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Neonatal Jaundice Detection using Colour Detection Method

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Abstract: Most of neonates develop neo-natal jaundice which is a physiological condition characterized by yellowish discoloration of the skin and conjunctiva as a consequence of increased levels of serum bilirubin in the blood of the baby during the first week after birth. When a newborn baby has jaundice, various clinical assessments need to be executed including evaluation of the history, physical examination, and severity of disease. If the severity is not detected early and if jaundice is left untreated then bilirubin level will increase gradually. Once it exceeds a certain level there is a possibility of deafness or certain forms of brain damage may occur. Generally, blood samples are taken and various laboratory experiments are performed to determine the exact bilirubin level. As the process is repetitive, it causes trauma to infants and it also requires experts to perform this test. So, it is necessary to have a non-invasive device which can regularly monitor the bilirubin levels. This paper aims to build a portable device which is meant for the quantification of jaundice level using colour detection based on Phototherapy method. A colour sensor has been used to measure the RGB component of neonatal skin shades printed on paper. A relationship between the blue component in the skin shades and bilirubin level has been observed. The percentage of blue among RGB components has been calculated. Based on this, the bilirubin level is computed and the state of jaundice is displayed.

Keywords: Neo-natal Jaundice, Bilirubin, Colour Sensor, Arduino Uno, Phototherapy.

I. INTRODUCTION

Jaundice in neonates is common. Neonates have more red blood cells than adults have and also the life span of red blood cells is shorter. When the red blood cells are broken down, a substance called bilirubin is made. When the baby is growing in the mother's womb, the placenta removes bilirubin from the baby's body. After birth, the baby's liver starts doing this job. Initially baby's liver is immature and hence it cannot do the task efficiently [1]. Thus bilirubin level increases which is the cause of jaundice. However this is normal and is common during the first week of life. Severe new-born jaundice may occur if the baby has a condition that increases the number of red blood cells that need to be replaced in the body. Bilirubin level will increase gradually if the severity is not detected within proper time interval and if jaundice is left untreated. Once it exceeds a certain level there is possibility of deafness or certain forms of brain damage may occur. Generally blood samples are taken and various laboratory experiments are performed to access the exact bilirubin level[2].As the process is repetitive, it causes trauma to infants and also requires experts to perform this test. This demands a non-invasive and easy technique to detect and monitor bilirubin level at regular intervals. In this paper, a portable hardware device which can detect the bilirubin level and jaundice state by non-invasive technique has been proposed. A colour sensor (TCS3200), an Arduino Unoboard based on ATmega328P microcontroller and a 16x2 LCD display unit have been used in making the hardware device. Adobe Color CC, an online software, is used to extract the RGB component of skin from the image**.** TCS3200 is a programmable light to frequency converter. It consists of configurable silicon photodiodes and a current-to-frequency converter on a single monolithic CMOS integrated circuit. The output is a square wave whose frequency depends on the intensity of light. The full-scale output frequency can be scaled by one of three preset values via two control input pins (S0, S1). In the TCS3200, the light-to-frequency converter reads an 8 x 8 array of photodiodes. There are sixteen photodiodes each for Blue, Green and Red filters. Additionally, there are 16 photodiodes with no filters. All the photodiodes of same colour are connected in parallel. Control pins S2 and S3 are used to activate a particular group of photodiodes. Since both input and output of TCS3200 is digital, it is compatible with Arduino Uno. The paper is structured as follows. Section 2 discusses the background. Section 3 discusses details of our work including basic concepts, device setup, block diagram, working of each module and initial data analysis. Section 4 contains results while Section 5 gives the conclusion.

II. BACKGROUND

A lot of research have been already conducted to detect jaundice in neonates. Different methods to detect neonatal jaundice are Phototherapy method, Image processing method etc. We have used Phototherapy method in this paper.

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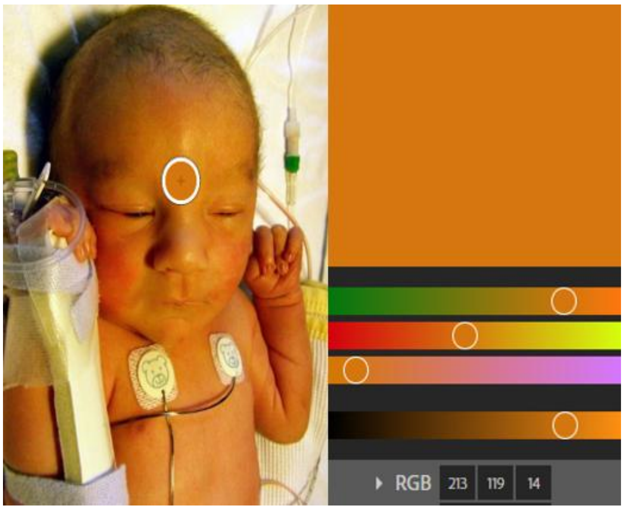

