reprogrammed (or reconfigured) with virtually limitless designs as the designer's needs change. FPGAs generally consist of a system of logic blocks (usually look up tables and flip-flops) and some amount of Random Access Memory (RAM), all wired together using a vast array of interconnects. All of the logic in an FPGA can be rewired, or reconfigured, with a different design as often as the designer likes. This type of architecture allows a large variety of logic designs dependent on the processor's resources, which can be interchanged for a new design as soon as the device can bereprogrammed.

Today, FPGAs can be developed to implement parallel design methodology, which is not possible in dedicated DSP designs. ASIC design methods can be used for FPGA design, allowing the designer to implement designs at gate level. However, usually engineers use a hardware language such as VHDL or Verilog, which allows for a design methodology similar to software design. This software view of hardware design allows for a lower overall support cost and designabstraction.

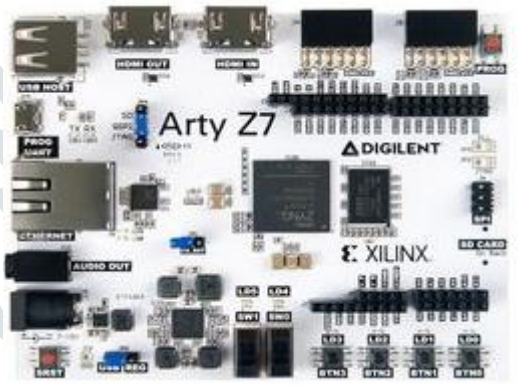



Fig3: FPGA Board

Arty Z7 is a development platform for embedded vision. It is a ready to use development platform designed around the Zynq-7000™ All Programmable System-on-Chip (AP SoC) from Xilinx. The Zynq-7000 architecture tightly integrates a dual core, 650MHz ARM Cortex-A9 processor with Xilinx 7-series FPGA logic. This pairing grants the ability to surround a powerful processor with a unique set of software defined peripherals and controllers, tailored by users for the target application. The Vivado, Petalinux and SDSoC toolsets each provide an approachable path between defining custom peripheral set and bringing its functionality up to a Linux OS or bare metal program running on the processor.

## IV.DESIGN AND EXPERIMENTAL SETUP

### 4.1. Experimental Setup

Slide test samples are captured through a high resolution camera and stored as png image on the personal computer.

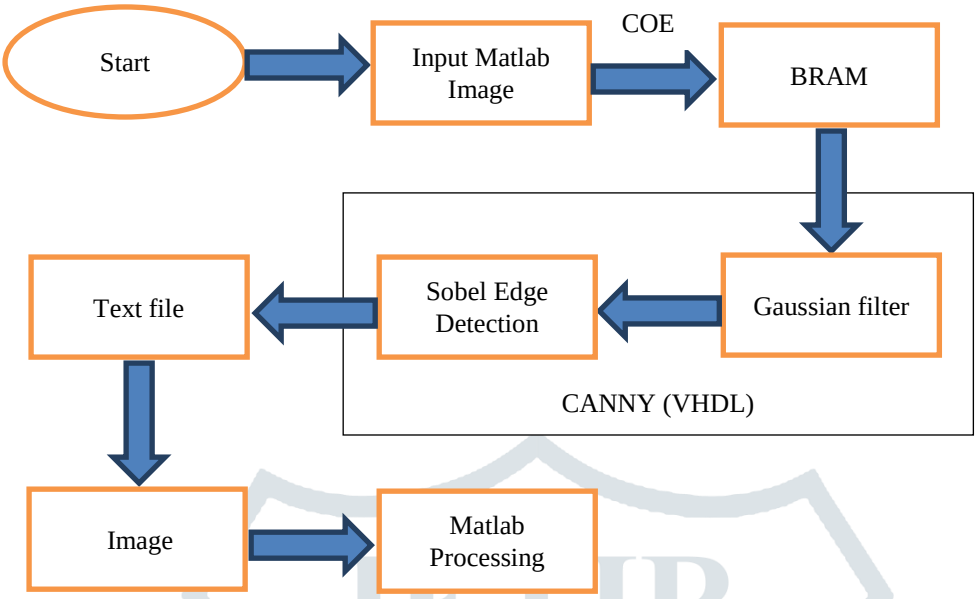



Fig 4.1: Block Diagram of Proposed Method using Canny Edge Detection

### 4.2 Acquiring data

Three samples of the same blood are taken on a slide, each mixed with reagent anti-A, anti-B, anti-D respectively and images of slide are taken. These images are digital images stored in PNG format and are pre-processed using color plane extraction. The original slide test image is used as input is as shown in results

### 4.3 Color Plane Extraction

The color plane contains colour information of images. In color plane extraction, image is first converted from RGB image in to a gray image. Gray Scale is simply reducing complexity. To store a single color pixel of an image (RGB) we need 8x3 =24 bits (R= 8 bit, G= 8bit, B= 8 bit) but when we convert RGB to Gray image only 8 bit required to store a single pixel of an image so we will need 33% less memory to store the image than RGB.

