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Prototype for Blood Typing Based on Image Processing

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ABSTRACT

Among the most fundamental and fundamentally important medical tests is blood typing. Worldwide, blood typing is among the most used diagnostic procedures. It is a prerequisite for every significant medical operation, including blood transfusions. Despite the test's apparent simplicity, even a little mistake might have devastating consequences, including even death. It is still possible to get someone's blood type using an antiquated, error-prone analogue approach, even in this day and age. To get over this problem, this research explains a novel way to find out someone's blood type by using image processing methods. Most mistakes in blood type determination stem from missing signs of reagent agglutination in the blood sample. In this work, we focus on a method that can identify agglutination in blood tests by analysing test images and identifying the blood type according to whether reagents agglutinate or do not when mixed with blood.

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Introduction

Red blood cells (erythrocytes) and blood are categorised according to the presence or lack of certain proteins termed antibodies and antigens. Blood consists of plasma, which contains red blood cells, white blood cells, and platelets. The surface of red blood cells contains antigens, whereas plasma contains antibodies. The body's immune response system includes antibodies, which detect foreign substances and set off the system's destruction process. Two antigens, A and B, are used mostly for blood type classification. Here are the four main types of blood: Type A blood is characterised by the presence of antigen A on RBCs and anti-B antibodies in plasma. The B blood type is characterised by the presence of antigen B on red blood cells and anti-A antibodies in plasma. The AB blood type is characterised by the presence of both the A and B antigens on red blood cells but the absence of antibodies to either antigen in plasma. Blood type O is characterised by the absence of antigen A and antigen B on RBCs and the presence of antibodies to both A and B in plasma. There are two types of antibodies that every human being has; when one of these is found on red blood cells, it means that the other antibody is present in the plasma. The ABO type classification describes this kind of categorization. A person's blood type is inherited from their parents, much like many other traits. When antibodies are detected in the blood, it sets off an immunological response that targets that specific antigen. When a person with blood type A gets a transfusion from someone with blood type B, the anti-B antibodies in their plasma detect the type A antigen in the donor blood and mount an immune response to eliminate it. This is why it's possible to have negative side effects after getting blood transfusions from someone with a different blood type. In many circumstances, people also die because transfusions are administered incorrectly. Since red blood cells (RBCs) from persons with blood type O do not contain any antigens that may elicit an immunological response in another person, those who have this blood type are considered universal donors. Type O is the most prevalent blood type in the world. Because their blood plasma contains antibodies that induce an immunological reaction upon detection of either the A antigen or the B antigen, or both, persons with type O can only receive blood from other people with type O. Among the several ABO blood types, AB is the most uncommon. Because their plasma does not contain anti-A or anti-B antibodies, people with blood type AB may accept blood transfusions of any kind. But only other AB type folks may receive their blood donations. Those who are able to give and receive blood are known as type-A donors and recipients. They can't take blood from those with type B or AB since they have anti-B antibodies. Nevertheless, as universal receivers and donors, they are able to give blood to those with blood type AB and receive blood from those with type O. Blood transfusions between persons of the same type B are possible. They are unable to accept blood transfusions from individuals of type A or type AB because to the existence of anti-A antibodies. Nevertheless, as universal receivers and donors, they are able to give blood to those with blood type AB and receive blood from those with type O. The RhD antigen is another protein-based antigen found in blood. One name for this is the Rhesus factor or Rh-factor. Among the several Rh antigens, RhD stands out as both the most prevalent and consequential, eliciting the strongest immune responses. Another way to categorise this kind is by whether or not it has the RhD antigen. A result is deemed positive if the antigen is detected, and negative otherwise. The Rh antigen may be harmful to someone who is Rh-negative if blood is given to them the wrong way. Transfusing Rh-positive blood to a Rh-negative individual causes the body to produce anti-Rh antibodies. The subsequent transfusion of Rh-positive blood causes hemolysis because the antibodies target the freshly transfused blood. The standard procedure for determining a person's blood type involves dividing a blood sample into four equal parts and then mixing each component with a separate antibody solution. This allows the

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lab to identify the blood type. Agglutination is the process by which the antibody solution clumps together in the presence of a specific antigen in the blood.A blood type test requires a laboratory or a lab technician, which is often not available in places like public health centres, battlefields, or ambulances. As a result, knowing the recipient's and donor's blood types becomes crucial in the event of an emergency transfusion. In situations like these, when a skilled laboratory technician is not available, the traditional approach to testing becomes inappropriate and useless. In this study, we provide an accurate and efficient method for detecting a person's blood type by combining numerous image processing algorithms with a photograph of the fast blood test card or plate used to mix the antibody reagents with the blood sample.

