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Method and Model for Jaundice Prediction Through Non-Invasive Bilirubin Detection Technique

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***Abstract*— In this paper, we have focused on developing a method and model to detect jaundice using non-invasive techniques. The yellow discoloration is used to measure bilirubin concentration for determining the level of jaundice in infants. Hyperbilirubinemia or Neonates Jaundice is commonly happened in the neonates or newborns due to rise in the of the amount of bilirubin concentration in the body. Current detection techniques, however, require clinical tests with blood samples or other particular equipments. As a result, newborns often depends on visual assessments of their skin color at home, which is known to be unpredictable. Therefore, to detect newborn jaundice non-invasively we are going to develop a technique based on yellow discoloration of the skin. Neonatal hyperbilirubinemia, especially kernicterus; may be prevented by screening for neonatal jaundice at early stage. The proposed system is accurate in the diagnosis of neonatal jaundice, and can reduce the need for blood sampling.**

Keywords—Hyperbilirubinemia; non-invasive; Transcutaneous Bilirubinometer; Transcutaneous Serum Bilirubin

I. INTRODUCTION

Numbers of medical devices are becoming increasingly common for fitness, heart rate check and various other devices. As the technology increasing day by day, people move towards the efficient and low cost technology. People want the technology that save time money and provide good results.

Neonatal jaundice is the common problem in the newborns [1,2]. It is found that the neonatal jaundice occur more in Asian neonates than the Caucasian neonates. Jaundice is also known as icterus. It causes yellowing of skin and whitening of eye that is known as sclera. Almost all the [3] infants are jaundice proned; among them around 60% are term and 80 % are preterm infants. Jaundice occurs due to breakdown of Red Blood Cells; the breakdown process is known as Hemolysis if the cell breakdown rate occurs at rate faster than the usual it increase the level of bilirubin in the body and causes jaundice to the infants. Bilirubin concentration can be detected using two technique i.e. Invasive techniques and Non-invasive techniques. In invasive detection, a physical examination is carried out to look for sign of swelling of liver and legs ankles or feet, which might indicate cirrhosis of the liver. Urine be tested to check Urobilinogen, which is produced when [3] bilirubin is broken down to find high or low level of bilirubin concentration can help pin point the type of jaundice. Blood test may be used. Whereas in Non-invasive detection can be done by using Trancutaneous bilirubinometer. Transcutaneous Bilirubinometry works by directing light into the skin of neonate and measures the intensity of specific wavelength that is returned. The number of wavelengths, used is variable in different transcutaneous bilirubinometer. The meter analyzes the spectrum of optical signal reflected from the neonates' subcutaneous tissues. These optical signals are converted to electrical signal by a [4] photocell. These are analyzed by a microprocessor to generate a serum bilirubin value.

A moderate level (6mg/dl- 9 mg/dl) can be tolerable and easily treated but delay in the treatment can cause fatal and irreversible brain damage of the newborn. Therefore, early detection of the newborn jaundice is mandatory. Most of the infants are affected by jaundice after discharged from the hospitals. Visual assessment generally used at home, where laboratory takes too much time to provide the results. Parents and clinicians are usually determine the jaundice by visual assessment. Various studies show that the accurate results are not provided by visual assessments even experienced professionals are unable to determine the exact level of jaundice. In this paper we present the design of a system that evaluate jaundice level by detecting serum bilirubin coloration on a strip. The system is based upon the smartphone embedded camera images and a calibration card formed in the Matlab.

II. RELATED WORK

James W. Kronberg *et al.* [4] introduced a trancutaneous bilirubin detection device. This device was based on the absorption of light by the skin at particular wavelength. The amount the light absorbed by the skin is proportional to the amount of illness. Steven L. Jacques *et al.* [9] analyzed a ;device, which was based upon the maturity dependent optical properties of the skin. Refraction of red , yellow orange lights along with these light reflection of blue light determine the concentration of bilirubin. Later on Buttitta *et al.* [10] introduced a device in which two lights were transmitted through the infant skin one is completely absorbed and another one was partially or not absorbed by the skin. The reflected light intensity is used to determine the bilirubin concentration. David P. Dewitt *et al.* [8] developed a device which was also based on the two-filter design technique. This device was able