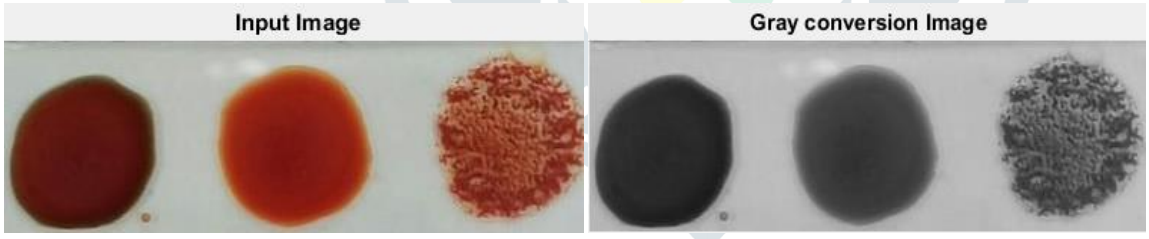



Fig 4.3: RGB and GRAY Image

Generally, Gray scale image indicates the image where each of its pixel is representing a range of particular amount of light. In MATLAB, a gray scale image is a data matrix whose value represents intensities within some range. MATLAB stores an image as an individual matrix, with each element of matrix corresponding to one image pixel.

### 4.4Canny Edge detection through FPGA

Gaussian filter is applied to gray converted image to reduce image noise.In the Proposed system Canny Edge detection is used to find the edges in the given input image as the performance of canny edge detection operator is much better than Sobel, Roberts, Perwitt, zero crossing and LOG (Laplacian of Gaussian) with respect to image appearance and object boundary localization.

Canny approach is a way of edge detection in image processing which works by detecting discontinuities in brightness. Canny edge detection is a multistep detection algorithm which can detect edges from the pixel image. Smooth the image with a Gaussian filter to reduce noise and unwanted details and textures through the equation

$G(m, n) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(z-\mu)^2}/2\sigma^2$

Canny edge detection is a multistage Algorithm to detect a wide range of edges in images. This detector finds edges by looking for local maxima of the gradient f (x, y).

The gradient is calculated using the derivative of gaussian filter. This method uses two thresholds to detect strong and weak edges and includes weak edges in the output only if they are connected to the strong edges.

### 4.5 Matlab Processing

Canny Edge detector output is in the text form which is converted to an image. The obtained image is splittedinto threesegmentswithin the sets of pixels. Image Splitting is generally based on two basic intensity values it has m number of rows add n number of columns. Each of the elements in this matrix representation is called a pixel. In Fig 4.5 the image is divided into three parts Group A, Group B and Rh factor according to the width of the image.

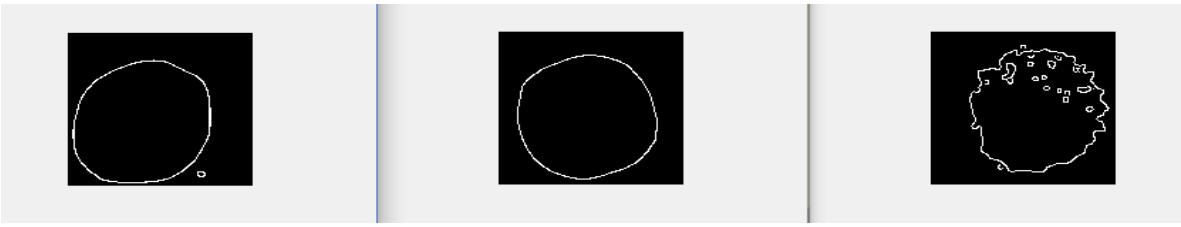


Fig 4.5: Image Splitting

After detecting the edges the next step is to count the number of edges present in Group A , Group B and Group Rsh.The detected output images is shown below for O positive.
Detected edges from the three segments are,
Group A = 2
Group B = 1
Group Rsh = 17

