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Tech Meets Health: Predicting Anemia and HB Through Image Processing

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ABSTRACT

Anemia is a very common medical condition in which the count or size of red blood cells is reduced, and it limits oxygen transport to the body. In most cases, it requires invasive and costly blood tests for diagnosis. India is Struggling to keep up the World Health Assembly targets for anemia reduction by 2025 .Anemia Mukt Bharat strategy Introduced in 2018. It is Aiming at iron and folic acid Nutritional support to adolescent girls as they provide the Renewed opportunity to eliminate or reduce the burden and break the intergenerational cycle of anemia before entering into the pregnancy [16]. Strengthening adolescents' nutrition is beneficial to adult health. It produce triple dividends- better health for adolescents now, Enhanced health and performance in their future adult life and lowered health risks for their offspring. (World Health Organization, 2018) At this stage, there is still the chances of correcting nutritional deficiencies and possibly even bridging the gap on growth. Nutrition Interference in adolescent may help break the cycle of malnutrition, chronic disease and poverty. Adolescent girls' health and their status in general, and the frequency of anaemia in particular, are affected by factors such as deworming, underweight, vegetarianism, obesity and the presence of pallor. Some other factor have been found to be associated with anemia such as socioeconomic status, education, worm infestation, menstruation, and pregnancy in adolescent females [1] This research addresses the gap between traditional diagnostics in health and modern non-invasive approaches by using image analysis and mathematical modelling [11] through matlab, which would provide a scalable solution for screening Anemia in resource-constrained areas.

Keywords : Anemia Detection; Non-invasive Diagnosis; Image Processing; Curve Fitting; Hemoglobin Prediction

I. INTRODUCTION

Anemia is the condition that reduces the number of red blood cells or hemoglobin in the human body, which reduces the supply of oxygen to tissues. Anemia occurs due to various factors, bleeding and uneven nutrition results iron deficiency Anemia. Also chronic diseases like kidney related diseases, chronic diseases, inherited genetic disorders, e.g. sickle cell Anemia, thalassemia, etc. affects Anemia.

This condition is pretty common among college students, especially the residents in hostels, due to their different modes of living and modes of eating. This badly affects the physical as well as cognitive well-being. In this busy schedule of colleges, students will most likely be consuming less nutritious food, which may not feed them with the required nutrients for the strengthening of their immunity, thereby highly increasing Anemia cases. Furthermore, the individuals residing in town hostels sometimes find it impossible to get sufficient nutrient-rich food comprising iron, vitamins, and other essential ingredients, which makes them highly susceptible to Anemia cases.

Anemia makes them experience prolonged low-grade fatigue and lack of energy in which they fail to focus on what they are doing. Interference in such cognitive functions as memory and attention means the students struggle to keep up with the demands of academics. Also, Anemia weakens the immune system making the body more prone to infections and other illnesses leaving less room for academic schedules.

Living conditions in hostels may be really challenging for the students as it might have consequences on their physical as well as mental health. Poor timing of meals, the nutritional value provided by meals, and chronic fatigue may make it impossible for some students to participate in sports tournaments and other important activities. Hence, such hostel-inhabiting college students would be able to be enlightened to perform well in academics if their dietary changes, clinical support, and awareness programs were appropriately offered.

II. Literature Review:

Many studies have used machine learning approach for detecting Anemia non-invasively, machine learning techniques like CNN, Naïve Bayes, decision tree, k-NN, and SVM, to detect Anemia using medical images [12] of the conjunctiva, palpable palm, and fingernail color as input features, the resultant model demonstrated promising results. A study applied [13] on pallor analysis using images of the conjunctiva to detect Anemia [11]. The research utilized publically available data set for employing ensemble of Convolutional Neural Networks, Logistic Regression, and Gaussian Blur. Some study used image processing to extract RGB color and extracted 18 features in 3 different color after pre-processing and cleaning the images. Using those features, Anemia was predicted machine learning algorithms such as Support Vector Classifier, Random Forest, Logistic Regression, and XGBoost [12] [15] .A research [14] based on particular areas including only 0-6 month age group and for pregnant women and showing causes of anemia [20]. Study used to develop non-invasive method by eliminating light on images [17] [11]. The approach represent the digital images using curve fittings on the images to identifying important shapes (ROI) [18]and introduce method for non- linear curve fitting [2] [18]. It [3] reviews different image augmentation techniques [4] and their role in image processing. A study applied on to detect anemia as early as possible and prevent related health complication [5] [6]. Using quadratic curve fitting gives efficiency and accuracy in analysis [3].

III. Importance of monitoring Hemoglobin:

a. Tracking Treatment Progress:

In addition to monitoring the target hemoglobin levels in patients subjected to treatment, whether it is iron replacement and dietary modification or medication, it is also essential to track the response of the latter to the treatment. This keeps the clinicians in the know as far as the increase or decrease in the target hemoglobin levels expected due to the therapy or whether the treatment protocol needs to be altered in the patient's case.

b. Managing Chronic Conditions:

Of course, many patients with chronic diseases, like kidney failure or cancer, have fluctuating Hb, which leads to deterioration in the state of a patient, resulting in sometimes very severe Anemia that needs vigilant control.

c. Preventing Complications:

This also reflects blood counts that show symptoms of Anemia and decreased Hb levels. Periodic checks on the level of Hb can help one determine decaying numbers before they reach a critical low, which may indicate the patient is suffering from late-stage iron deficiency or other illnesses. Thus, low levels of hemoglobin are crucial in preventing such conditions with symptoms of extreme fatigue, increased strain on the heart, and inadequate oxygen supply to the organs.

d. Avoiding Over-Treatment:

Even if administered as a treatment through iron loading or repeated transfusions, close monitoring of hemoglobin levels is made to prevent high elevations which may cause blood clotting and damage to vital organs.

Thus, regular HB testing is a vital tool for maintaining optimal health and adjusting treatment approaches on time.