to determine the type of the treatment required to prevent the hyperbilirubinemia. Vinod K Bhutani *et al.* [11] introduced a device that depends upon the multi-wavelength spectral reflectance analysis. This device concentrates on those predischarge infants who have high risk of hyperbilirubinemia. Giovanna Bertini *et al.* [12] Introduced a first electronic device, which was used to determine whether neonates required TSB detection, or not. Gagan Mahajan *et al.* [13]study was undertaken to relate the correlation between the transcutaneous bilirubinometer with total serum bilirubin reading without using phototherapy. Yu-Hsun Chang *et al.* [2] evaluated the usefulness of JM-103 in Taiwanese neonates. At value of 9.4 mg/dl this device showed significant detection. Brad S. Karon *et al.* [14] determined that transcutaneous bilirubinometer able to detect risk of hyperbilirubinemia. Samar N. El-beshbishi *et al.* [1] discussed the review that the Transcutaneous bilirubinometer could be used for early detection of the sever hyperbilirubinemia. M. Penhaker *et al.* [15] proposed a device for detection of bilirubin. This device is ten times cheaper and easy to use. The variation of error was less than 4%. KA Jangaard *et al.* [16] Proposed that heel punctured cause painful to infants and distress to the parents. Billicheck can be used for detection of neonatal those who didn't receive phototherapy and does not have any patch or mark on the skin. Nurashlida ali *et al.* [17] introduced a non-invasively detection method for jaundice. This method uses optical techniques for detection. This technique is better to eliminate the pain occurred to the infants during taking blood samples.

A. *Gaps*

i. Transcutaneous bilirubin instrument measurements were inaccurate for measuring bilirubin levels in infants those were already receiving phototherapy and if an area of skin has any mark or patch.

ii. The mechanism was not as sensitive in the minute sample of preterm infants, and a larger reading was required before recommending the use of this instrument in this inhabitants.

iii. Transcutaneous bilirubinometer also affected by the color of the skin and the hemoglobin concentration present in the body because the color of the skin and hemoglobin concentration varied from person to person so that the measuring values are also varied.

iv. The biggest gap is that tracutaneous bilirubinometer is not able to detect the Hyperbilirubinemia (i.e.>= 14 mg/dl) stage correctly, which is the dangerous stage of jaundice.

III. ANALYSIS

To determine whether a newborn should receive phototherapy or an exchange blood transfusion, doctors or nurses reference specialized graphs with the newborn's age, number of weeks of gestation, and bilirubin [11] level. Figure (1) explain Bhutani nomogram graph. The Bhutani nomogram provides a means to evaluate a newborn's risk based on the percent of newborns in the study with given bilirubin levels and ages. High intermediate risk is considered above the 75th percentile, and high risk above the 95th percentile. Bilirubin levels are commonly expressed in milligrams per deciliter (mg/dl) or micromoles of bilirubin per liter (μmol/L)

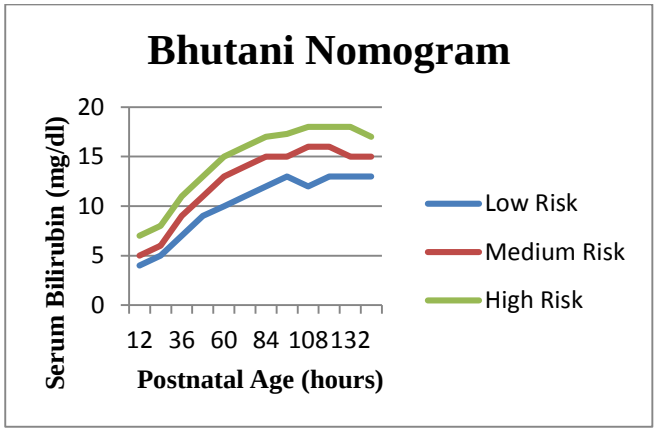

Fig. 1. Bhutani Nomogram Graph for Standard Bilirubin Concentration

A. *Experimental Method to Measure Bilirubin Concentration Non-Invasively*

The bilirubin concentration can be measured non-invasively by determining the yellow color discoloration of the skin. The steps to calculate the bilirubin concentration is described as below in the figure (2):

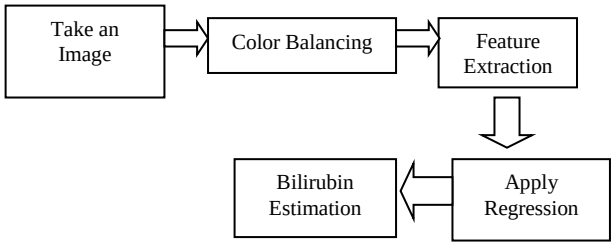

Fig. 1. Steps to Calculate the Bilirubin Concentration

B. *Color Balancing*

The image was converted into HSV model and normalized value of Red, Green, Blue was computed to make some of the effects of different lightning condition less [20] severe. The HSV stands for the Hue, Saturation and Value.

