Bilirubin Quantification and Jaundice Prediction

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Contents

Introduction

- Jaundice is a yellow discoloration of body tissues which is caused by the deposition of bilirubin.
- **Bilirubin** is a yellowish pigment that is made during the breakdown of red blood cells
- Bilirubin Level > 2.5-3 mg/dL.
- Results in yellowish skin, sclera (white region) of the eyes and mucous membranes.
- Symptoms : changed skin colour, abdominal pain, fever and dark-colored urine.

Challenges

- Drawbacks of Invasive Method of Detection
  - Blood Test : Costly, Time Consuming and Painful
- Drawbacks of Existing Non Invasive Method of Detection
  - Lacking ability of Smartphone Implementation, Explicit Definition of the ROI, Lack of Simultaneous Bilirubin Quantification, Lack of Accuracy
- 20% of newborns develop jaundice in the first week of life.
- Newborns and older adults remain the most affected.

Aim: Develop a Non-Invasive Technique for Bilirubin Level Quantification and Detection of Jaundice

Literature Review

Name of the Solution	Algorithms Used	Limitations
1. Non-Invasive Bilirubin Level Quantification and Jaundice Detection by Sclera Image Processing.	Machine Learning with regression algorithms	• High setup cost • Only for newborn infants. • Low Accuracy
2. A Novel Non-invasive Technique of Measuring Bilirubin Levels Using BiliCapture.	Machine learning and laboratory analysis	• Use of Bilirubinometer • Requires professional human intervention for measuring value. • Precision of device is vital before accepting it into clinical practice.
3. Neonatal Jaundice Diagnosis Using a Smartphone Camera Based on Eye, Skin, and Fused Features with Transfer Learning.	Deep learning (CNN)	• Difficult to implement on smartphone apps. • Requires full face images for detecting facial markers.

Problem Description and Objectives

- To utilise image processing and computer vision techniques for autonomous ROI extraction i.e, Sclera Segmentation.
- To develop a resource-efficient ML model to predict blood bilirubin level and detect the jaundice of the patient.
- To make a smartphone compatible model.
- To test and deploy application in real life circumstances.