IV. How it can be Useful:

An Anemia test may be possible non-invasively, at low cost, and even expediently by examining images from areas such as the conjunctiva inner lining of the eyelids and the palms. This can be based on symptoms apparent in Anemia that are manifested on the conjunctiva and palm as paleness and are known to arise with low hemoglobin levels. This will make the diagnostic procedure more efficient.

a. Non-Invasive Diagnosis:

This traditional Anemia diagnosis requires a blood test often diagnoses Anemia, which can sometimes be painful or uncomfortable for the patient. The process is fairly lengthy to the health providers and would be invasive, thereby causing discomfort or even hurting the concerned person, particularly children, old people, or maybe those in rural areas who are not privileged enough to access healthcare services.

b. Early Detection:

It can be in the form of objective signs, especially paleness of conjunctiva or palm (palmar pallor). An image-based approach enables it to be rapidly identified and corrective measures taken so that it does not progress into complications. The need is more stringent with boarding students who could be staying away from home and are hence more susceptible to the dietary patterns leading to nutritional inadequacy

c. Portable and Scalable:

This algorithm proves to be ideal for application in smartphone-based apps or even portable diagnostic tools [19] [17]. Since this algorithm is applied remotely, the individual can conduct the screening from any remote location, hence it also offers opportunities for telemedicine. The settings where more resources are not available and one also lacks the blood laboratory tests either because they are unavailable or delayed greatly benefit from this algorithm.

d. Time-Efficient and Cost-Effective:

This has the advantage of more rapid and cost-effective prediction of Anemia than in the case of using laboratory tests. There is less dependence on reagents, equipment, and health personnel. The preliminary identification for follow-up medical testing or treatment of some people is usually done by it. It is relatively cheap for mass population screenings.

e. Continuous Monitoring:

For a patient already diagnosed with Anemia, such as college students or hostellers, images to trace their condition may provide continuous easy data on recovery. Through this method, the levels of hemoglobin can be estimated without repeating blood tests, hence ensuring that the condition is controlled.

f. Application in Low-Resource Settings:

This will be revolutionary in places with scarce health infrastructure because it gives a predictive way of Anemia without the use of laboratory tests. Healthcare workers can take pictures with mobiles and then interpret them using algorithms, which have the possibility of improving the rate of detection of Anemia in underprivileged populations.

Overall, image-based prediction of Anemia, particularly in college students and hostellers, can increase awareness, facilitate quicker interventions, and lessen the burden of traditional testing, leading to improved health outcomes with minimal resources.

V. Flow Chart

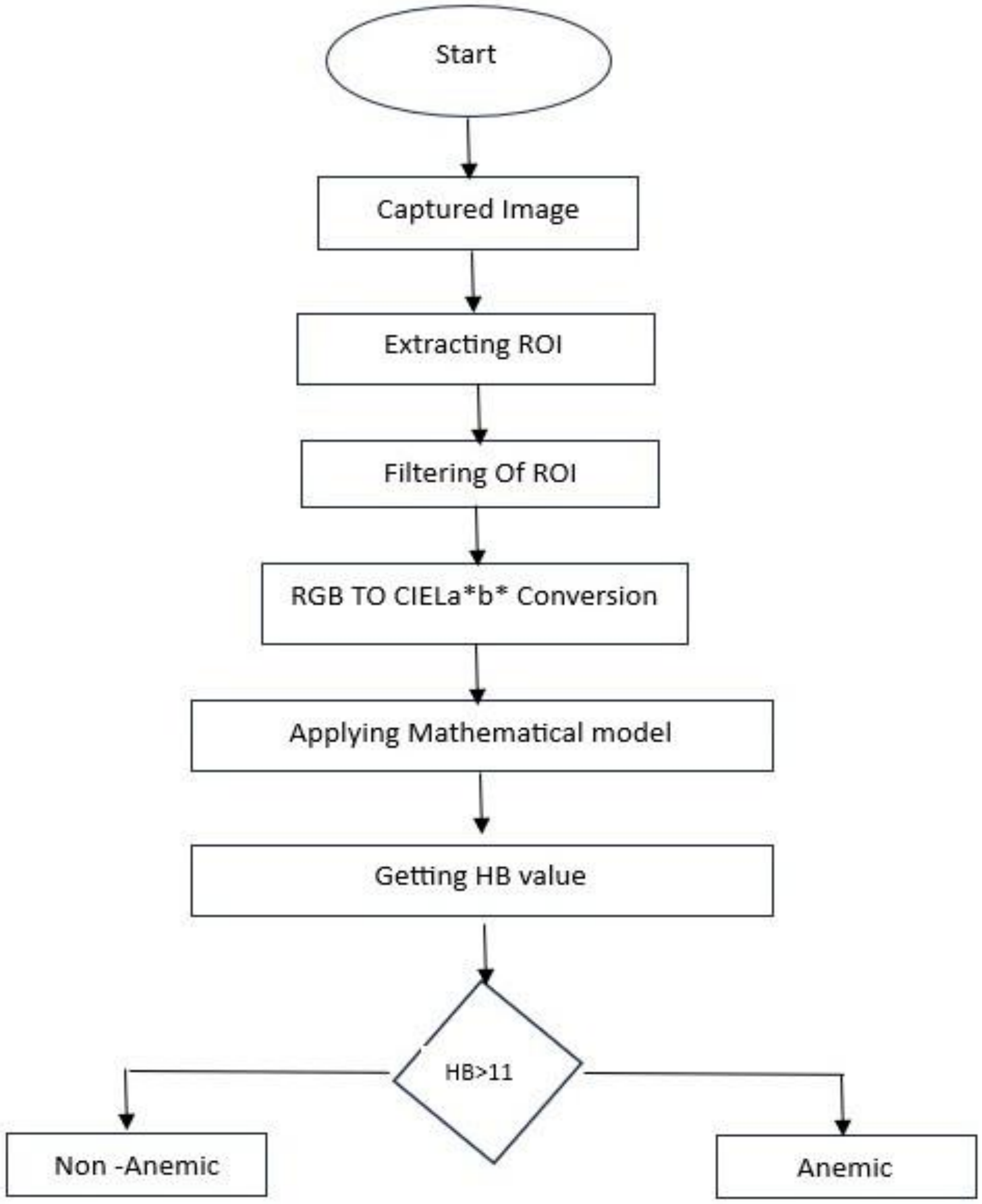


Fig:1

VI. Methodology

In this research use the following steps : data collection, image pre-processing, image augmentation, classification of Anemia status, and mapping to the original hemoglobin (HB) values.[15]