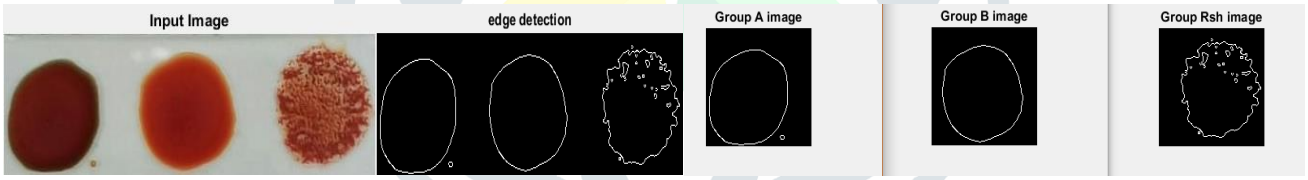
## V.EXPERIMENTAL RESULTS

Therearetwopartsofdetectingabloodgroup.Onepartisdetectingwhichgroupitbelongstolike A, B or O and another part is detection of positive or negative type. Both test are done in single slide. From our proposed method we detect the agglutination of the blood sample when they are mixed with antigens. When agglutination occurs that means, that type of blood group is detected for the current sample. If the part A of the slide has agglutination and part B does not agglutinate then we decide the detected group for the sample blood is groupA. Similarly, if partA do not have any agglutination and part B has agglutination then we decide that blood sample as group B. However,if there is no agglutination in any of parts then the detected blood group type is groupO and if the agglutination has occurred in both part A and B then the detected group is AB.

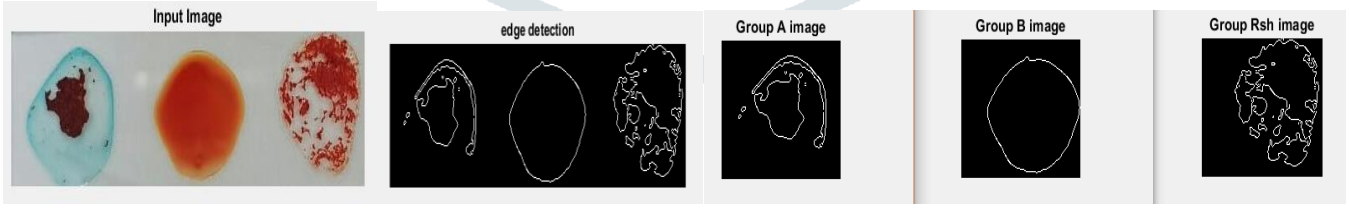
To check if blood is positive or not, we focus on the Rh-factor part. If any agglutination occurs in Rh factor part then blood group is positive and if the agglutination does not occur then the blood group is negative.

Below in Fig 5 are samples of each blood group type , their respective edge detected output and splitting of the samples respectively