Section I: The Problem: In order to type blood, why is it necessary to use image processing techniques?

Examining the incidence of agglutination is the conventional method for determining a person's blood type. Professionals at hospitals and diagnostic labs often analyse blood samples to determine the patient's blood type by seeing which antigen solutions the blood agglutinates with. The fact that specialists aren't constantly on hand raises the danger of improper transfusions even more, especially in emergency situations like those involving ambulances or battlefields. Miscalculations, such as transfusing the incorrect blood type to a patient who desperately needs blood, are possible outcomes of this procedure, as is the case with any human-driven approach. The likelihood of this happening is not enormous, but it does happen. The patient's life might be jeopardised as a result of this seemingly little error.By developing an image processing pipeline that can identify agglutination using certain algorithms, we were able to drastically enhance the accuracy and precision of human blood type detection, therefore eliminating the entire human error issue. Our method drastically cuts down on the amount of time it takes to acquire test results, which is invaluable in emergency situations.

Thanks to image processing, we can use automated methods to detect agglutination in blood samples instead of relying on human observers.decreasing the potential for mistakes and stopping the transfusion of the incorrect

receiving blood transfusions. 2.1 What occurs in cases when a test cannot be carried out due to an emergency?

Because type O negative blood is so uncommon and nearly never available, it is sometimes given to patients in emergency situations when tests aren't possible or when there isn't enough time or equipment to do the tests, such as in an ambulance. Problems may arise if the patient is Rh-negative since O positive blood will be given to them if O negative blood is not available. It is possible for the patient to produce antibodies that target the Rh factor, leading to a potentially harmful immune response reaction. Part I: History and Relevant Experience There was a spike in the number of persons who had the improper blood transfusion in 2017, with an estimated 17,500 cases. It is important to note that blood is the primary component of blood typing. As a vital component of the human body, blood carries oxygen and other nutrients to all of our cells and helps them work together. It also connects different tissues. In many medical procedures and subsequent treatments, knowing blood type is crucial. Blood type detection has traditionally relied on plate or tube tests. The results of both of these tests are dependent on human observation, which introduces the possibility of human mistake. These outmoded practices are ineffective in producing optimal outcomes given the exponential growth of technological capability. A number of other approaches exist, but they are not very efficient, and they may need for specialised knowledge and expensive tools. Some examples of such techniques include gel centrifugation and microplate testing. It may be very challenging to do a blood type assay using any of these procedures during an emergency. Agglutination of the blood sample in response to three distinct antigen types—RhD, A, and B—is the standard procedure for determining a person's blood type. When an antigen is added to a blood

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sample, the result is agglutination. This means that the blood contains that antigen and belongs to the group that it was assigned to. Manually examining for agglutination patterns in blood samples after adding these three antigens allows for the possibility of human error in blood type determination. Adding a control or a different antigen solution, AB, which is a combination of antigens A and B, might further reduce the possibility of observational error. When calculating the blood type using a picture of the test palette, card, or slide, image processing methods are used to remove any possibility of human mistake. Basic image processing methods include picture segmentation.

processing. In segmentation, a bigger image is divided into several sub-images. To obtain more specific and precise results in calculations, the algorithms are run individually on the sub-divided image. There are several ways of image segmentation. Segmenting the image by cutting through the dimensions of the image is one of many image segmentation methods and the one used in our approach.

