Bio-Optics: Blood Type Determination based on Image Processing Techniques by utilizing an Optical Sensor Device

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Abstract: ***The proposed idea is a non-invasive method for identifying the blood group of a patient without puncturing/breaking the skin. The paper presents a method to automatically determine human blood type by applying image processing algorithms to the optically captured images of superficial capillaries underlying the skin surface. The technique embeds Multiwavelength Light (MWL) scattering method as light passes/cuts through the capillaries for dynamically classifying blood cells based on specific antigens on the Red Blood Cell (RBC) surface. The portable optical device (camera) along with the photo-detectors form the basic detector structure: Used to detect the scattered light distribution/pattern produced by the blood cells to determine the blood type without drawing the blood samples from the body.***

Keywords: Blood types, Optical Sensors, Camera, Photo-detectors, Multiwavelength Light, Light scattering, Image Processing, Pattern matching, Filters

1. Introduction

Blood typing is a technique to identify what specific type of blood a person has. The differences in human blood are due to the presence or absence of certain protein molecules called antigens and antibodies. The antigens are located on the surface of the red blood cells and the antibodies are in the blood plasma. Individuals have different types and combinations of these molecules.

According to ABO and Rh blood grouping systems, a person can belong to either of following 8 blood groups: A Rh+, A Rh-, B Rh+, B Rh-, AB Rh+, AB Rh-, O Rh+ and O Rh-. The blood grouping is done by technicians in laboratories by slide test which is a manual method. Most of the techniques applied are still based on the principle of interaction between antigen and antibody and subsequent agglutination (i.e. clumping) of RBCs (positive result).The absence of agglutination indicates the lack of interaction (negative result).

This manual blood grouping procedure presents undesirable drawbacks: slowness and non standardized accuracy since it depends on the operator's capabilities and tiredness.

Hence, it is necessary to develop an automated system for blood group identification [7]

2. Background

Antigens are usually proteins and polysaccharides located on external surface of red blood cells having many epitopes of different specificities. This is because proteins are usually hundreds of amino acids long and are composed of 20 different amino acids. Certain amino acids are able to interact with other amino acids in the protein chain and this causes the protein to fold over upon itself and assume a complex three-dimensional shape.

Now, blood is typed, or classified, according to the presence or absence of these markers (antigens) found on red blood cells and in the plasma that allow your body to recognize blood as its own.

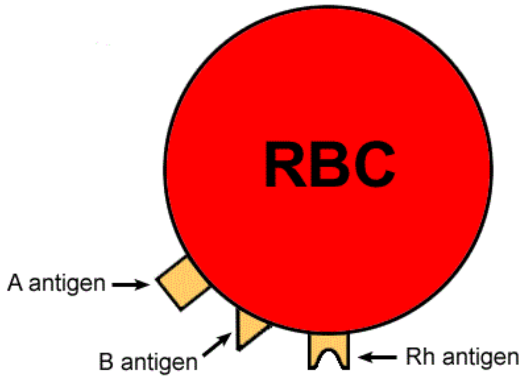

Figure 1: A red blood cell (RBC) with different antigens on the surface of its membrane. The antigens are glycoproteins with unique molecular shapes. They have molecular weights of 200,000 to 300,000.

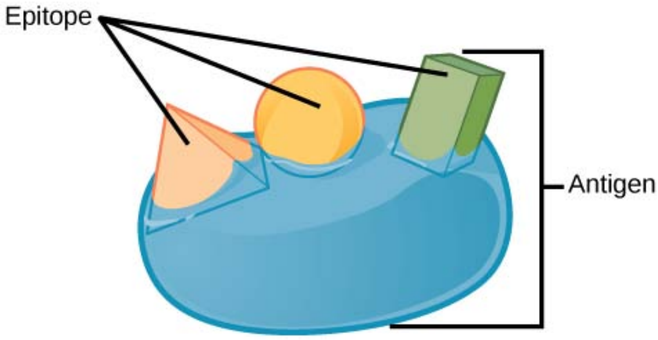

Figure 2: Epitope is a part of an antigen molecule to which an antibody attaches itself –antigenic determinant