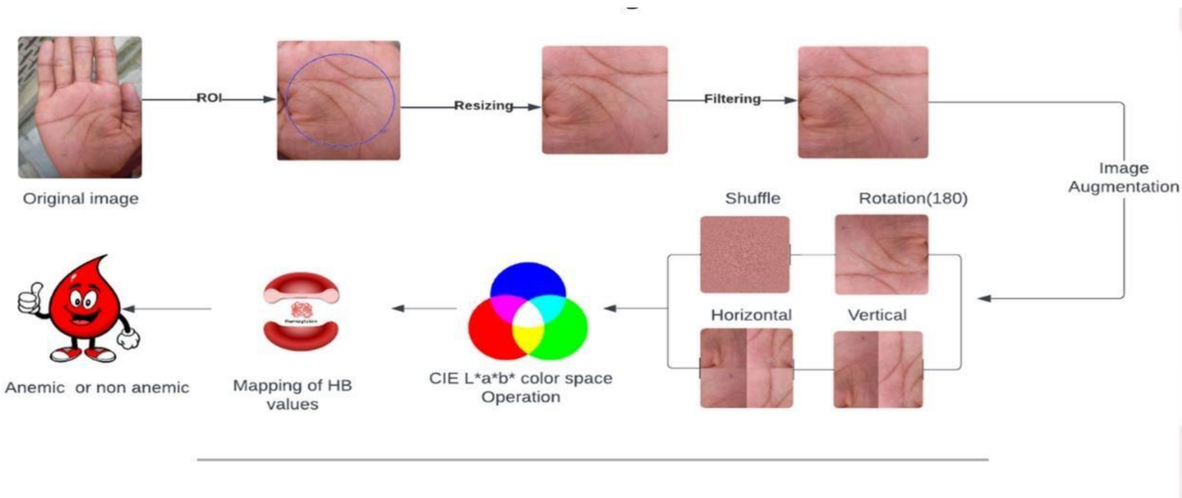


Fig:2

a. Data Collection:

The data needed for this research was collected by arranging four different camps in our college campus. By circulating google consent form amongst the participants involved in the camp, the general information along with the hemoglobin (if known) of each candidate was collected. At the same time, we captured the images of conjunctiva of eyes (left and right) and palms (left and right) in our 48-megapixel camera of android mobile which is minimum pixel camera that any common person can afford. The age group considered for this research is 18 to 25 years. The condition for capturing the images was not directly exposure to sunlight, but in the shadow under the natural sunlight. No particular angle was fixed while capturing the images, the images were captured using random angle. The complete information was maintained properly in the excel sheet along with the images.

b. Pre-processing of Images:

Images captured during the camps, involved noise such as reflection of light in the images. To nullify the effect of light, all the images were pre-processed. The pre-processing involved extracting the ROI (region of interest) of eye from each image by cropping the central part of the eye conjunctiva [11]. The ROI (region of interest) of palm was extracted by fixing radius from the center point of the palm and the circular region under the radius was extracted. After extracting the ROI's of both eyes and palms, the light reflection(noise) in the ROI was reduced by applying the Gaussian Blur filter. Gaussian Blur filter uses two functions and these two functions generates the third function known as convulation. The convolution creates normal distribution of pixel values of images and smoothens the random pixels, reducing the noise.

Fig 3 : Original Eye

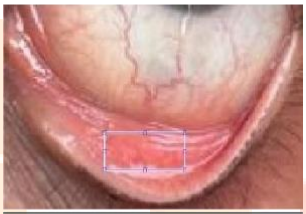


Fig 4 : ROI

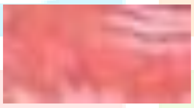


Fig 5: ROI

Fig 6: Filtered ROI

As the dataset was limited, to get more accurate results the dataset was increases using data augmentation technique. This technique considered rotation, flipping and shuffling. Rotation fixes 90, 180, and 270 degrees angle and rotates the images accordingly [8] [9] Flipping works on specific axis consisting of horizontal axis reflection, vertical axis reflection, and both (horizontal and vertical) axis reflection. Flipping involves mirroring of the images. Horizontal flipping reflects the image along vertical axis, vertical flipping reflects the image along horizontal axis, both (horizontal and vertical) flipping reflects the image along diagonal axis. [8]

1 2 3
4 5 6
7 8 9

Fig : original

3 2 1
6 5 4
9 8 7

Fig : Horizontal Flipping

9 8 7
6 5 4
3 2 1

Fig : Vertical Flipping

Shuffling involves rearranging the pixels or the small block of pixels of an image . Shuffling is applied on rows, columns and both.

1 2 3
4 5 6
7 8 9

Fig : Before Shuffling

7 8 9
1 2 3
4 5 6

Fig : After Shuffling

Augmentation technique was applied on each image under consideration. Augmentation technique boosted the accuracy of the result by increasing the dataset. [9] [3] [20]

Fig: Dog

Fig: Rotation_90degree

Fig: Rotation_180degree

Fig: Pixel-shuffling

Fig: Horizontal-flipping

Fig: Vertical-flipping

c. **Actual Implementation:**

Our code calculate the hemoglobin value form the given RGB (red, green and blue) mean value. And classify the person whether anemic or non-anemic by image processing technique. Let's see the steps follow by this process.

Steps:

i. **Extract RGB Components:**

First step is to extract the red, green and blue component from the given RGB image. As image represented in matrix and each pixel of image contain three values of the corresponding color channels [16]

242	242	241	239	230
240	245	248	243	235
236	242	246	245	238
238	240	243	245	245
241	241	240	247	252