Color Plane extraction is a technique involving a certain color plane from the image which is believed to contain the maximum amount of information that one could extract from an Image. Usually, the green color plane of the RGB spectrum has the maximum value for the objects present in the Image. So, extracting the green color plane from the image processes and refines the Image. Thresholding is another popular and effective technique used in image processing or refining techniques. There are several thresholding techniques. Global thresholding is one of the simplest and most used techniques among other various thresholding techniques. Global thresholding usually involves binarisation of the image as foreground and background resulting in the removal of noise and unnecessary details present in the image. To further more refine the blood sample image we can use Edge detection techniques. One of such many edge detection techniques isCanny edge detection. In this edge detection technique, the image goes through a series of steps getting more and more refined at each step, and finally gives us an image with minimized noise and reduced disturbances which churn out a clear pattern of agglutination in the blood sample.

After all the processing of the image is done the occurrence of agglutination in the blood sample can be identified using the very concept of standard deviation with respect to the mean value which is used to identify the cluster of objects in the image. When there is agglutination in the blood sample the objects in the image get scattered all over and clear granules like objects can be seen on the contrary just a thin outline of the blood sample can be seen in case of no agglutination. This difference in the processed images can be identified very well by finding the Standard deviation between the objects in the image. Needless to say a sample without agglutination results in a lower standard deviation

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compared to a sample with agglutination. Each sample that has a standard deviation value less than a certain threshold was classified as samples where no agglutination occurred and samples with a standard deviation greater than the are classified as samples where agglutination occurred. This result for each segment is further used to determine the blood type.

I. IMPLEMENTATION

To obtain optimum results in detecting one's blood type detecting the occurrence of agglutination in the images with the highest possible accuracy is crucial. To get the best accuracy we followed the following techniques to process the image in order. Figure 3.1 shows the steps followed to process the image.

Figure 3.1 Flowchart of the processes followed to process the image

Colour plane extraction

The color plane of an image consists of the color information of the image. As the first step in processing the image, we extracted the green color plane from the image as green has the maximum value in the RGB color plane. We obtained the green color plane after removing the red and blue color planes by setting their value to 0 in the color filter array. Figure 3.2 shows the result of green plane extraction from an image.

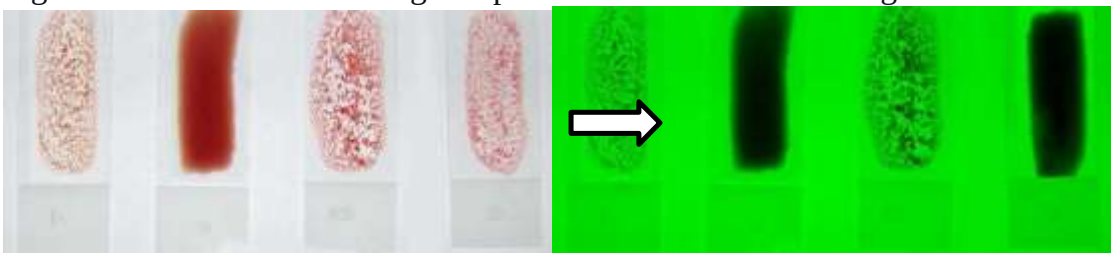

Figure 3.2 Extraction of the green plane from the blood sample image

Thresholding

Global thresholding

We made use of a technique called global binary thresholding which is one of the simplest thresholding methods which clusters the image into two clusters which are background and foreground. This thresholding creates a binary image from a greyscaled image. It can be considered as an operation that involves a test against a function T as below

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$$T = T[x, y, p(x, y), f(x, y)]$$

Where f(x,y) is a grey level at the point (x,y) and p(x,y) denotes some

local property of the point. A Threshold Image : g(x,y) = 1, if f(x.y)

> T or 0, if f(x,y) ≤ T

Pixels labeled 1 are foreground and pixels labeled 0 are background. T depends only on f(x,y) and the value of T solely relates to the character of pixels, this thresholding technique is known as global thresholding. Using this technique we binarised the blood sample image removing the unnecessary details and noise in the background. Figure 3.31 shows the result of global thresholding on a sample where agglutination occurs and Figure 3.32 shows the result of global thresholding on a sample where no agglutination occurs.

