Detection of Anemia from Image of the Anterior Conjunctiva of the Eye by Image Processing and Thresholding

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***Abstract*— World Health Organization (WHO) identifies anemia, a health hazard condition marked by the deficiency of red blood cells or hemoglobin in the blood stream, as maligning a quarter of the total world population. An automated, quick and reliable detection of anemia is hence imperative. Preliminary detection of anemia is usually undertaken visually by the physician by examining the color of the anterior conjunctiva of the eye and confirmed with an invasive blood test. In this study, we designed a mechanism for the automated detection of anemia through non-invasive visual method. Our process involves the detection of anemia by analyzing the anterior conjunctival pallor of the eye. It operates by quantifying the conjunctival color from digital photographs of the eye taken with a smartphone camera of appropriate resolution under adequate lighting conditions with the help of an android application that we have devised. These images are then processed to obtain the red and green component spectra of the conjunctiva color and compared against a threshold to determine whether the patient is anemic or not. We employed our method on 19 test subjects with known hemoglobin levels. The results obtained from our process agreed with the patient's blood report in 15 out of the 19 cases which translates to an accuracy of 78.9 percent. Our study was aimed towards the automation of healthcare facilities in underdeveloped parts of the world lacking proper healthcare facilities like hospitals and healthcare centers. Thus we developed a computerized, noninvasive, simple, cost effective, easy to use and portable primary screening test for anemia which can provide a viable alternative to invasive methods of anemia detection and have major humanitarian impact in the underdeveloped areas of the world.**

Keywords*— *Anemia detection, image, photograph, filtering, thresholding, image processing, edge detection, eye, anterior conjunctiva, hemoglobin concentration, non-invasive method

I. INTRODUCTION

According to a study conducted by the world health organization (WHO), 24.8 percentage of the entire world population was considered to be anemic between the year 1995 and 2005 [1, 2]. The Hemoglobin concentration in the human blood is considered as the gold standard for the detection of anemia. This is an intravenous process which requires specialized surgical equipment. Recently, figure prick blood sample is taken for lab testing but blood testing requires much time and may expose healthcare workers to risks of blood-borne infections [3-4]. Examination of the conjunctival pallor of the eye is usually used to rapidly screen for anemia in many clinics, Physicians generally pulls down the eyelid and subjectively examine the color of the anterior conjunctival pallor membrane. The clinical sign for anemia detection can prove to be quite useful in many cases, but still the lack of inter-observer agreements in many situations and low sensitivity of anterior conjunctival color can undermine the authenticity of the visual detection process [5-7]. Color scale cards, which consists of the color spectrum and the corresponding hemoglobin concentration is used in many occasions to alleviate the problem of inter-observer disagreement and human error to make the visual detection process more reliable [8].

Hemoglobin is the primary constituent which contributes to the pigmentation found in human blood. It possesses a bias in reflecting the red component of the light falling on its surface compared to the green component which it predominantly absorbs. This is the chief reason for the deep reddish appearance of hemoglobin [9]. Hence, by comparing the red and green components of the RGB color spectrum of the conjunctival pallor, it is possible to obliquely estimate the hemoglobin concentration in the human blood stream [9, 10].

Due to lack of proper healthcare and medical facilities in underdeveloped countries, many people are vulnerable to anemia. This situation can be alleviated if an indication of anemia can be estimated without involving expensive blood tests, which are unavailable in many of these areas. Even the availability of doctors or medical workers are spotty. It would be a great help if the presence of anemia in a patient can be detected using non-invasive methods which does not include expensive tests or even the presence of a doctor or medical worker. The presence of anemia in a person can be an indication of other diseases like jaundice and lack of nutrition. The detection of anemia can serve to indicate the presence of other diseases as well.

In this study, we wanted to find out if the RGB spectrum calculated from digital photographs taken in sufficient lighting conditions provide a good approximation of the hemoglobin concentration of the human blood stream. Our objective was to construct a non-invasive process of detecting anemia from a photograph of the anterior conjunctival pallor of the subject's eyes using a suitable smartphone of appropriate camera quality.

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We observed that RGB spectrum of the image of the anterior conjunctiva shows considerable correlation with the hemoglobin concentration of blood as indicated in the subject's blood report. Our findings suggest that the detection of anemia using an image of the eye can indeed prove to be a potential non-invasive, reliable, user friendly and affordable substitution for the detection of anemia where an invasive blood test is not available.