3. Concept

The idea presented here deals with Multiwavelength light scattering mechanism for automatically classifying blood cells depending on the presence/absence of antigenic components on the surface membrane of the red blood cells [4]. The light from the optical device passes through antigenic substances, epitopes of antigens, and thereby allowing light with a distinct wavelength to pass/deflect/diffract/reflect completely. When this narrow band of light hits the specimen, certain compounds in the specimen (i.e. natural compounds or cells) deflect/scatter light based on the energy of the incoming ray. This deflected light is detected with the help of sensitive photo-detectors (or sensors) installed in the camera by capturing multiple images of a specific focus area. These captured images reveal the blood type based on scattered light pattern picked up by the camera or optical device.

The absorption component provides information on the chemical composition and the scattering component on the size/shape and structure of the cell integrants. Since scattering properties depend on the refractive index of the measured objects, which, in turn, is governed by chemical composition, simultaneous measurement of both absorption and scattering gives clear idea of antigenic substance on the surface. Furthermore, since refractive index of any substance and therefore its absorption and scattering properties vary with wavelength, a single MWL measurement can provide a sufficient number of independent data points to extract information on multiple parameters (in cases of complex composition and/or complex structure) of measured objects i.e. antigenic properties of surface elements.

3.1 Algorithm

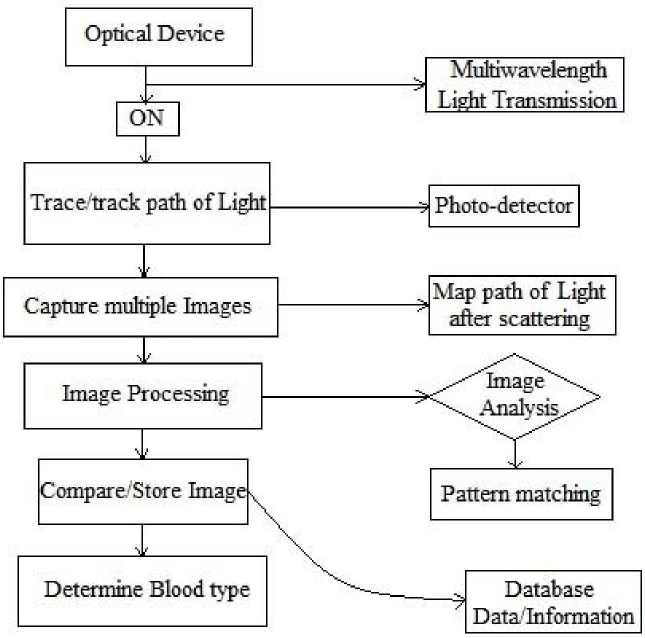

Figure 3: Flowchart of human blood group determination

(Note: Multiwavelength light produces deflections based on angle of incidence the light makes when it hits different molecular structured/shaped epitopes obliquely that are resident on the RBC membrane - to produce a specific pattern)

3.2 Technique

3.2.1 Steps

1) The optical device is placed on the patient's fingertip in a similar way as to how pulse oximeters are used in hospitals to measure blood oxygen levels – Device is turned on to fire multiwavelength light onto the skin surface.
2) The sensitive photo-detector traces the path of light on being deflected or absorbed by the red blood cells.
3) When illuminating at certain frequencies, light is absorbed by the hemoglobin in the red cells, and at the same time due to coherent nature of illumination – light gets scattered by small margin on hitting the edges of the antigenic determinants having specific structure/shape.
4) The pattern of this light scattering is captured by keeping the optical device ON for certain specified time to capture the after-effects of scattering – Multiple images are taken by the device in a succession to trace/track scattered light.
5) Subsequently, image processing algorithms recognize these scattering events and record the pattern/distribution of scattered light – which depends on the molecular shapes of epitopes of various antigens like antigen A, antigen B, Rh antigen – The MWL is highly sensitive to size, shape, and composition of RBC occurring due to the presence of epitopes of different antigens.
6) The recorded pattern gives an estimate of the concentration (or type) of antigens (or antigen-antibody or antigenic substance) in the blood cells – which provides an estimate of the blood type – e.g. Blood type A has antigen A on its RBC surface