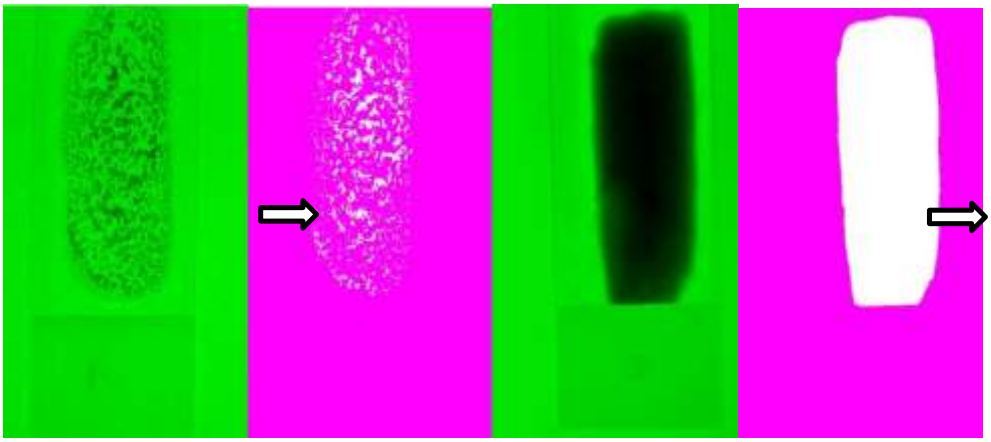

Figure 3.31 Global Thresholding (agglutinated)

Figure 3.32 Global Thresholding (non-agglutinated)

√

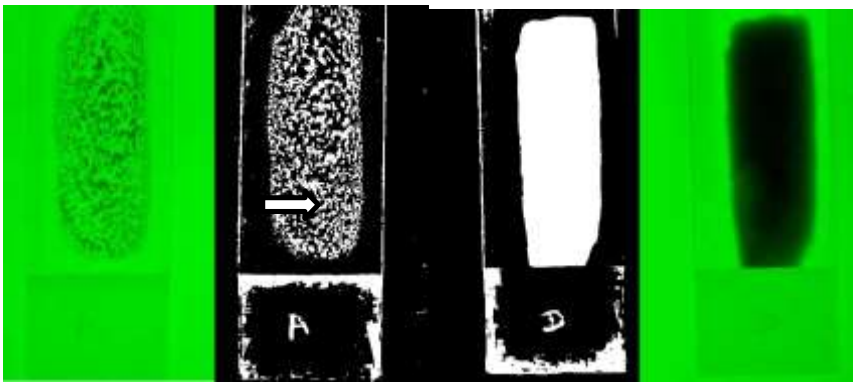

Figure 3.41 Gaussian adaptive thresholding(agglutinated)

Figure 3.42 Gaussian adaptive thresholding(non-agglutinated)

Edge Detection techniques

Edge detection is one of the most fundamental processes which significantly helps reduce the number of pixels(data) to process while also maintaining the structural aspect of the image. These kinds of techniques are usually used in detecting points in a digital

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image at which the image brightness changes sharply. Points at which brightness changes sharply are organized into a set of curved line segments termed edges.

Canny edge detection

We made use of a technique called canny edge detection which is an edge detection operator using a multi-stage algorithm to detect a wide range of edges in images developed by John F. Canny. Figure 3.51 shows the result of canny edge detection on a sample where agglutination occurs and Figure 3.52 shows the result of canny edge detection on a sample where no agglutination occurs.

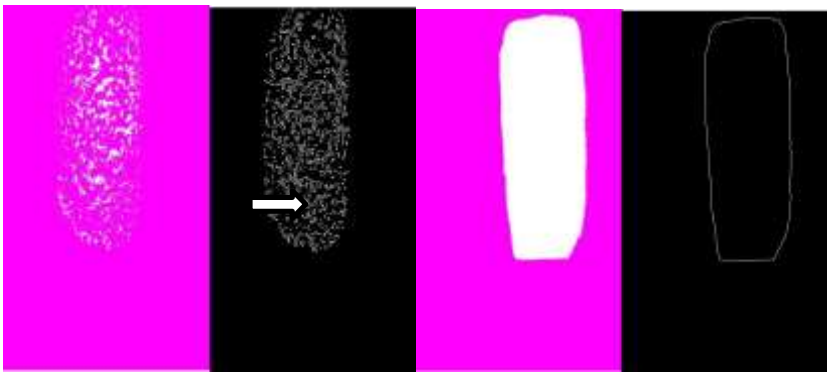

Figure 3.51 Canny edge detection (agglutinated)