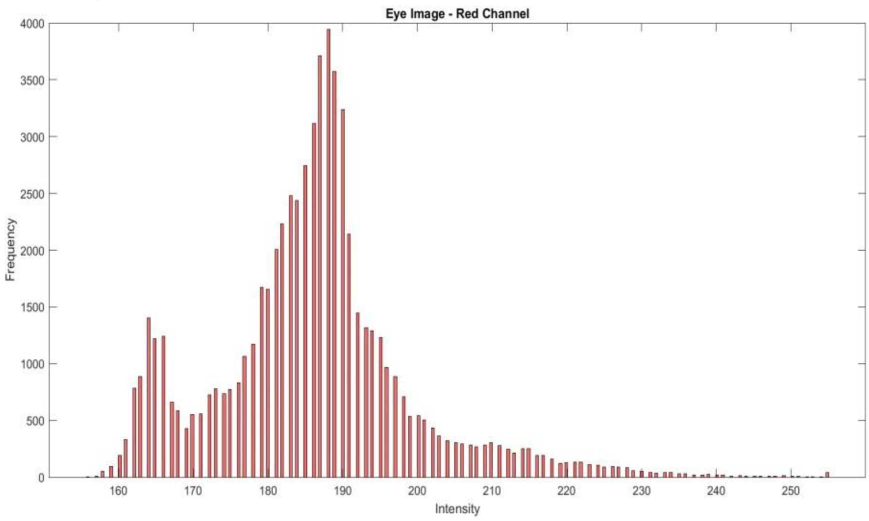
Fig : R-component matrix

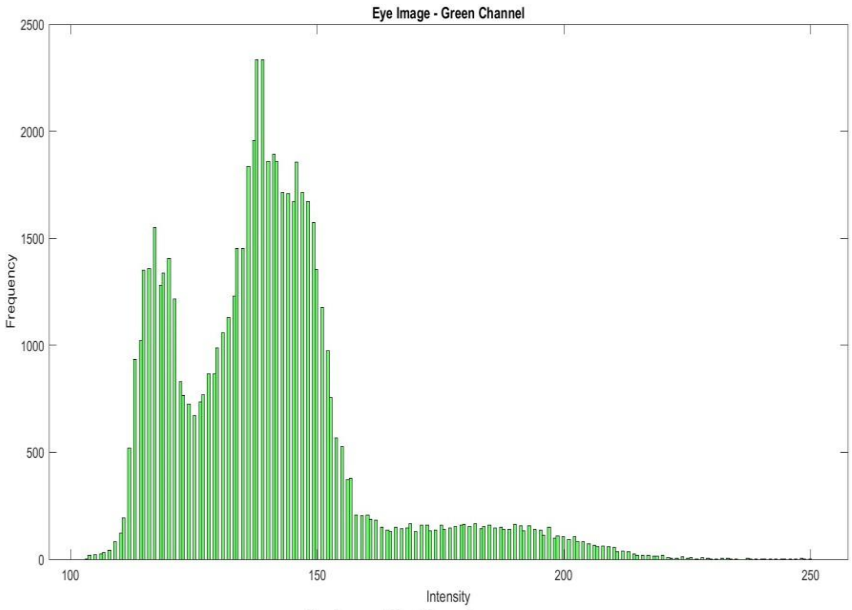
132	129	125	123	115
136	133	127	120	120
134	133	128	114	125
130	132	133	119	133
125	132	139	136	142

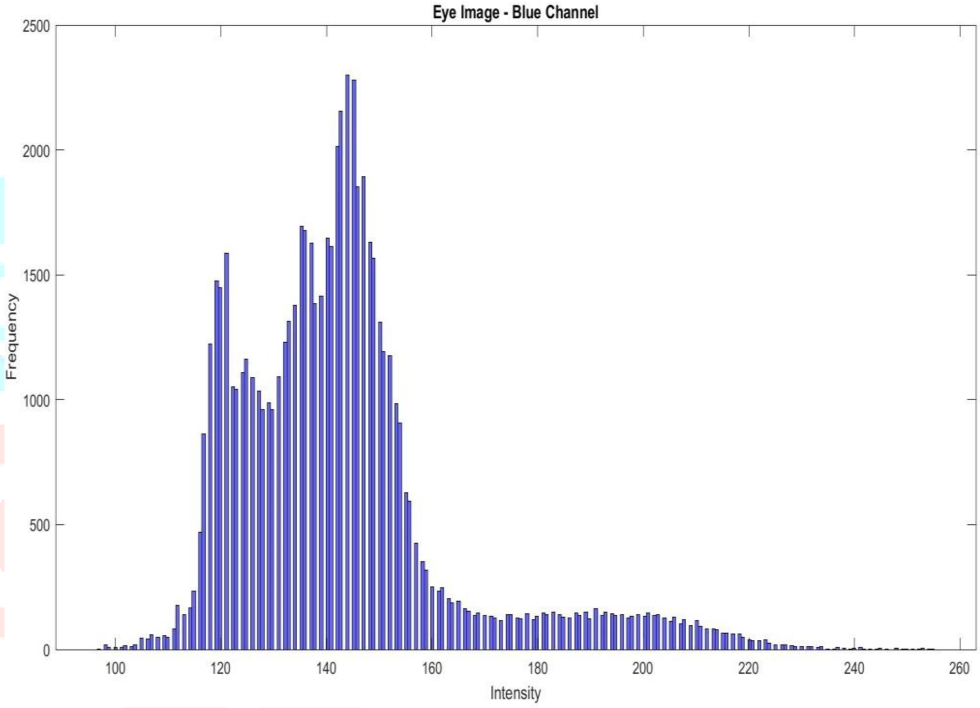
Fig : G-component matrix

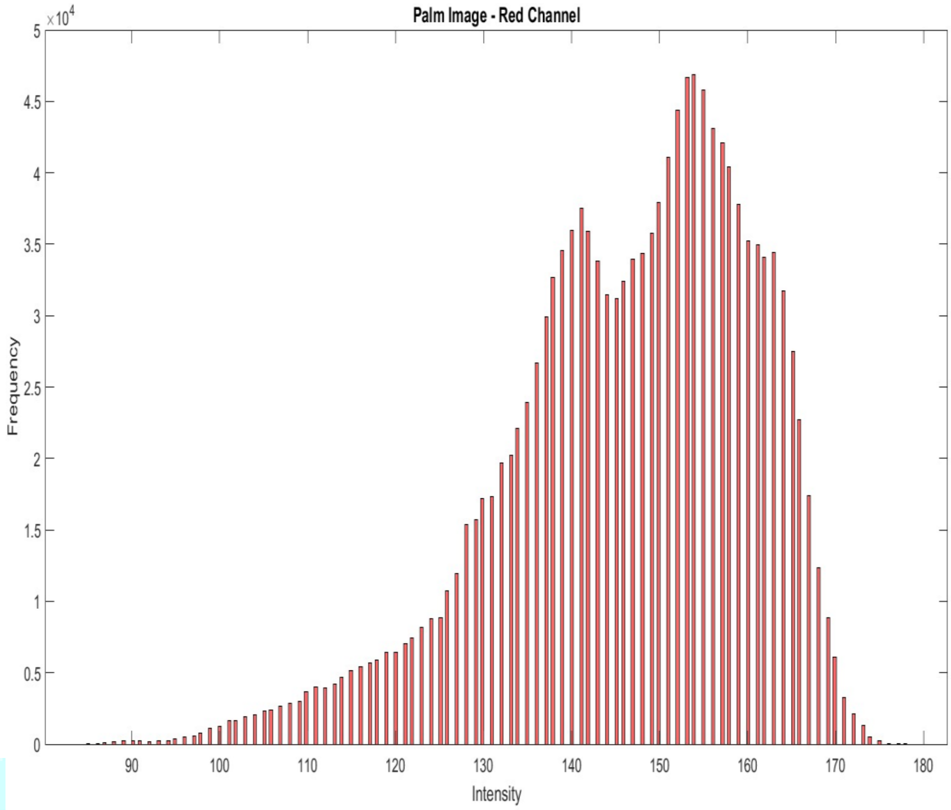
109	123	125	128	129
106	118	123	130	134
98	109	116	125	130
99	107	116	120	126
103	111	117	117	120