II. Methodology

A flow chart constituting the entire process is presented in Fig. 1. This shows the major parts of the developed algorithm where each segment would be described in detail in the following sections.

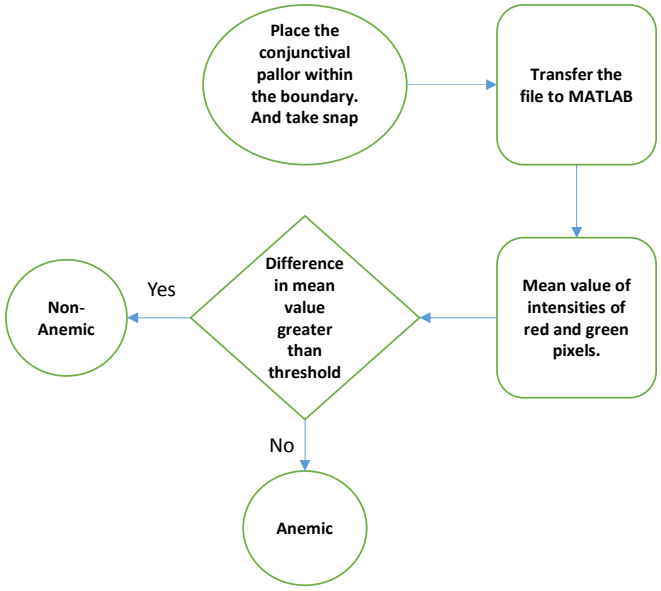

Fig. 1 A flowchart depicting the major parts of our algorithm

A. Taking the photograph

The process begins by first taking a picture of the anterior conjunctiva of the eye with a standard back facing camera of a smartphone in ambient lighting condition. It is done by pulling the lower eyelid softly with the thumb and taking the photograph so that the anterior conjunctiva is in focus and as magnified as possible. We developed an android application that adds a frame to the standard camera app of any android smartphone. A screenshot of the camera app taking a picture of the anterior conjunctiva along with the frame is given in fig. 2. When taking the photograph, it was made sure that the anterior conjunctiva was placed as much as possible inside the black frame. The picture along with the frame was then transferred to MATLAB for image processing. The camera flash was turned off to avoid excessive glare while taking the photos. The quality of the picture taken had considerable effects on the detection algorithm. Improperly taken picture may undermine the whole process. So, the picture should be taken with the best camera available. The photographer should have stable hands as excessive shaking makes the image blurry and may result in erroneous readings. Also taking the picture in daylight is recommended.

B. Image Processing using MATLAB

The next step of the process involved image processing and matching the conjunctival color with standard anemia index cards used by physicians for visual inspection of anemia. First, the images were taken into MATLAB. The part of the image inside the black frame were then cropped using the image processing tools of MATLAB. The Sobel edge detection algorithm was used to detect the appropriate frame boundaries. A number of other edge detection algorithm was also tried but the Sobel algorithm proved to be the best suited in this case.

Next, the white part of the sclera on both sides of the iris was extracted. This was done in the following order.

- The entire image was first converted to grayscale.
- Next, the Hough circle algorithm was run to detect the iris of the eye. The picture was initially converted to grayscale as the Hough algorithm works better in black and white images rather than color images.
- A suitable radius was approximated and a circle was drawn taking the iris as the center.
- Next, the formed circle was cropped from the original color image and the iris that was detected earlier was also eliminated from the cropped circle thus leaving only the white part.

Next, the extracted white part was used as a reference of the brightness of the anterior conjunctiva. This created a soft threshold so that too dark or bright images ceased to give erroneous result.

C. Detection of Anemia using RGB thresholding

After the extraction of the white sclera and anterior conjunctiva were completed, both parts were saved in different images. The RGB value of the anterior conjunctiva was then extracted. The RGB spectrum was then standardized using the brightness of the white sclera part for the purpose of the soft thresholding as mentioned before. Next, the red color intensity of the RGB spectrum was compared to the green color intensity to determine whether the person was anemic or non-anemic. We calculated the mean red pixel intensities and green pixel intensities. From our data we found that the difference between the two means were small for anemic patients compared to non-anemic patients.