Figure 3.52 Canny edge detection (non-agglutinated)

Algorithm**:**

The whole process of canny edge detection can be divided into five parts,

- Gaussian filter**:**
  Gaussian filter is applied to smoothen and remove noise in the image to prevent false detection caused by it. To slightly smoothen the image Gaussian filter kernel is convolved with the image.
  Equation for Gaussian filter kernel of size (2k + 1)* (2k + 1) is
  $H = \frac{1}{e2\pi\sigma^{ij}}$
- Finding the Intensity gradient of the Image**:**he Canny algorithm uses four filters to detect vertical, horizontal, and diagonal edges in the blurred image. The edge detection operator returns a value for the 1st derivative in the horizontal direction (G*x*) and the vertical direction (G*y*). From this the edge gradient and direction can be determined:

  $G = \sqrt{G_x^2 + G_y^2}$

  $\Theta = atan2(G_y, G_x)$
- Gradient magnitude thresholding or lower bound cut-off suppression:
  It is an edge thinning technique that is applied to find the locations with the sharpest change in intensity value. The algorithm compares the edge strength of the current pixel with pixels in the positive and negative gradient directions and if the edge strength of the current pixel is greater than any other pixel in the mask with the same direction, the value will be preserved. Otherwise, the value is suppressed.
- Double Threshold:
  This process will suppress the pixels with a threshold value lower than the low threshold value and mark pixels as weak edge pixel if its gradient value is between the high and low threshold values and marks the pixels as strong edge pixel if its

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gradient value is greater than the high threshold value.

- Edge tracking by Hysteresis:
  In this process the weak edge pixels which are caused by the latter reasons are removed and to track the edge connection, blob analysis is applied by looking at a weak edge pixel and its 8-connected neighborhood pixels. As long as there is one strong edge pixel that is involved in the blob, that weak edge point can be identified as one that should be preserved.

Passing all these steps the image gets more and more refined and approaches its final form which is used to detect the occurrence of agglutination which is used to determine the blood type.

Sobel edge detection

We tested out the Sobel operator which is a discrete differentiation operator, computing an approximation of the gradient of the image intensity function. It is named after Irwin Sobel and Gary Feldman who presented the idea of an isotropic 3x3 Image Gradient Operator. Sobel operator is based on convolving an image using a small, separable, and integer-valued filter in both horizontal and vertical directions.

Formulation:

The Sobel operator uses two 3x3 kernels that are convolved with the original image to calculate the approximate derivatives. We define **A** as the source image and **G**x and **G**y are two images that at each point contain the horizontal and vertical derivative approximations.

The Magnitude of the resultant Gradient: $G = \sqrt{G_x^2 + G_y^2}$

The Direction of the resultant Gradient: $\Theta = arctan \frac{Gy}{Gx}$

But using this method invites redundant details which need a greater amount of distillation of the image which inturn asks for more corner noise distillation. Therefore, we stuck to the Canny edge detection method to refine the image.

Detecting Agglutination Patterns using the Standard Deviation of the objects in the image

After all the refining using the above-described techniques, we obtained an image that shows clear patterns if agglutination occurs in the blood sample and just a plain outline of the sample otherwise. From the images obtained after processing, we found out that the standard deviation of the image varies by a very good margin between images with and without agglutination. This is evident in Figures 3.61 and 3.62.Hence we computed the average standard deviation between the objects in the image and if the standard deviation passes a certain threshold value we can conclude that agglutination has occurred in the given blood sample. Accordingly for each sample, we used all the above-defined techniques and calculated the standard deviation to obtain the result of the occurrence of agglutination in the given sample.