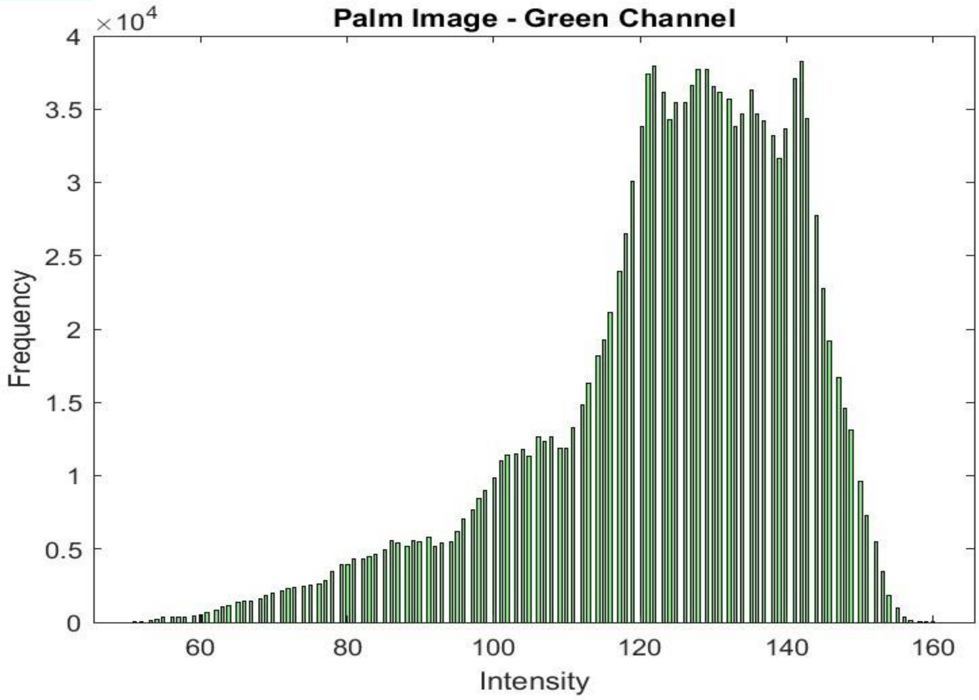
Fig : B-component matrix




Eye Image - Green Channel
Frequency
Intensity
2500
2000
1500
1000
500
0
100
150
200
250


Eye Image - Blue Channel
Frequency
Intensity
2500
2000
1500
1000
500
0
100
120
140
160
180
200
220
240
260


Palm Image - Red Channel
×10^4
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Frequency
90
100
110
120
130
140
150
160
170
180
Intensity


Palm Image - Green Channel
×10^4
4
3.5
3
2.5
2
1.5
1
0.5
0
Frequency
60
80
100
120
140
160
Intensity

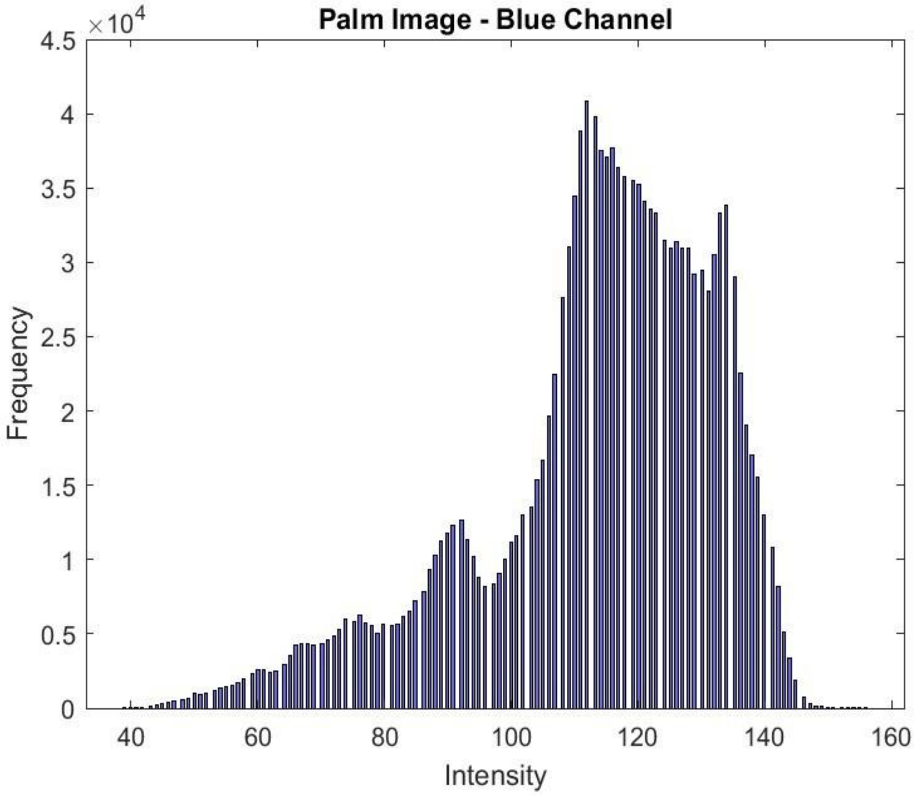


Fig : Histogram of RGB channels of eye and palm

Observing above histograms, the intensity for red channel for eye and palm is highest in comparison with green and blue. The conclusion from above histogram visualization is, the red channel is more dominant.

ii. Calculate Average RGB values:

In this step calculate the mean value of each RGB component. This is helpful to give more accurate sense toward predicting Hb value and classifying person whether anemic or not

Compute Mean RGB:

Next, goes towards the calculate the mean of RGB values to get separate single mean value of red, green and blue chanels.

iii. Convert to CIE Lab Color Space:

What is mean by CIE Lab Color Space?

It was developed by International Commission on Illumination in 1976. Shortly it is known as CIE Lab or another name is CIELB or Lab. It design to model the all color that understand easily by the human eye. As we know that one image contains many types of colors including effect of light and all. So CIELAB is better color space as compare to another color space as it separate the reflection, light from image gives accurate color.