As hue varies from 0 to 1.0, the corresponding colors vary from red, through yellow, green, cyan, blue, and magenta , back to red, so that there are actually red values both at 0 and 1.0. As saturation varies from 0 to 1.0, the corresponding [20] colors (hues) vary from unsaturated (shades of gray) to fully saturated (no white component). As value or brightness,varies from 0 to 1.0, the corresponding colors become increasingly brighter. Compute R',G',B' and cmax, cmin value for RGB to HSV conversion of the image as done using equation (1) to (13):

$$R' = R/255 \quad (1)$$

$$G' = G/255 \quad (2)$$

$$B' = B/255 \quad (3)$$

$$cmax = \max(R',G',B') \quad (4)$$

cmin= min(R',G',B') (5)

$$\Delta = cmax - cmin \quad (6)$$

Hue Calculation:

$$H = 0^0, \Delta = 0 \quad (7)$$

$$H = 60^0 * \left(\frac{G'-B'}{\Delta} mod\ 6\right), cmax = R' \quad (8)$$

$$H = 60^0 * \left(\frac{B'-R'}{\Delta} + 2\right), cmax = G' \quad (9)$$

$$H = 60^0 * \left(\frac{R'-G'}{\Delta} + 4\right), cmax = B' \quad (10)$$

Saturation Calculation:

$$S = 0,\ \Delta = 0 \quad (11)$$

$$S = \frac{\Delta}{cmax},\ \Delta \neq 0 \quad (12)$$

Value Calculation:

$$V = cmax \quad (13)$$

C. Color Chart Formation

The color chart was created for standard bilirubin level [15] shades of each block size of 26 *26 and one block was kept blank. Where, x represents the empty/ hollow block to paste strip/skin sample image as shown in figure (3)

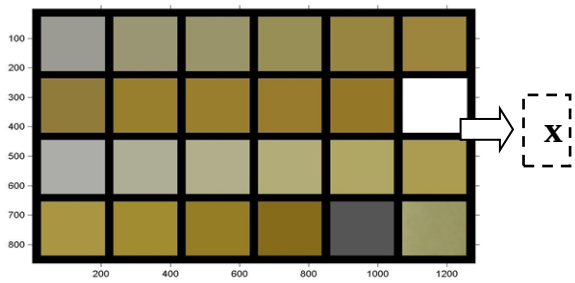

Fig. 3 Color Chart

D. Machine Regression

The regression algorithm was applied on the card, which contains the sample image pasted on one block. The regression algorithm employs an ensemble of different regression. The aim of [2] machine learning is to build a model that makes decisions based on facts in the presence of uncertainty. As adaptive algorithms identify [13] patterns in color segment. A computer "learns" from the observations, therefore, when exposed to more clarification, the computer improves its decision-making performance. In this model four different Regressions are used. The four regression are

- *Least Angle Regression*- LARS regression uses a variant of forward feature selection to decide what features are most useful. Instinctively, this regression helps to eliminate redundant features, while [2] creating new features based on their association to the chosen features. Essentially, the best predictor from the feature set is chosen by developing a single-feature, linear regression [15] from each feature.
- *Lasso - Elastic Net Regression*- Lasso is a regularization technique for performing linear regression. Lasso includes penalty term that constrains the size of the estimated coefficients. Lasso is a shrinkage estimator; it generates coefficient estimates that are biased to be small. A lasso estimator [2] can have smaller mean squared error than an ordinary least-square estimator when it is applied it to new data. Lasso sets more coefficients to zero. Elastic net is a hybrid of ridge regression and lasso regularization. Like lasso, elastic net can generate reduced model by [13] generating zero-valued coefficients as described by equation (13). For given value of λ a non-negative parameter, lasso solves the problem of non- negative parameters.

$$\min_{\beta o\, \beta} \frac{1}{2N}\sum_{j=1}^{N}(y_i - \beta_0 - x_i^T) + \lambda \sum_{j=1}^{p} \left|\beta_j\right| \quad (13)$$

