

Performance Analysis of IoT- Based Cyanosis Detection Device in Medical Training

Abstract. Cyanosis is a blue coloration around the mouth and lips. Since cyanosis is a symptom of a potentially serious and life-threatening disease as heart failure, an early, fast, and accurate recognition of cyanosis coloration is crucial. Cyanosis recognition in a newborn baby is quite challenging as color is perceived subjectively among new medical trainees. Cyanosis color can be influenced by lighting conditions, colored objects around the baby, visual perception, and the eyes condition of the observer. Hence, this project aims to develop the IoT based cyanosis detection device for newborn assessment in medical training application that aims to detect and evaluate correct cyanosis color values. The proposed system is a combination of hardware and software development and has been integrated with IoT applications for data monitoring and analysis. The feedback from the user is gathered to get their expectations and design requirements. The next design solution is prototype construction which is based on the user's preferences from the conducted market survey. For conclusion, the color error, comparison of color swatch between the actual and measured color, and the status of the data whether cyanosis or non-cyanosis was analyzed using the developed cyanosis device.

Streszczenie. Sinica to niebieskie zabarwienie wokół ust i warg. Ponieważ sinica jest objawem potencjalnie poważnej i zagrażającej życiu choroby, takiej jak niewydolność serca, kluczowe znaczenie ma wczesne, szybkie i dokładne rozpoznanie sinicy. Rozpoznanie sinicy u noworodka jest dość trudne, ponieważ kolor jest postrzegany subiektywnie przez nowych stażystów medycznych. Na kolor sinicy mogą wpływać warunki oświetlenia, kolorowe przedmioty wokół dziecka, percepcja wzrokowa i stan oczu obserwatora. Dlatego ten projekt ma na celu opracowanie opartego na IoT urządzenia do wykrywania sinicy do oceny noworodków w zastosowaniach szkolenia medycznego, które ma na celu wykrywanie i ocenę prawidłowych wartości koloru sinicy. Proponowany system jest połączeniem rozwoju sprzętu i oprogramowania i został zintegrowany z aplikacjami IoT do monitorowania i analizy danych. Informacje zwrotne od użytkowników są zbierane w celu poznania ich oczekiwań i wymagań projektowych. Kolejnym rozwiązaniem projektowym jest budowa prototypu, która bazuje na preferencjach użytkownika z przeprowadzonego badania rynku. Podsumowując, błąd koloru, porównanie próbki koloru między rzeczywistym i zmierzonym kolorem oraz status danych, czy sinica, czy nie sinica zostały przeanalizowane za pomocą opracowanego urządzenia do sinicy. (Analiza wydajności urządzenia do wykrywania sinicy opartego na IoT w szkoleniu medycznym)

Keywords: Cyanosis, life-threatening disease, newborn baby, color, detection device, IoT, RGB color, CIELAB.

Słowa kluczowe: sinica, IOT, badania medyczne

Introduction

Cyanosis refers to the blue purplish discoloration that can be found in the thinner skin at certain regions and in mucous membranes [1]. For examples around the lips, earlobes, fingernails, and toes. After the birth, cyanosis is a common clinical finding in newborn infants and it is caused by a low percentage of oxygen saturation in the body, normally below than 85 percent. In medical, cyanosis can be classified as a central, peripheral and differential. This study focused on a central cyanosis as this type of cyanosis apparent in the mucous membranes area and it is easy to see area.

Color is seen as subjective among medical trainees making the cyanosis recognition in a newborn infant is quite challenging. This is because there are a few factors that can influence color such as colored object around the subject, lighting condition in the environment and the eyes condition of the observer. Since cyanosis is a symptom of a life-threatening disease such as heart failure, an early evaluation is important due to the potentially serious diseases [2].

Cyanosis can be diagnosed using the clinical assessment of infant color. Until now, doctors use the Appearance, Pulse, Grimace, Activity, and Respiration (APGAR) scoring method to evaluate the discoloration on skin among newborn infants [3]. APGAR score is a test that given for newborn infant after birth. If cyanosis is present, the APGAR scores are lower. Besides that, cyanosis also can be diagnosed by using the pulse oximetry screening for oxygen saturation monitoring. Pulse oximetry is widely used in the clinical assessment as the function is to measure the level of oxygen saturation in body [4]. From the available literature searched, there is no such low-cost cyanosis

detection device that can evaluate the cyanosis coloration in quantitative color values. While the authors in [5] focused on exploring how the cyanosis coloration can be recreated in a baby manikin for medical training by exploring a technology deployed to measure the cyanosis coloration, this study focused on the cyanosis color detection and measuring the oxygen saturation which also relate with cyanosis occurrence in a baby.