Fig 1: Jaundiced sample 1, % of Blue = 4.05

Phototherapy is based on treatment with a special kind of light. The infected area is illuminated with light of specific wavelength and change in properties of light after reflection from the skin is noted. Based on this information, detection or treatment is done. One common use of Phototherapy is treatment of skin disorders, chiefly psoriasis, acne vulgaris, eczema and neonatal jaundice. In order to detect neonatal jaundice, Light Emitting Diodes (LED) of specific wavelength are employed as a source of light, which is incident on infant's skin. The light is reflected back and absorbed by photodetector. The output of photodetector is then processed, calibrated and bilirubin level is determined. Laser diode and infra-red LED can also be used as a source of light but these are not suitable for infant's skin. In [3][5], the concentration level of bilirubin in dermis layer of skin has been detected using skin optic theory using LED and photodiode. In [4], different shades corresponding to different wavelengths of yellow colour are used for testing jaundice. Here each shade corresponds to certain bilirubin level in the neonates. Colour sensor consisting of 4 LEDs and an LDR is used to detect these shades and the corresponding bilirubin level.

In [7], image analysis of stool colour is compared to colour grading by a colour card, and the stool bilirubin level test is done to detect cholestatic jaundice in infants. In [8], digital images are acquired in colour, in palm, soles and forehead. RGB attributes are analyzed with diffuse reflectance spectra as the parameter to characterize patients with either jaundice or not, and those parameters are correlated with the level of bilirubin. By applying support vector machine, healthy and sick patients are distinguished.

In order to correlate the colour shade with appropriate bilirubin level and to train the device, we have used the same shades along with prescribed bilirubin level as in [4].Four shades of yellow colour having different wavelengths correspond to different levels of jaundice. Henceforth, these four shades will be called as training shades.

III. DETAILS OF THE PROJECT

A. Basic concept

Fig 2: Jaundiced sample 2, % of Blue = 4.67

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In phototherapy method the baby is undressed and is exposed to light. It has been seen that blue light in the range of 460-490 nm is most effective for phototherapy. Light in this range is mostly absorbed by bilirubin and hence reflection will be minimum [6][9]. Hence, the reflection of blue light will be minimum from jaundiced neonatal compared to non-jaundiced neonatals. A comparative study has been made by analysing the RGB components of the images of both jaundiced and non-jaundiced neonates.

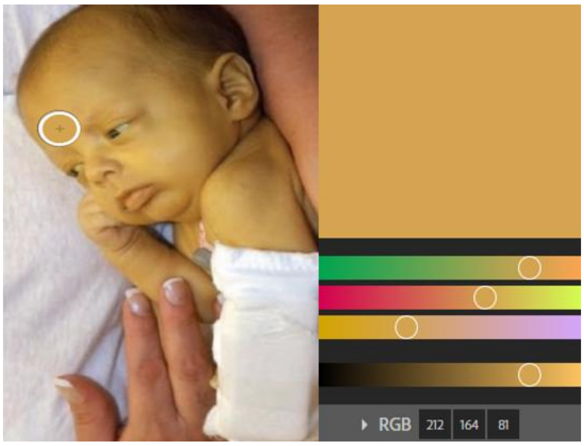

Fig 3: Jaundiced sample 3, % of Blue =17.7

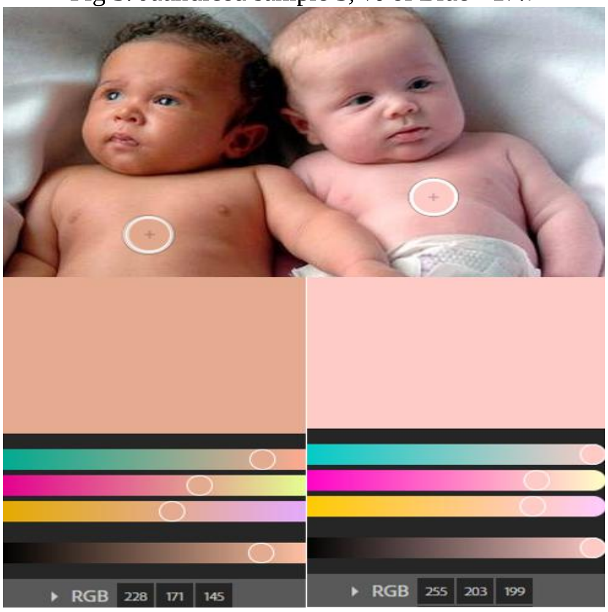

Fig 4b: Non Jaundiced sample 3b, % of Blue = 30 Fig 4a: Non Jaundiced sample 3a, % of Blue = 26 Fig