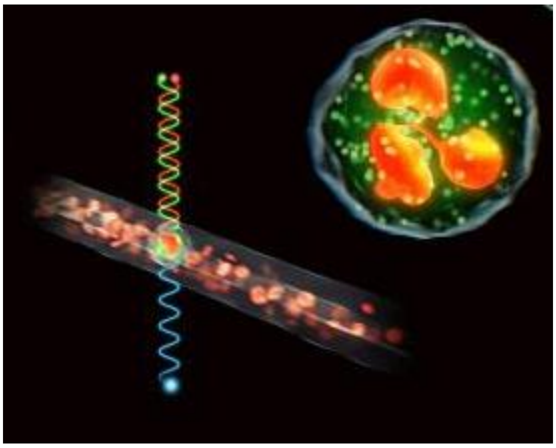

Figure 4: The amount of multiwavelength light scattered off the cells as it passes through the blood can be measured, which gives information concerning the type of antigenic constituents on the surface of red cells [3]

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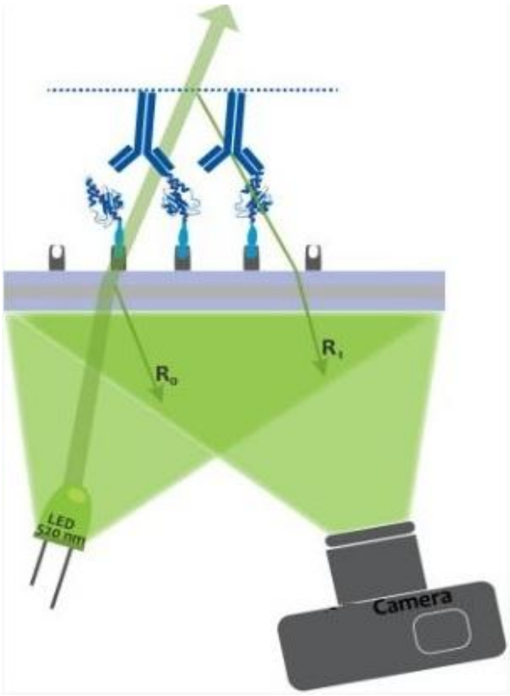

Figure 5: Illumination provided by the LED (MWL) light aids in capturing the scattering of multiwavelength light as it passes through the antigenic fabric; Ray R_0 and R_1 depict the reflected light captured by the photo-detectors in the optical device [8]

(Note: In the above diagram LED light and Camera are shown as separate devices – to simplify/ease-out the understanding of the concept. In the final product, both these entities will be embedded in one portable device – wherein multiwavelength light is fired from one end of the camera and the photo-detectors located on the other end of the camera lens capture the internal scattering of light)

4. Image Processing

Manipulation of Images using various Filters and Transformations is known as Image processing. Image, as it is represented in computers, is nothing but a matrix of intensities values for the three layers, namely red, green and blue.

4.1 Acquisition of blood images is done using an Optical device (camera)

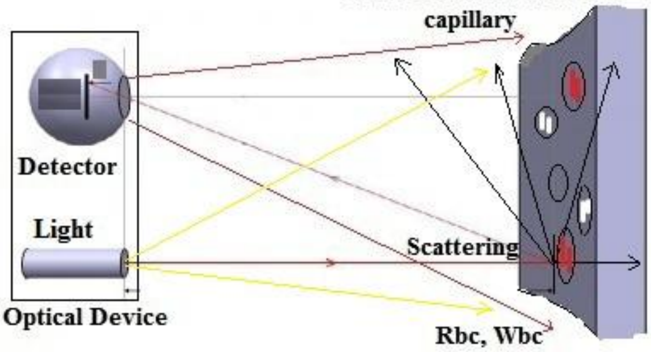

Figure 6: Scattering of light triggers the photo-detectors to trace the path of light reproduced in the images captured by the optical device

4.2 Pre-processing

The role of pre-processing is to segment the interesting pattern from the background. The pre-processing also defines a compact representation of the pattern - Noise filtering and normalization is done in this step to thereby improve the quality of images.