Components of CIE Lab Color Space :

The CIELAB color space mainly having three components i.e. L*, a* and b*.[10] [19]This components are help to model human vision and provides good understanding of uniform representation of colors. See how it is important in giving correct color.

➢ L* (Lightness) :

- It represent the lightness or brightness of a color, mostly how color appears like ligh or dark in shade.
- It ranges from 0 to 100. Means 0 represents the completely dark that is black color and 100 represents the maximum brightness.
- L* not directly show any intensity but helps to understand how bright color is seems to human eye.
- It helps in adjusting brightness in an image.

➢ a*(Green-Red axis) :

- It shows the color is between the green and red colors.
- It is lies in between -128 to +127.
- Negative values shows the color is green, positive values shows the color is red and zero value shows the neutral color i.e. neither green nor red.

- a* component use in color based segmentation and enhancemnt.

➢ b*(Blue-Yellow axis) :

- It shows the color is between the blue and yellow colors.
- Value of b* is lies in between -128 to +127.
- Negative values shows the color is blue, positive values shows the color is yellow and zero value shows the neutral color i.e. neither blue nor yellow.
- a* component use in color based segmentation and enhancemnt.

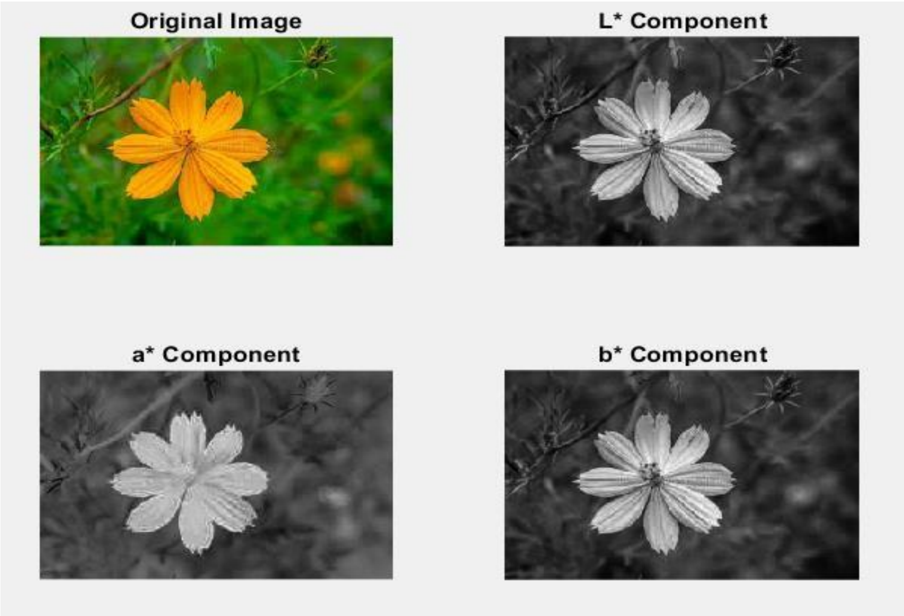


Fig : Explaining CIE Lab Color Space

0.9602	0.9447	0.9632	0.9840	1.0265
0.9614	0.9620	0.9632	0.9840	1.0265
0.9772	0.9780	0.9623	0.9831	1.0256
0.9789	0.9789	1.0014	1.0227	1.0661
1.0144	0.9974	0.9998	1.0211	1.0644

Fig : L* matrix

-1.4393	-1.4690	-1.5292	-1.6571	-1.7208
-1.3999	-1.4288	-1.5214	-1.6126	-1.7048
-1.3999	-1.4288	-1.5214	-1.6126	-1.7048
-1.3924	-1.4210	-1.5129	-1.6031	-1.6995
-1.3924	-1.4210	-1.5129	-1.6031	-1.7296

Fig : a* matrix

1.0692	1.0940	1.1446	1.2488	1.3038
1.0483	1.0729	1.1474	1.2265	1.3051
1.0483	1.0729	1.1474	1.2265	1.3051
1.0509	1.0756	1.1504	1.2298	1.3070
1.0509	1.0756	1.1504	1.2298	1.3315