Proposed Methodology

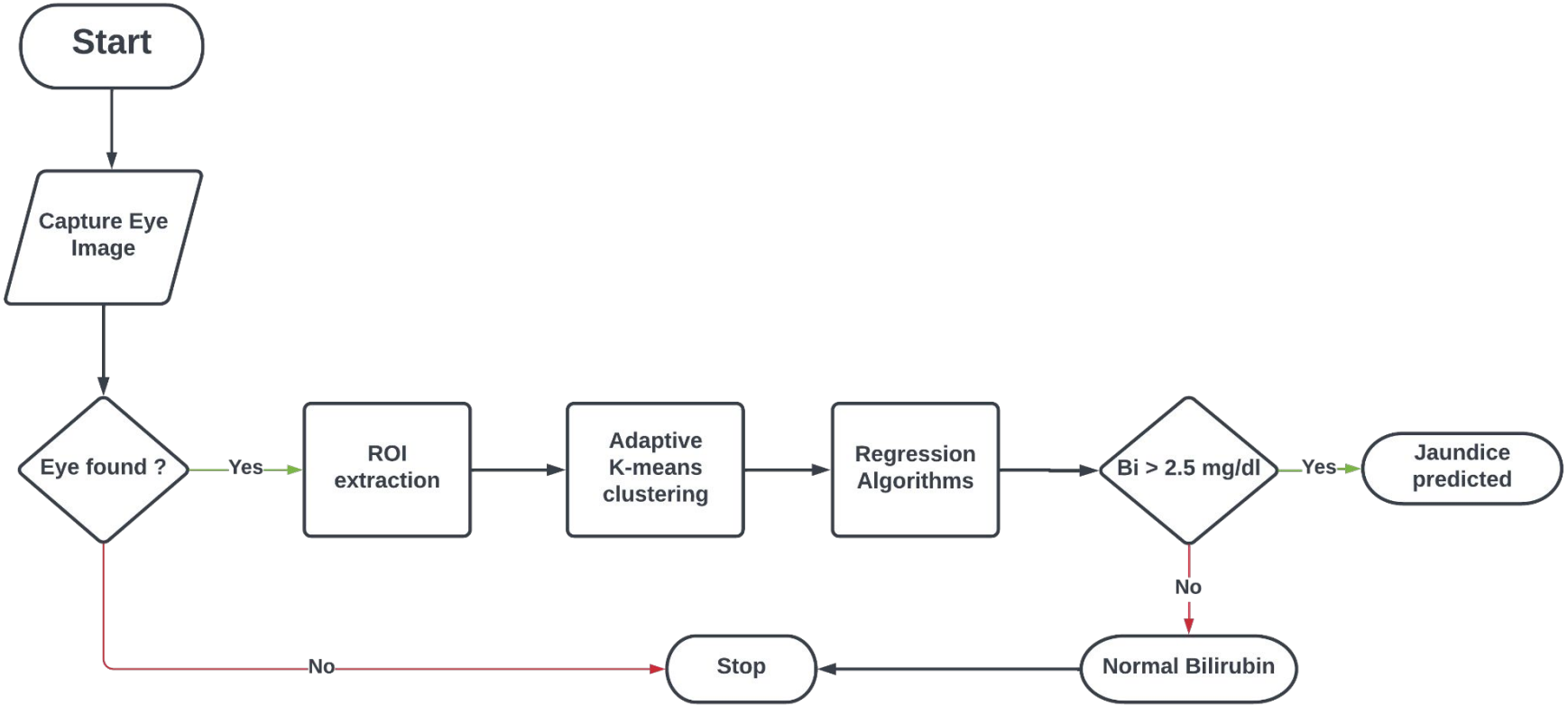
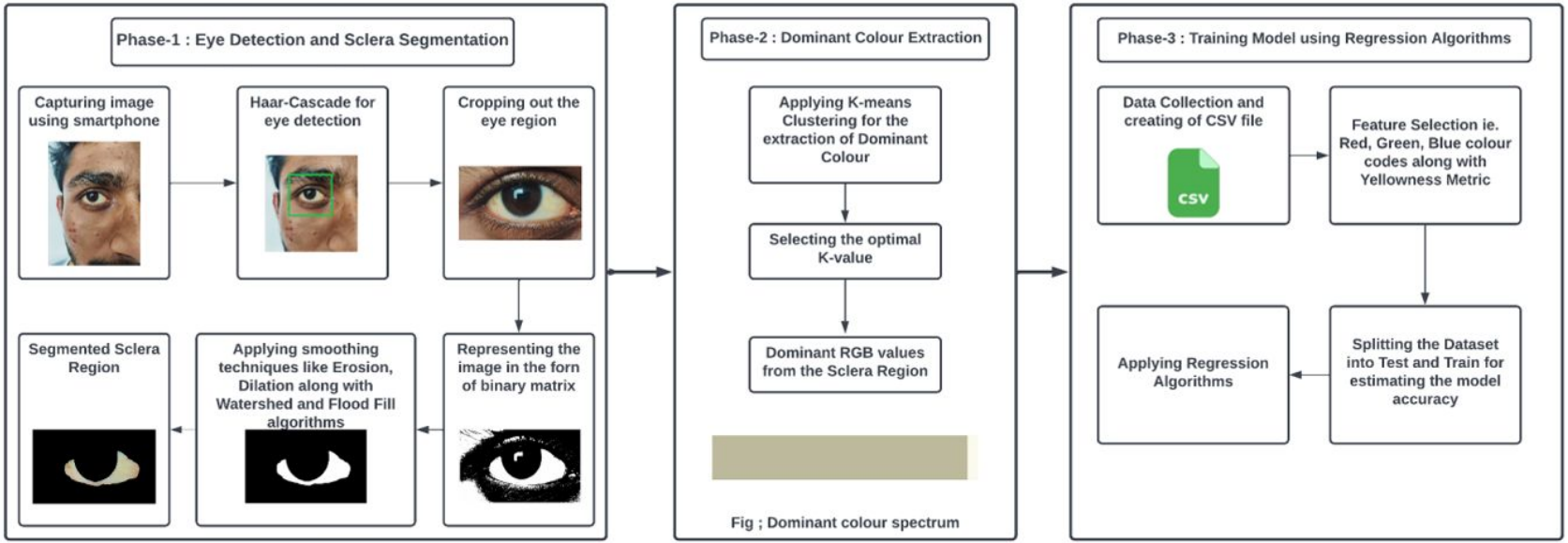