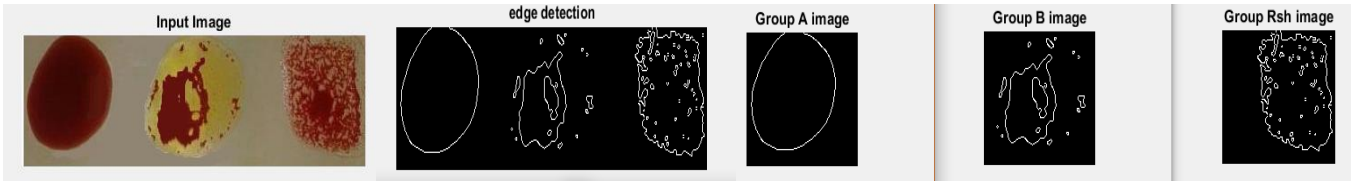
1. O +



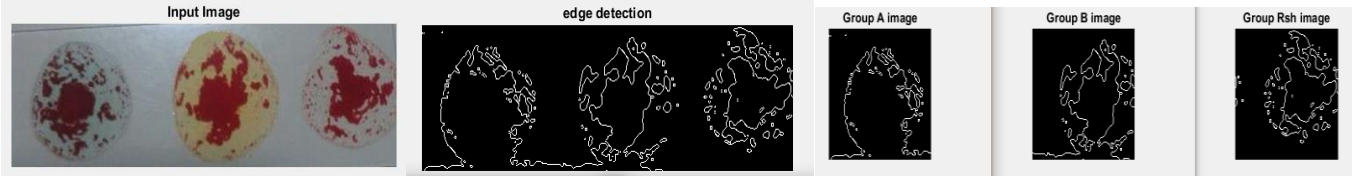

2. A+



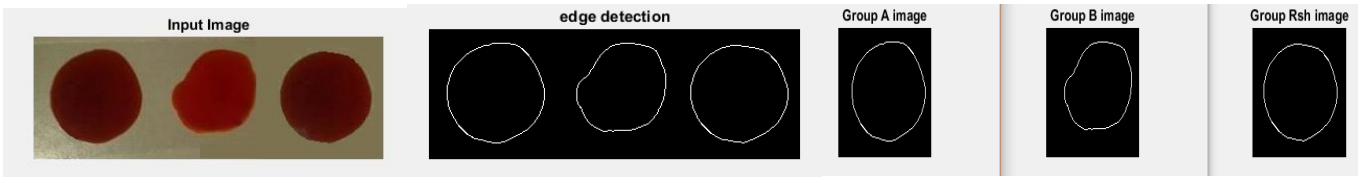

3. B+




4. AB+

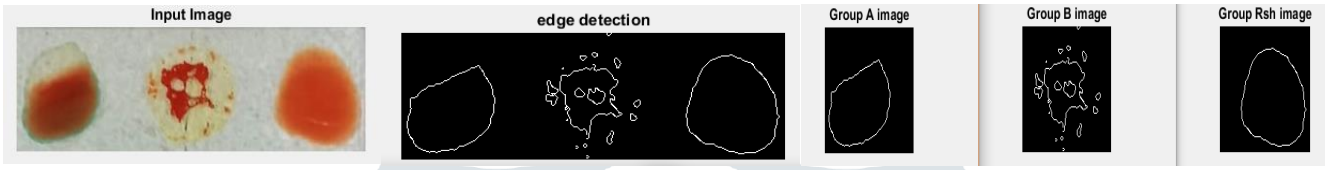


5. O-




6. A-


7. B-




8. AB-


Fig 5 : Blood samples with their FPGA output(canny edge output) and its processing in Matlab respectively

| Sample | Number of edges in part A | Number of edges in part B | Number of edges in part Rh factor |
|---|---|---|---|
| **O +** | 2 | 1 | 17 |
| **A+** | 9 | 1 | 29 |
| **B+** | 1 | 16 | 52 |
| **AB+** | 29 | 24 | 51 |
| **O-** | 1 | 1 | 1 |
| **A-** | 19 | 2 | 2 |
| **B-** | 1 | 17 | 1 |
| **AB-** | 10 | 10 | 3 |

Table 1 : Number of Edges calculated in the samples

From our proposed model, we got the information stated in Table12. Using this information from the Table1, we will do further calculations.
Let us declare three variables n1, n2 and n3 for part-A, part-B and part of Rh-factor respectively. Where,

n1= number of detected edges in part A
n2= number of detected edges in part B
n3= number of detected edges in part of Rh-factor
If there is no agglutination then it detects minimum 1 edge to maximum 3-5 edges so the threshold value is taken as 5 here.

In sample O+, the number of edges for partA is 2 so here (n1=2)< 5.Herethebloodsample for Type A has not been agglutinated. Similarly, number of edges for part B is 1.Here (n2=1) <5, therefore the blood sample has not been agglutinated. As well as for Rh factor, the detected edge is 20. (n3=20)>5 which means the sample blood is agglutinated. Thus, we found O+ blood Type. By combining all the outcomes, we finalize the accurate blood group of the input blood sample. All the other samples were measured in the same way.

## VI. CONCLUSION

In this thesis, a new and efficient process of digitally blood group detection model is proposed which is applied for the image sets that we can collect from hospitals. Image sets are captured by a mobile device and then processed through the image processing methods and algorithms. We counted the edges for each image and by analyzing the data we computed blood type from our sample captured real life image. Both, experimental result with of our collected dataset and comparison with the real time diagnostic result indicate promising process of effective performance. This paper presents a new and efficient model of blood group detection with image processing techniques. We worked on a real time dataset that consists of 100 blood samples. The blood sample was segmented in three parts and then we applied Canny edge detection method. After that, we counted the detected edges to determine the blood group of the sample. The experimental result with of our collected dataset and comparison with the real time diagnostic result indicate promising process of effective performance.

Hardware implementation of the proposed algorithm on FPGA demonstrates a power consumption of 890 mW from a 2.5 V power supply. Blood group characterization using our FPGA implementation requires only 5.6 s, while a desktop computer-based algorithm with Matlab implementation on a Intel core i5 processor with 8 GB RAM and 1.60 GHz clock takes 16.113s. The presented device is faster, more portable, less expensive, and consumes less power than conventional instruments. The proposed hardware solution achieved accuracy of 99% when tested with over 100 different blood samples.

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