5: Non Jaundiced sample 4, % of Blue = 35

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The circled portions in the baby's body represent shades whose RGB component is extracted. It is seen that blue component in jaundiced neonatal is lower than non-jaundiced one. In this paper, this concept has been used to detect jaundice.

B. Device Setup
At first, TCS3200 (colour sensor) has been configured to get the appropriate RGB values. For this purpose, Red, Blue, Green and Black colour shades printed on paper has been used. For calibration of Red component, the value of R in Red shade with '255' and value of R in Black shade with '0' have been mapped. Same procedure is followed for the calibration of Green and Blue component. After that percentage of blue is calculated using obtained RGB value. Obtained percentage of blue has been normalized i.e. percentage of blue value in blue shade is mapped to 100.
The training shades have been printed on paper. Using colour sensor, the normalized percentage of blue for each training shade is calculated. The best fit graph between obtained normalized percentage of blue and assigned bilirubin level has been plotted. From this curve, a linear equation is obtained. This has been done using MATLAB software by curve fitting method. The obtained linear equation is further used to calculate the bilirubin level based on normalized percentage of blue from any shade. This obtained bilirubin level and the state of jaundice has been displayed on LCD display. State of jaundice is decided by the processing unit based on bilirubin level.

C. Block diagram and working principle
The Fig 6 shows the basic block diagram.

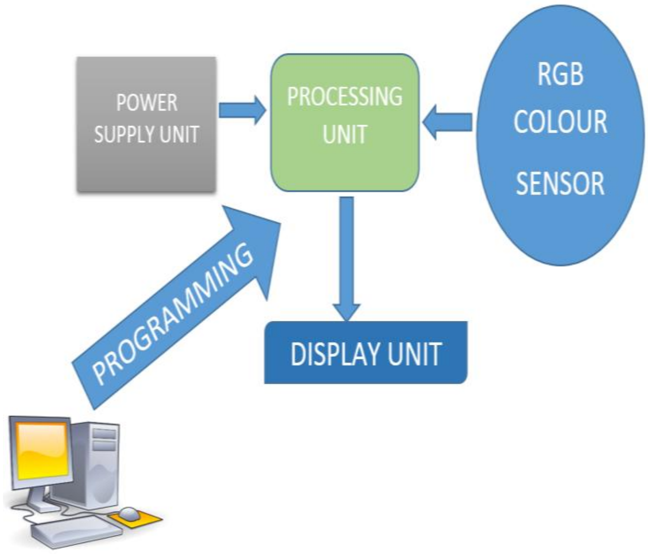

Fig 6: Basic Block Diagram

The power supply unit provides 9V DC supply to processing unit. RGB colour sensor (TCS3200) senses the RGB component of skin shades printed on paper and transfers it to the processing unit, based on Arduino Uno. The Processing unit maps RGB value to specific values in order to configure the colour sensor followed by calculation and normalization of percentage of blue taken from colour sensor. Based on predefined equation, the appropriate bilirubin level is determined. Hence the state of jaundice is ascertained and the result is transferred to the display unit.

D. Initial Data Analysis
The data which correlate the shade of skin colour and corresponding bilirubin level are mentioned in the following table.

Table1: Training data relating colour shade and bilirubin level

S.I No.	Shade of Colour	Assigned Bilirubin level (mg/dl)
1		11
2		13
3		17
4		21

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The Fig 7 shows the best-fit curve and the linear equation. The latter is obtained by plotting the graph between normalized percentage of blue and assigned bilirubin level and applying the best curve fitting tool using MATLAB.