To determine the threshold value a number of subject's eye images were analyzed whose anemia level were previously known. We manually selected a threshold difference of means based on inspection of data for anemic and non-anemic patient. We found that a mean difference of 1.5 was suitable for our given data.

III. Results

A. Data collection

With the support from the staff of Dhaka Medical Collage Hospital, we were able to collect a number of photographs of patients (both anemic and non-anemic) along with their Hemoglobin levels extracted from their blood report. The photograph of 19 patients were collected with a Xiaomi Redmi Note 3 pro smartphone which has a 16MP back facing camera. The photos were taken in daylight with the camera flash turned off for proper ambient lighting conditions.

Among the 19 patients, 7 of the patients were male and the rest 12 were females; 3 of the male patients were anemic and 5 were non-anemic according to the patient's blood report. Among the female patients, 7 of them were anemic, whereas, 4 of them were non-anemic. We tested our process on the images of all 19 of the patients to test the accuracy of our system compared to the readings obtained in their actual blood work.

A list containing the patient's actual anemia state as reflected in their blood test report, their hemoglobin level and the predictions made by our algorithm is given in table 1.

TABLE 1: List of patients with their actual anemia state and the predictions made by our algorithm.

Patient Number	Actual Hemoglobin level (gram/100 ml)	Presence of anemia according to blood report	Anemia Prediction though our process
1	7.2	Yes	Anemic
2	7.7	Yes	Anemic
3	8.2	Yes	Anemic
4	11.8	No	Non-Anemic
5	6.9	Yes	Anemic
6	11.7	Yes	Non-Anemic
7	8	Yes	Anemic
8	10.3	Yes	Non-Anemic
9	16.0	No	Non-Anemic
10	15.7	No	Non-Anemic
11	15.4	No	Non-Anemic
12	15.3	No	Non-Anemic
13	13.6	No	Non-Anemic
14	14.8	No	Non-Anemic
15	11.2	Yes	Non-Anemic
16	12.2	No	Non-Anemic
17	11.3	Yes	Non-Anemic
18	11.6	No	Anemic
19	13.2	Yes	Anemic

Among the 19 readings, 15 of them were correctly predicted by our algorithm that translated to an accuracy of about 78.9%.

B. Detailed analysis

The detailed analysis of 2 photographs (1 Anemic and 1 Non-anemic) has been shown in detail. A screen shot of the app taking the picture of sample 1 is given in Fig. 2.

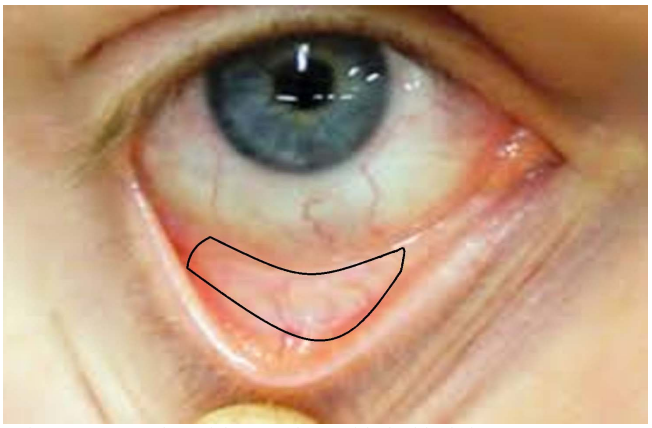

Fig. 2 A screen-shot of the app along with the block frame

Fig. 3 Photograph of the conjunctival pallor of Patient 9

Histograms of the red and green spectrum of the anterior conjunctival pallor of patient 1 (anemic) has been given in Fig. 4 whereas that of patient 9 (non-anemic) has been given in Fig. 5. Next the red spectrum of each sample is compared with the green spectrum and the difference in the color intensity of the two spectrum are compared to decide whether the patient is anemic or non-anemic.