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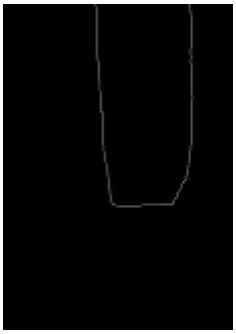
standard deviation = 46.272



standard deviation = 17.800

Figure 3.61 Standard deviation of an agglutinated sample

Figure 3.62 Standard deviation of a non agglutinated sample

RESULT

The process we came up with using image processing techniques includes 5 stages namely,color plane extraction, global thresholding, canny edge detection, Computing Standard deviation and mean. The average standard deviation of agglutinated samples was found to be 50 and that of non-agglutinated samples was found to be 17.47 and not much variance was found in both of these values. So the midpoint of both these values can be safely considered as the threshold. Using a dataset of images, we obtained a standard deviation threshold of **33** above which a sample is considered to be agglutinated and below which a sample is considered not agglutinated.

After the detection of agglutination, the blood group is determined using the following table.

Antigen A	Antigen B	Antigen AB	Antigen RhD / D	Result
Agglutinated	Agglutinated	Agglutinated	Agglutinated	AB+ve
Agglutinated	Agglutinated	Agglutinated	Not Agglutinated	AB-ve
Agglutinated	Agglutinated	Not Agglutinated	Agglutinated	Faulty test
Agglutinated	Agglutinated	Not Agglutinated	Not Agglutinated	Faulty test
Agglutinated	Not Agglutinated	Agglutinated	Agglutinated	A+ve
Agglutinated	Not Agglutinated	Agglutinated	Not Agglutinated	A-ve
Agglutinated	Not Agglutinated	Not Agglutinated	Agglutinated	Faulty test
Agglutinated	Not Agglutinated	Not Agglutinated	Not Agglutinated	Faulty test
Not Agglutinated	Agglutinated	Agglutinated	Agglutinated	B +ve
Not Agglutinated	Agglutinated	Agglutinated	Not Agglutinated	B -ve
Not Agglutinated	Agglutinated	Not Agglutinated	Agglutinated	Faulty test
Not Agglutinated	Agglutinated	Not Agglutinated	Not Agglutinated	Faulty test
Not Agglutinated	Not Agglutinated	Not Agglutinated	Agglutinated	O +ve
Not Agglutinated	Not Agglutinated	Not Agglutinated	Not Agglutinated	O –ve
Not Agglutinated	Not Agglutinated	Agglutinated	Agglutinated	Faulty test
Not Agglutinated	Not Agglutinated	Agglutinated	Not Agglutinated	Faulty test

The results obtained using an image of a sample blood test areshown in Figure 5.1 below.

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Figure 5.1 A sample image used for testing

Standard deviation of segment 1(Antigen A) = 46.272 ⇨ Agglutinated

Standard deviation of segment 1(Antigen B) = 17.057 ⇨ Not Agglutinated

Standard deviation of segment 1(Antigen AB) = 53.634 ⇨ Agglutinated

Standard deviation of segment 1(Antigen RhD or D) = 17.800 ⇨ Not Agglutinated

Result Obtained = **A –ve**

II. CONCLUSION

Making Use of GraphicsThe blood type may be efficiently and effectively determined using processing procedures.This technique allows one to ascertain a patient's blood type in a very little period of time. Adopting this strategy as a business solution has the potential to save lives while also adding substantial value. Public datasets are unavailable, and COVID-19 constraints prohibit us from accessing private datasets, thus we have had to work with a small group of photos. A comparison between the outcomes of the real-time diagnostics and the experimental results of our gathered dataset both point to a potential outcome of effective performance with high precision. Even the slowest computers can execute and deploy our solution since it requires a few basic processes, which makes it incredibly computationally efficient. A low-cost end-to-end prototype that uses raspberry-pi or Arduino to capture images of blood samples placed in centrifuges, processes the images using the aforementioned method to determine blood group, and then directly updates the patient's electronic health record is our long-term goal. We also intend to integrate pattern recognition and make it compatible with all types of tests.Further in the road, we'd want to build a smartphone app that can identify a person's blood type only by taking a picture of their blood test.

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