Fig. 1. Conceptual Flowchart

Overview


Phase-1 : Eye Detection and Sclera Segmentation
Capturing image using smartphone
Haar-Cascade for eye detection
Cropping out the eye region
Representing the image in the forn of binary matrix
Applying smoothing techniques like Erosion, Dilation along with Watershed and Flood Fill algorithms
Segmented Sclera Region
Phase-2 : Dominant Colour Extraction
Applying K-means Clustering for the extraction of Dominant Colour
Selecting the optimal K-value
Dominant RGB values from the Sclera Region
Fig ; Dominant colour spectrum
Phase-3 : Training Model using Regression Algorithms
Data Collection and creating of CSV file
csv
Feature Selection ie. Red, Green, Blue colour codes along with Yellowness Metric
Splitting the Dataset into Test and Train for estimating the model accuracy
Applying Regression Algorithms

Experimental Setup

Programming Language: Python

Development Environment: Google Colab (GPU), Jupyter Notebook

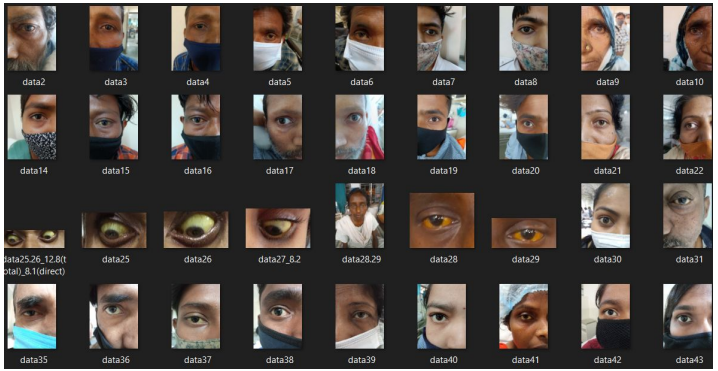
Libraries required:

- os (for file system management)
- cv2 (OpenCV for image processing)
- math (mathematical operations)
- numpy (for numerical computations)
- PIL (Python Imaging Library for image manipulation)
- sklearn (for clustering algorithms and metrics)

Statistical Information of Dataset

All	Participants Details		Age (years)		Sex		Bilirubin (mg/dL)	
102	Jaundice	Non-Jaundice	Range	Avg.	M	F	Range	Mean
	66	66	18 to 75	35.5	59	47	0.5 to 25	4.43

Table provides Statistical Information of the dataset used for applying all the Machine Learning and Computer Vision Techniques. Using this, we get to have an overview of the different categories of data available with us.
Jaffa mug
Source : AIIMS Raipur 2022



PHASES OF IMPLEMENTATION

Phase 1: Sclera Segmentation

- Haar Cascade Technique for Eye Detection
- Cropping out the Eyebrows
- Image Representation in the form of Binary Matrix
- Smoothing Techniques like Erosion and Dilation

Modified Data

Figure 9.1: Improper lighting image

Figure 9.2: Manually Modified Image for Training

Phase 2: Dominant Color Extraction

- Adaptive K-Means Clustering can be implemented which chooses the optimal value of K i.e., number of clusters depending on the range of colors.
- Complete Spectrum of colours in the Segmented Sclera Region can be visualised.
- Dominant color can be obtained in the form of a RGB code.