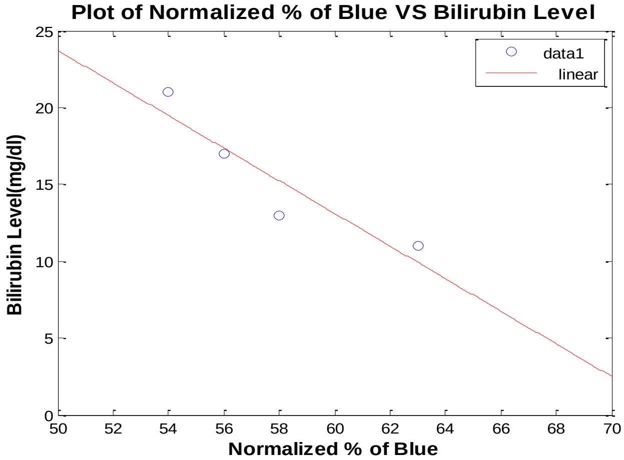

Fig 7: Relationship between bilirubin level and normalized % of blue

$$y = -1.0615*x + 76.799$$

Using the above equation, bilirubin level is calculated corresponding to a particular shade. The processing unit will determine the state of jaundice. This determination of state is done based on the decision table given below.

Table 2: Decision making table

Bilirubin level(mg/dl)	**Stage of Jaundice**
Bilirubin level < 4	Normal
4 < Bilirubin level ≤ 10	Mild
10 < Bilirubin level ≤ 20	Severe
20 < Bilirubin level	Critical

IV. RESULTS

In order to test the working of the device, few sample images of both jaundiced and non-jaundiced neonates have been taken. The shade of skin colour has been extracted and printed on the paper. These images are taken from Google images[10 -14]. These are treated as sample images. Given below are the images used and also the shades of skin colour extracted from the images along with the responses which we get after testing.

Fig 8: Sample images for testing

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Table 3: Response for jaundiced sample

Sample No.	Extracted skin colour of jaundiced sample	Estimated Bilirubin level(mg/dl), State of jaundice
1		17.36 Severe
2		15.23 Severe
3		9.92 Mild

Table 4: Response for non-jaundiced sample

Sample No.	Extracted skin colour of non-jaundiced sample	State of jaundice
4a		Normal (<4mg/dl)
4b		Normal (<4mg/dl)
5		Normal (<4mg/dl)

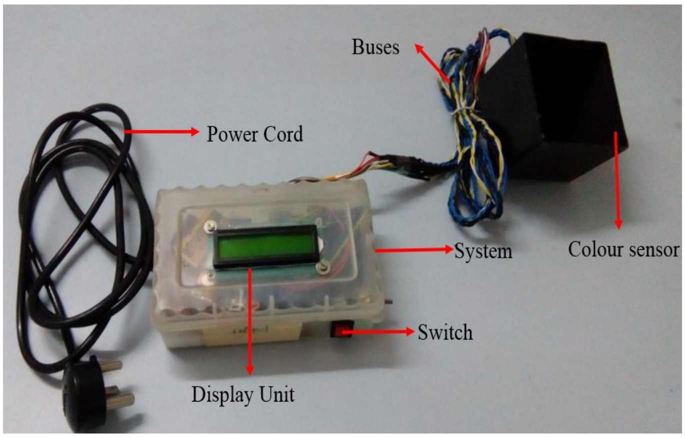

Fig 9: Final Setup

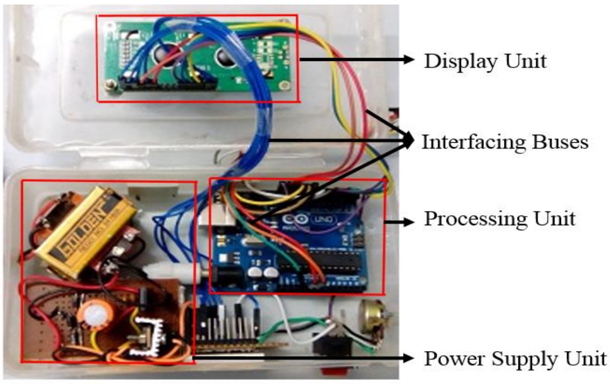

Fig 10: Internal view of device

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V. CONCLUSION

In this paper, the bilirubin level of a neonatal baby is measured by a non-invasive method. The set-up uses a colour sensor which measures the normalized level of blue colour present in the photographic image of the skin of the baby. The measurement is done on Arduino platform. A relationship has been established between this normalized level of blue colour and the bilirubin level. It has been observed that the level of blue colour is inversely proportional to the bilirubin level. Analysis shows that a baby is affected by jaundice if the blue level falls below a threshold level. The bilirubin level and the degree of severity of the jaundiced condition of the baby are displayed on LCD display unit. Though the proposed technique gives fairly good results, further studies are necessary to compare these results with those obtained from conventional blood tests carried out on actual neonatal babies.

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