Fig : b* matrix

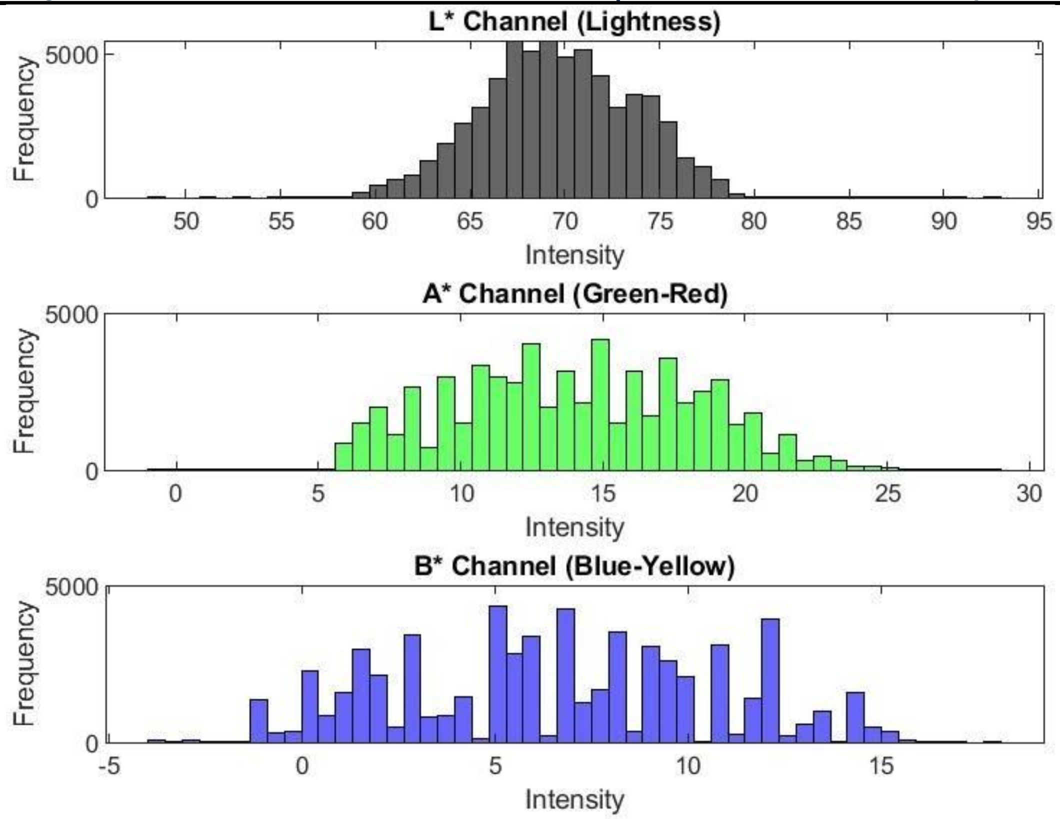


Fig : Histogram of L* a* b* channels of CIELAB color space

As analyzing or manipulating thes L*, a* and b* components seperately we perform modern type of color analysis. We convert our calculated RGB values into the CIE Lab color space. Using above usefulness we use CIELAB color space to predicting the person is anemic or non-anemic.

iv. Predict Hemoglobin (HB) Levels:

By using values of red and green channels from the RGB color space and the b* value in the CIE Lab color space, we used the equation to evaluate the hemoglobin (Hb) levels of the person. As Hb is of red color so we take only these three components for our guess of hemoglobin and best accuracy. We will be able to provide a prediction of an individual's content of hemoglobin, using both objective parameters and clinical, or visual observations with the help of this formula.

```
exponent = -1.922 + 0.206 * r_mean - 0.241 * g_mean + 0.012 * b_mean;
```

Where r_mean and g_mean are mean of RGB values and b_mean is the value of b* generates from CIELab color space and exponent will store in new variable named Hb for ease of calculation.

```
Hb = exp(exponent) / (1 + exp(exponent));
```

And then converting Hb value to range 7-15 g/dL

```
Hb_g_dL = c + ((d - c) * (Hb - a_range)) / (b_range - a_range);
```

Where , a_range = 0 as range minium for Hb (Normalized) b_range = 1 as range maxium for Hb (Normalized)
c = 7 as new range minium in g/dL
d = 15 as new range maxium in g/dL

v. **Set Thresholds for Anemia Classification:**

We have established a minimum cut-off value for Hb. A patient who falls into Anemia is one whose calculated Hb will be below this value, while it is just the opposite if above the value. Now, we further refine our analytical procedure so that we may evaluate plasma Hb value much more closely.

We constructed the formula by taking up fixed values and RGB values from images, with specific interest in the b* component of the CIE L*a*b* colour space. This model actually helped us arrive at an estimation of Hb levels in g/ml, but it was not quite accurate because our dataset was non-linear. [3]

d. **Transition to Curve Fitting:**

To overcome this limitation, we shifted our focus to curve fitting, a technique well-suited for modeling non-linear data. This approach enabled us to create a more flexible model that could better capture the underlying relationships within the data.

i. **Defining the Quadratic Model**

In this study, we use a quadratic model to predict hemoglobin (HB) levels. The equation for the quadratic model is:

$$\mathbf{y = ax^2 + bx + c}$$

- y = the actual HB value (measured).
- x = predicted HB value (from the image analysis).
- a, b, and c are coefficients that need to be optimized.

ii. **Why a Quadratic Model?**

The quadratic model introduces a non-linear relationship, allowing us to capture more complex variations between the predicted and actual HB levels. Unlike linear models, quadratic models can account for subtle deviations and improve prediction accuracy.

iii. **Curve Fitting Process**

Curve fitting involves optimizing the parameters a, b, and c by minimizing the difference between the predicted HB values and the actual HB values. This is achieved using **Least Squares Regression (LSR)**.

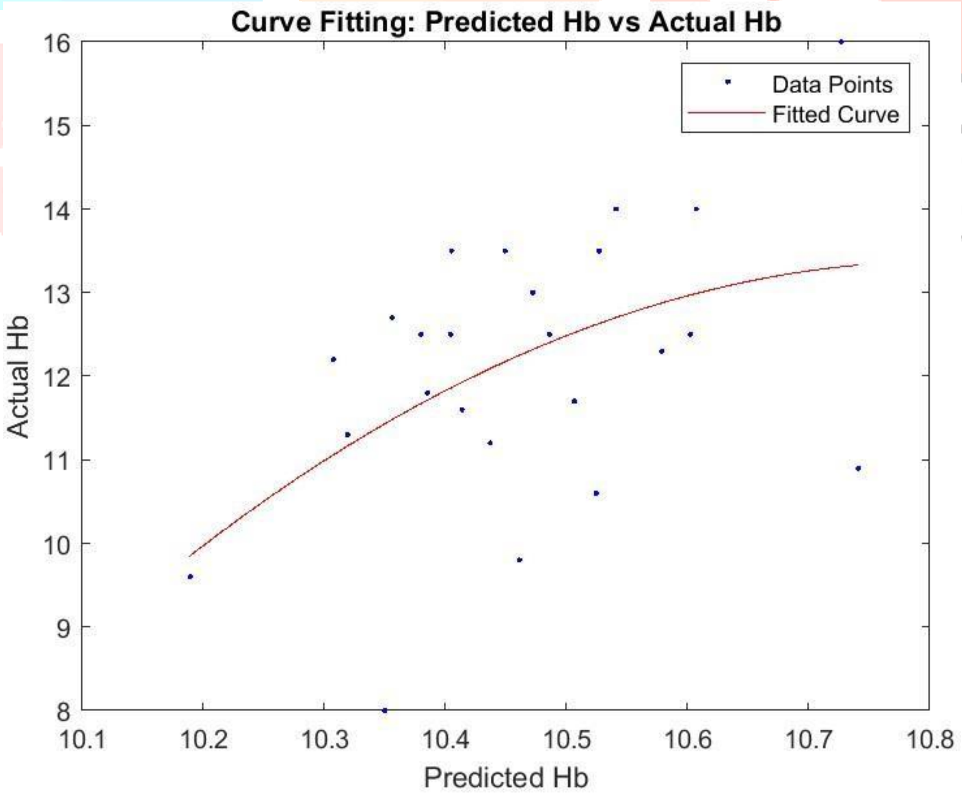


Fig : Curve Fitting Graph

Goal of LSR: Minimize the sum of squared residuals (errors), where residuals are the vertical distances (errors) between predicted and actual values.