Fig. 4. Spectrum and Dominant Color

Phase 3: Bilirubin Quantification

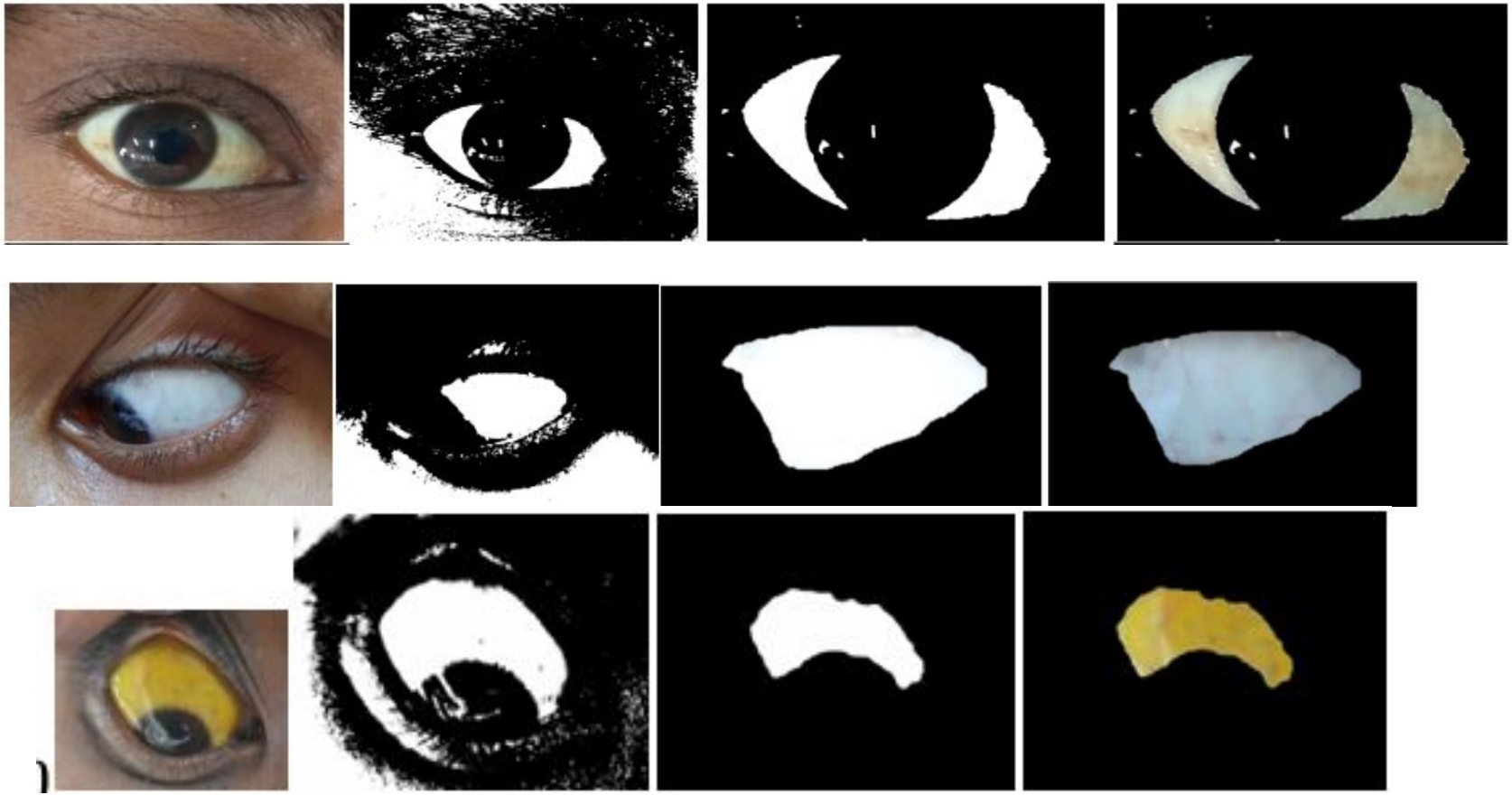
- Yellowness Metric can be calculated using the obtained RGB code.