4.3 Pattern matching/Recognition and interpretation

This step involves identifying the repetitive pattern in the images by using various pattern matching algorithms.

MATLAB programming is used as a software tool for effective pattern matching algorithm implementation and image analysis. Here the sensitive detectors map the path of light by taking multiple images and plot it onto a graph to represent minute fluctuations of scattered light.

The captured images are consolidated to elucidate the specific pattern for a particular blood group type. Filters (Low-pass/High pass filters, etc.) are applied to these captured images to reduce noise produced by the unwanted deflections from other molecules/components of blood like platelets, etc. to establish a settled pattern for a blood type. This data is stored in the database for future pattern matching processes.

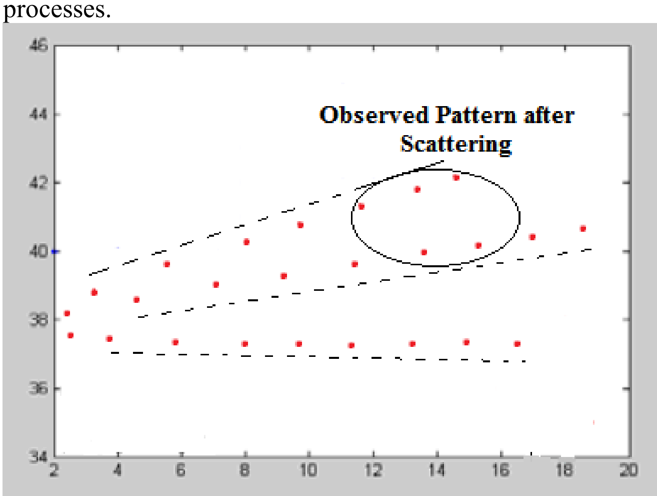

Figure 7: Multiwavelength light scattering in mapped onto a graph showing minute deflections by antigenic substances in blood – A common pattern is matched for particular blood type based on these deflections.

5. Recent Developments

An international team of researchers has developed a portable device for placing on the fingertip that counts white blood cells without a blood test. The technology which combines an optical sensor with algorithms is designed for use on chemotherapy patients, who could know their immune system levels in real time. It could also have utility in detecting serious infections.

The technology includes a portable optical system, which provides oblique illumination with LEDs and is able to capture images of surface capillaries under the skin with cellular resolution. The acquired videos are subsequently analyzed by automatic algorithms capable of detecting white blood cells and calculating their concentration

The device is placed on the patient's fingertip. With a small lens, the system captures images of capillaries very close to the surface in the nailbed. When illuminating at a particular frequency, light is soaked-up by the hemoglobin in the red cells, an effect that does not happen with the white cells. This means that the leukocytes appear as small transparent particles moving inside the capillary. Subsequently, the project's image processing algorithms recognize these events and count them, providing an estimate for their concentration in the blood [1]

Figure 8: A prototype demonstrating a portable microscope placed manually on the patient‟s fingertip to take videos of microcirculation in very peripheral capillaries (*Credit: Research Laboratory of Electronics/MIT*)

6. Conclusion

The methodology presented in this work, based on Image Processing, allows determining safely, the blood type of a patient, within a short time without the necessity of taking blood samples, thereby eliminating the pain of being stuck with a needle. The process is useful in emergency situations, blood transfusions, etc. as it greatly reduces the time and hassle of manually testing blood compatilibility for the patient.

7. Future work

The idea/method presented in the paper could be extended to any commercial optical equipment like camera, etc. with minor modifications to the device. The technique could further be extrapolated to Smartphone cameras (equipped with image processing or neural networks) for obtaining results at low cost and within a short-time. The „portability‟ factor could therefore add a commercial value to the innovative solution.

8. Acknowledgement

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