The error function can be expressed as:

$$E(a, b, c) = \sum_{i=0}^{n} (y_i - (ax_i^2 + bx_i + c))^2$$

Where:

- y_i : Actual HB value for i^{th} sample.
- x_i : Predicted HB value for i^{th} sample.
- n: Number of samples.

iv. Minimizing the Error

To determine the best-fit coefficients a, b, and c, we minimize the error function E (a, b, c) This is done by:

Taking the partial derivatives of E (a, b, c) with respect to a, b and c.

$$\frac{\partial E}{\partial a} = 0, \frac{\partial E}{\partial b} = 0, \frac{\partial E}{\partial c} = 0$$

This results in a system of linear equations.

Solving the system of equations to obtain the values of a, b and c.

e. Results:

This fitting gave an improved accuracy for the case of hemoglobin, and the prediction increased to around 80% correct by using the fitting technique. This improvement shows that our approach is more in line with properties of this specific data set.
For that reason, curve fitting transitioned into a robust solution for us in predicting Hb levels from non-linear data, hence providing more reliable outcomes in our Anemia detection efforts.

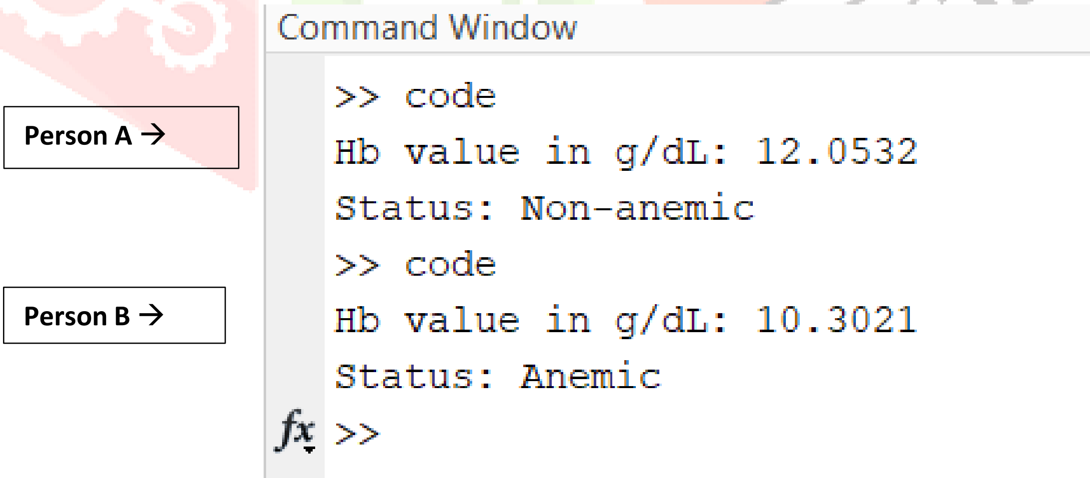


Fig : Output window of matlab

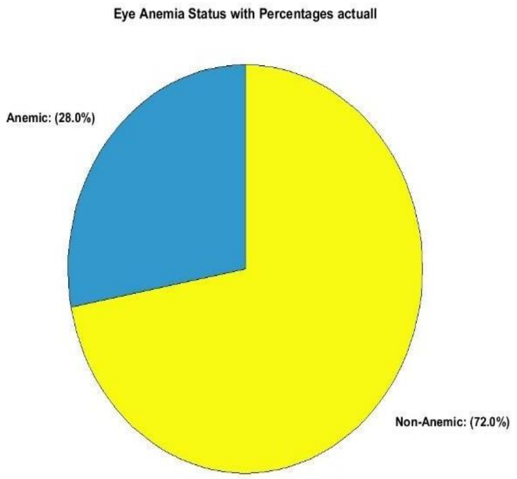


Fig : Percentages of Data Distrubution based on Anemic Condition

Table : Accuracy Analysis

Images	Title	Actual HB		Predicted HB		Accuracy
		Anemic People	Non-Anemic People	Anemic People	Non-Anemic People	
eye	Status Prediction	28	72	32	68	90%
	Hb value Prediction	28	72	36	64	80%
palm	Status Prediction	28	72	38	62	76%
	Hb value Prediction	28	72	54	46	40%

Total dataset consisted of 100 people, among them 28 are anemic and 72 are non-anemic for both eye and palm, considering actual HB. For status prediction of anemia for eye images 90% accuracy has been obtained as mentioned in above table. For HB value prediction of anemia for eye images 80% accuracy has been obtained using curve fitting model.

For status prediction of anemia for palm images 76% accuracy is been obtained as mentioned in above table. For HB value prediction of anemia for palm images 40% accuracy has been obtained using curve fitting model.

VII. Future Scope:

i. Medical condition affects the coloration of conjunctiva which indeed can affect the result hence to avoid it, studies in future can add medical history of patients of to account for health conditions affecting conjunctiva.

ii. Need to increase the accuracy of Hb prediction and status prediction of palm.

iii. Creating Standard Operating Procedures (SOPs) for capturing images, such as lighting conditions and camera settings to maintain uniformity across input. Increasing data size to include people from diverse ethnic background, across age and gender.

iv. Automate image pre-processing steps to increase quality of input images and eliminate the need of manually pre-processing of images and ensure consistency in inputs.

v. Combine metrics like blood pressure and glucose level with HB value for better health assessment of patients.

vi. Creation of mobile application for easy interaction [16]

VIII. Conclusion:

This project introduces a non-invasive method for predicting Anemia and HB levels using image analysis of the eye conjunctiva and palm. Images are captured using a 48 MP camera, processed with MATLAB's Image Processing Toolbox, and analysed using a curve-fitting mathematical model. Curve fitting is an approximation technique for data trends by mathematical functions that improves the accuracy of prediction. The technique involves extracting regions of interest (ROI) from images, converting RGB values into the CIE Lab* colour space for accurate colour analysis, and increasing the dataset through rotations and flips. It predicts Anemia status with 80% accuracy by analysing pallor variations in the conjunctiva and palm, key indicators of Anemia. The study used images from 100 individuals aged 18–25, especially focusing on the accessibility needs of resource-limited rural areas and college students with restricted healthcare access. This proof-of-concept research demonstrates an easy, inexpensive, and non-invasive Anemia screening tool, making early detection and continuous monitoring feasible. This approach emphasizes the potential of image processing to simplify evaluations, reduce healthcare costs, and improve health outcomes. In the future, a mobile application will be developed in order to transform this approach into a user-friendly and portable screening tool for large-scale Anemia detection and HB value estimation.

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