$$Y=B/(R+G+B)$$

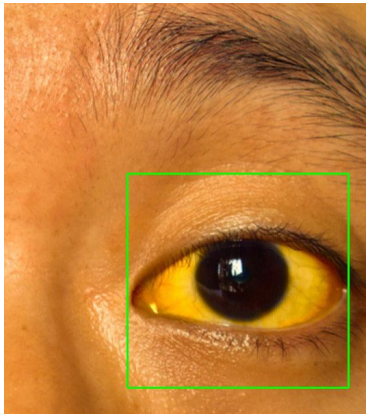
- Multiple Linear Regression will be implemented by making use of R, G, B and Yellowness Metric as predictor variables for the prediction of Bilirubin.

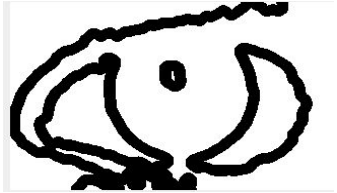
$$Bilirubin = a1R - a2G - a3B - a4Y + a5$$

Results:



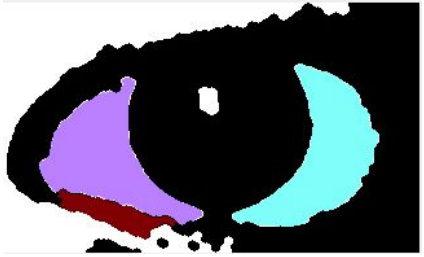
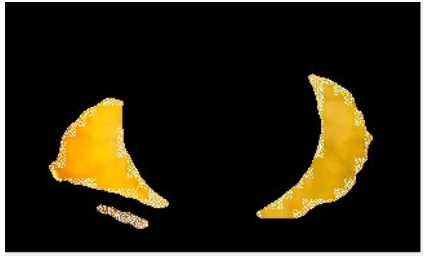
Result : Jaundice





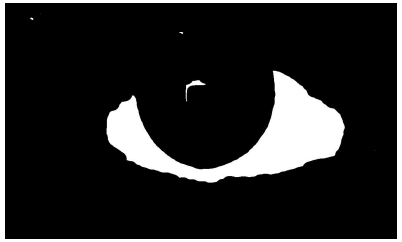


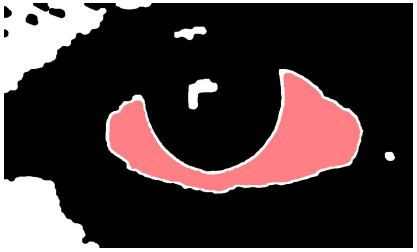



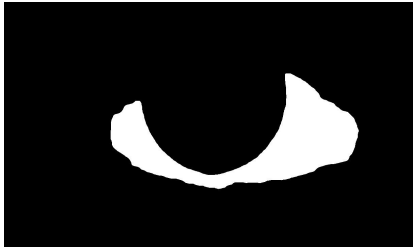
Optimum K value = 3
Dominant Color = [252, 246, 170]

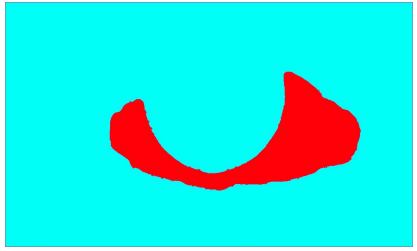
Estimated Bilirubin Value of Patient: 3.1263053892215567

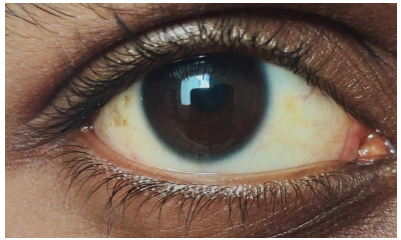
Results:

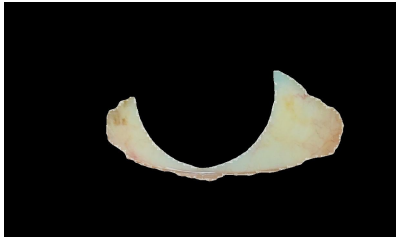












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Optimum K value = 3
Dominant Color =  [174, 158, 132]
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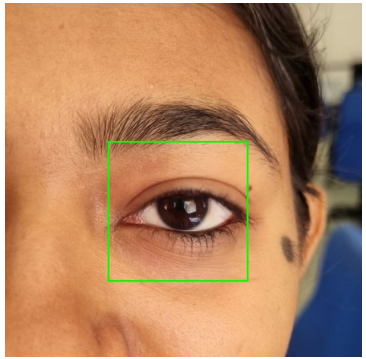
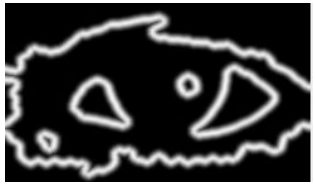
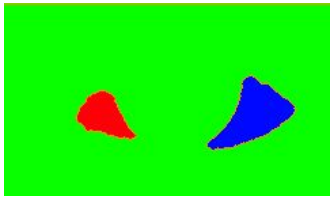
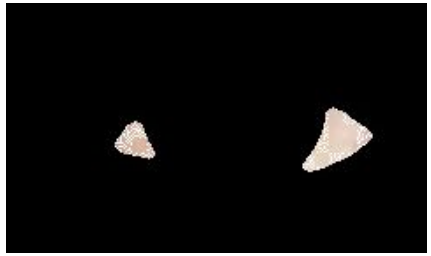
Estimated Bilirubin Value of Patient: 2.3421206896551707
```

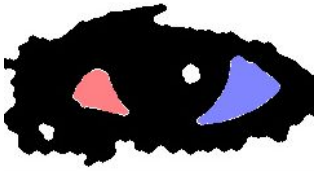
Result : Non Jaundice







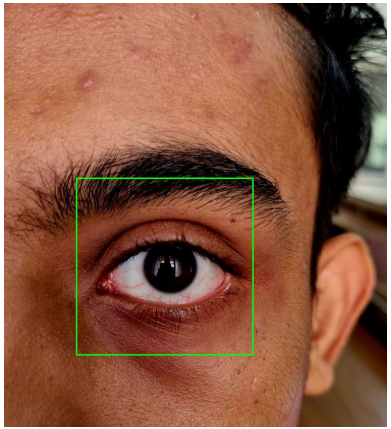


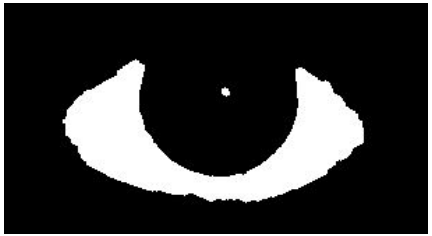


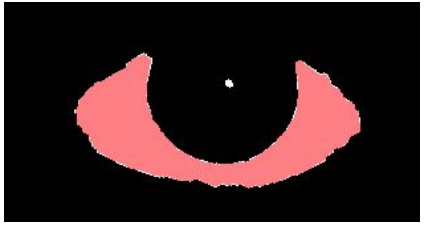
Optimum K value = 4
Dominant Color = [254, 249, 239]

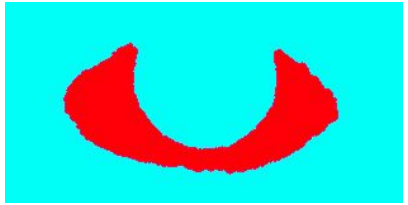
Estimated Bilirubin Value of Patient: 1.9393342318059301

Results:





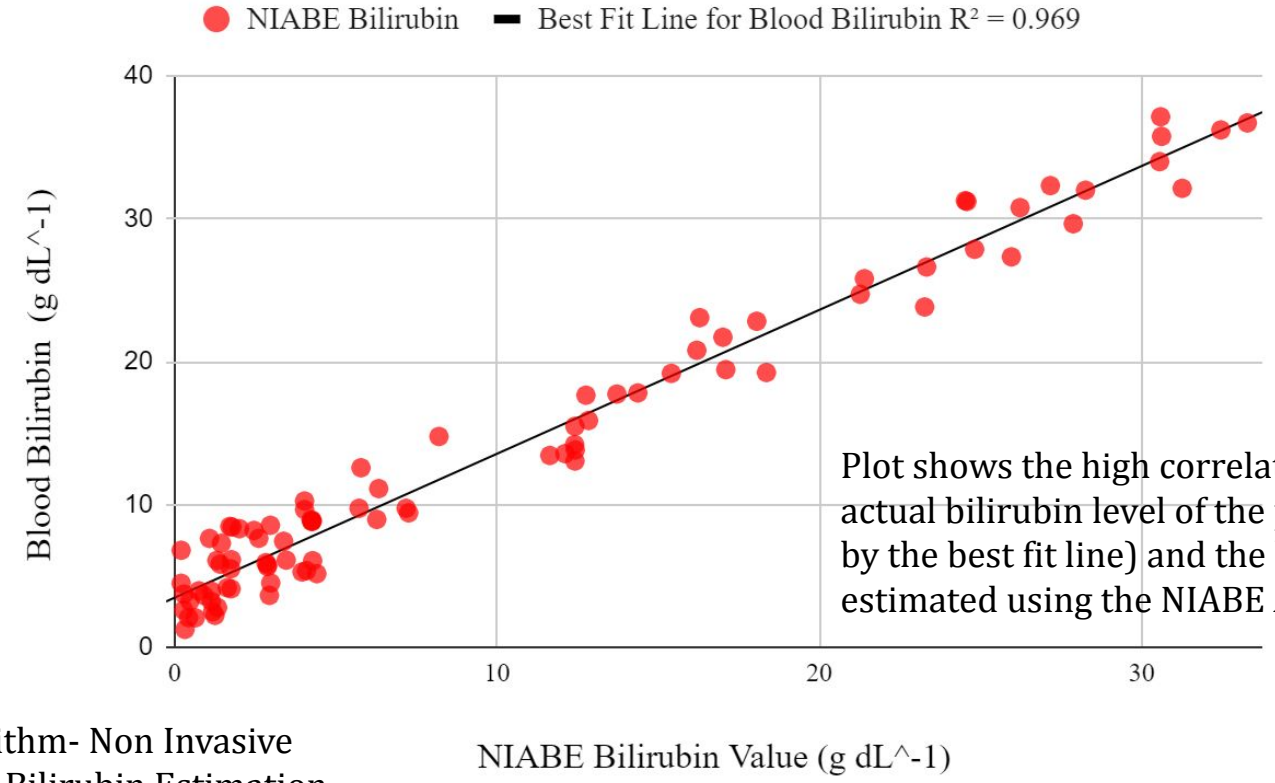




Optimum K value = 3
Dominant Color = [254, 248, 247]

Estimated Bilirubin Value of Patient: 1.843550066755673

Results and Analysis



Plot shows the high correlation between the actual bilirubin level of the patient (displayed by the best fit line) and the bilirubin estimated using the NIABE Algorithm.

NIABE Algorithm- Non Invasive Autonomous Bilirubin Estimation

Novelty

- Novel, Non Invasive Technique of Bilirubin Quantification
- Selection of ROI : Sclera (White Region of Eyes)
- Extract the ROI autonomously from the captured eye image.
- Will Develop model using image processing techniques which can be easily implemented on smartphone without the necessity of additional equipment.

Conclusion

- Deployment of the model on a Smartphone application will make it handy for patients. We are looking forward to build a model which can predict the bilirubin levels of patients and can be easily integrated on smartphone devices.
- Organizing newly collected images, and augmenting them resulting in a well structured Dataset for future research purposes. (New Dataset)

References

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