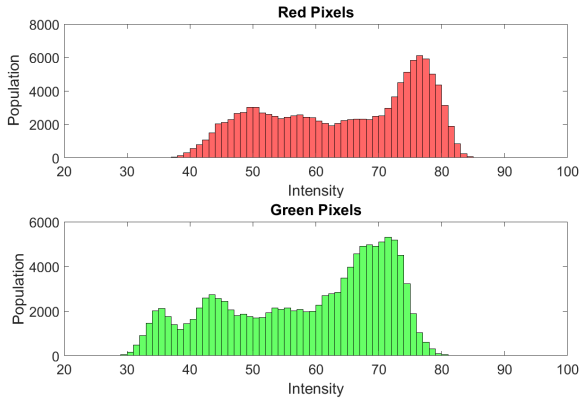

Fig. 4 Histogram of Anemic patient

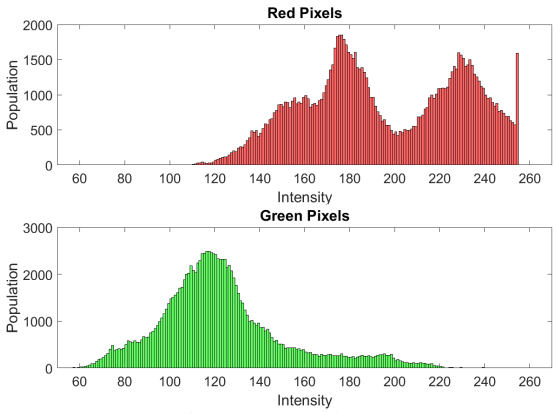

Fig. 5 Histogram of Non-anemic patient

On examining the two histograms closely it can be seen that, in case of an anemic patient (Fig. 4), the color intensity population of the green spectrum is more spaced towards the high intensity side (right side) compared to the red. This substantially large intensity of the green color compared to the red color is used to label this patient anemic.

On the other hand, for the non-anemic patient (Fig. 5), the opposite occurs, that is, the population of the red color spectrum is more spaced towards the high intensity side (right side) compared to the green color. So the intensity of the red color is greater than the green color in case of a non-anemic patient.

The algorithm decides the state of a patient by averaging the color intensity of the red and green spectrum and then comparing the two values. A suitable threshold is estimated and if the difference between the two spectrums is greater than the threshold value then the algorithm labels that patient as Non-Anemic. The difference is calculated as:

$$\text{Mean red color intensity} - \text{Mean green color intensity} \quad (1)$$

So in case of moderately anemic patients like Patient-1, the value of the difference can also come out to be negative. This happens when the mean red color intensity is less than the green color intensity.

IV. Humaniterian impact

The deficiency of red blood cells or Anemia still persists to be one of the major causes of health hazard in many underdeveloped regions throughout the world [2]. The first step towards mitigating the risks of anemia is the early detection of this syndrome. Most conventional methods of anemia detection rely on a chemical blood test performed on the intravenously acquired blood sample of the patient in question. However, due to the lack of proper medical facilities or hospitals in many areas, this intravenous method of anemia detection becomes highly inconvenient at certain times. In many patients, the detection of anemia is eventually delayed until it causes irreversible organ damage which may even lead to death in certain occasions.

Our method of the detection of anemia requires no intravenous blood samples and can be quite conveniently administered requiring only the availability of a camera enabled smartphone which is becoming increasingly available in recent times. The process is user friendly with requires no prior specialized skills to operate making it very convenient to administer.

V. Conclusion

In summary, we have perfected a process of non-invasive process for the successful detection of anemia with a 78.9% accuracy. The process involves taking a picture of the conjunctival pallor of the eye using the camera of a smartphone with suitable regulation in sufficient lighting with the help of an android application which we devised. The image taken is next transferred to a computer via the internet or any other means available. A computer program then processes the image to extract RGB spectrum of the anterior conjunctival pallor and compares it with a pre-determined threshold value to conclude whether the subject is anemic or not. The value of the threshold is determined based on our collected data so the quantity of the data has a considerable impact on the accuracy of the system and a larger and more diversified collection of data injected into our algorithm would substantially boost the accuracy. Furthermore, the threshold of anemic and non-anemic patients can also depend on his/her geographical location which can be incorporated into the program if data from different regions is available. This method of anemia detection can prove to be a crucial tool in the fight against anemia in the lesser developed regions of the world. This can result in a significant increase in the health conditions in those areas along with a sufficiently less deaths caused by the effects of anemia. Moreover, this method can also be employed to detect the lack of blood caused by other means like blood loss due to physical injury of various organs of the body.

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