- *K-NN Regression*- The first regression algorithm is an encapsulated k-Nearest Neighbor regression (k = 7) [17]. Intuitively, this regression takes a more "local" estimate of the bilirubin level based upon [9] training points that have similar feature values. In this regression, when an unknown test vector is analyzed, the k-nearest neighbors are found around the test vector in the [2] database of features. The L1 norm is a variable, which is used to calculate the nearest neighbors feature. Feature points from the neighbors are used to train a linear support vector regression and new regression is built each time whenever a new test point is analyzed.
- *Support Vector Regression*- Instead of minimizing the observed training error, Support Vector Regression attempts to minimize the generalization error bound so as to accomplish generalized performance. The idea of SVR is based on the computation of a linear regression [31] function in a high dimensional feature space where the input data are mapped via a nonlinear function. Support Vector Machine are learning machines implementing the structural risk minimization inductive principle to obtain good generalization on a limited number of learning patterns. Structural risk minimization involves concurrent attempt to minimize the empirical risk.

E. Final Output

If the difference is less than the empirically derived threshold of 1.0 mg/dl, the collection "agrees" and the mean is chosen. If the difference is greater than 1.0 mg/dl, then the second highest bilirubin value (*i.e.*, the 90th percentile) is chosen. This helps to bias the regression algorithm to select a large bilirubin value when the ensemble does not agree. If the variation of experimental value of bilirubin concentration from the actual value of bilirubin concentration is greater than 5% then the technique is not considered to be completely accurate.

Therefore, the developed technique variation must be less than the 5 % of the actual value then to validate the result. Table 1 contains the variation of actual and experimental result and the error percentage due to variation in output from standard value of bilirubin concentration.

TABLE I. TABLE STYLES

Observations	Bilirubin Concentration		
	Actual Values	*Experimental Values*	*Error Percentage*
1	3	3	0
2	6	6.2	3.3
3	9	9	0
4	12	12	0
5	15	15	0
6	18	19.5	8.3
7	21	22.7	8.09
8	24	26	8.33
9	27	29.5	9.2

Figure (3) describes the variation of experimental value from actual value of bilirubin concentration and its error percentage

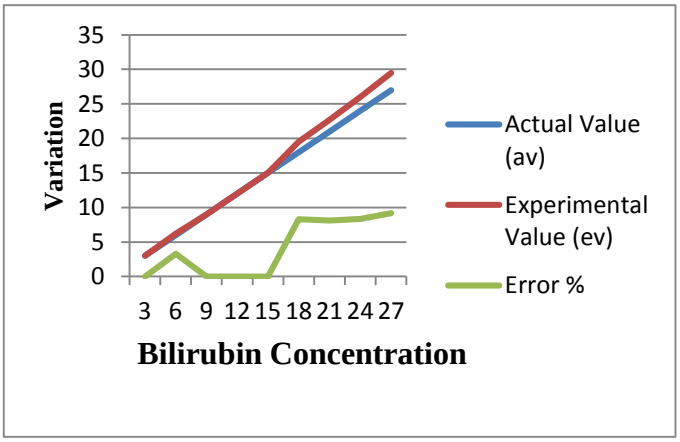

Fig.3. Error Percentage

CONCLUSION

We have designed a new method and model to detect jaundice, which is based on the yellow discoloration of the bilirubin samples. The outputs of the different bilirubin samples are included in the result. The R,G,B value is varied for different concentration of the bilirubin. We take different samples of bilirubin in different condition of light. Firstly the 3mg/dl sample has been taken and then compared it with the standard color chart, it is analyzed that the exact value of the sample is determined by the developed technique. We repeat this process for 6mg/dl, 9mg/dl, 12mg/dl, 15mg/dl, 18mg/dl, 21mg/dl, 24mg/dl, and 27mg/dl bilirubin concentration sample image, we find that the sampled value up to 17 mg/dl the developed device is able to detect bilirubin concentration reliably. After 17mg/dl, the developed technique is not able to detect bilirubin concentration exactly. The error percentage is less than 5 % for bilirubin concentration value up to 17mg/dl. The experimental results were able to detect jaundice for bilirubin concentration upto 14mg/dl where as our work able to detect jaundice for bilirubin concentration level of 17mg/dl.

FUTURE SCOPE

Jaundice detection at early stage is necessary to avoid high risk of hyperbilirubinemia. So that it is required to detect jaundice at early stage. The future work can be extended to detect jaundice for values greater than 17mg/dl and can be implemented for different skin shades. A app can be develop for smartphones so that jaundice can be detect at home at early stage without need to rush towards the laboratory to detect jaundice

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