In this study, the color space for the cyanosis color quantification was explored. Color is outcome from the electromagnetic radiation of a range of wavelengths that are visible to our eye. Basic elements needed to see the color are a light source, an object and an observer. As we know that color is subjective and have many perceptions due to a lot of different colors at the surrounding. The developed cyanosis device measured and collected the data in RGB color space by employing the TCS3200 color sensor. The color sensor will measure the color by detecting red, green, and blue. Then, the data need to be converted from RGB to CIELAB. The reason we need the CIELAB color system because we want to quantify the cyanosis color as what our eyes can see the colors [6].

Hence, this project aims to develop the Internet of Things (IoT) based cyanosis detection device for newborn assessment in medical training application that aims to detect and evaluate a correct cyanosis color value. The proposed system will be a combination of hardware and software development and must be integrated with IoT application for data monitoring and analysis. This device is hoped to help the medical trainees to recognize cyanosis fast and accurate to increase the effectiveness in simulation-based medical training in respiratory medicine.

Literature Review of Color Detection Devices

Bilirubin level will be increased if the jaundice is left untreated early and once the level is exceeded there is a possibility of deafness or certain forms of brain damage may occur. Blood samples and several laboratory experiments will be taken and performed to get the exact bilirubin level. The process is repetitive, and it can cause a trauma to newborn infants. The author in [7] focuses on developing a non-invasive device to quantify the jaundice level using color detection based on the Phototherapy method. This portable device is using a color sensor TCS3200 to measure the RGB component of neonatal skin shades printed on paper. The observation of the relationship between the blue component in the skin shades and bilirubin level has been made. The LCD display is used to show the bilirubin level and the status of jaundice.

The author in [8] focuses on developing an inexpensive color sensor to detect the concentrations of hydrogen cyanide gas with low ppm. Glass fiber paper that contains monocyano cobinamide CN(H₂O) Cbi was used and put directly above the TCS34725 color sensor. The light reflected from the paper change upon exposure to hydrogen cyanide at concentrations of 1.0 until 10.0 ppm as function of 25, 50 and 85% relative humidity. A more effective response between hydrogen cyanide and CN(H₂O) Cbi due to more rapid color change happened at higher humidity.

The development of direct photometry non-invasive bilirubin device has been introduced by the author in [9] as the measurement of jaundice among newborns is essential in determining the possible treatment to prevent serious illness. This non-invasive device is developed to overcome the issues related to the invasive method such as blood tests which is resulting in blood loss and increased risk of infections. Direct photometric measurements are based on suitably solved serum at the wavelength of 455nm. The spectrophotometer sensor has been made by using LDR and LED. This sensor is used to determine the level of jaundice among newborns. The device can display the conditions of jaundice such as normal, mild, and critical with LED light by using LCD.

The author in [10] focused on developing a color-based sorting process of recyclable materials and remote monitoring of the sorting system. The system provides data acquisition for color temperature and object proximity. Components that have been used in this project are TCS34725 RGB color sensor, ARM microcontroller (STM32 Family), communication interface, and block of several MOSFET based switches. The color sensor is used to analyze a piece of plastic materials that need to be sorted pass through a conveyer belt. Each material will be blow-off to appropriate container depending on the color.

A urine hydration system for detecting hydration status automatically by using a color sensor as the color indicator based on the urine color has been developed by the author in [11]. As urine color is a reliable indicator for hydration status, TCS34725 color sensor has been chosen to detect the urine color. The cloud platform which is Firebase has been used to record the hydration status data on daily basis and all information related to urine can be accessed by Android smartphone. The prediction is compared with urine specific gravity (USG) as a golden standard to evaluate the accuracy of hydration status.

The designing of the ColorTact device which use a color sensor that play the present audio information about the distinctive areas of a tactile diagram on a smartphone application has been conducted by the author in [12]. The target for this finger-worn assistive device is specifically for the visually impaired to explore the tactile diagrams with

audio feedback. When scanning a particular region on the tactile map, the smartphone will receive the information about the color. The Flora color sensor TCS34725 is used as color detection in implementing the prototype.

In order to help the visually impaired people to recognize Malaysian Ringgit banknotes easily, the author in [13] proposed a project by using an embedded decision tree classifier for developing the assistive technology that can assist the visually impairment. The embedded decision tree modelled in Arduino Lilypad as a microcontroller board obtains the color information for recognizing each class of banknotes based on the reading given by the input. The author proposed the color sensor known as TCS34725 as input for detecting the different colors of Malaysian banknotes as it has RGB sensing elements. Lilypad Buzzer which produced different kinds of notes sound is used as the output.

The author in [14] proposed a project that is simple, easy to handle, and able to get an accurate reading for the bilirubin level of the neonates. The bilirubin jaundice (BiliDice) device is developed by using a TCS230 color sensor, Arduino Uno as a microcontroller, and LCD display. This non-invasive device is using the color sensor to sense the RGB component of skin color and it can monitor the bilirubin levels on the LCD display. However, this proposed device is still in the early development progress.

A low-cost, lightweight, simple, and user-friendly color sensor has been proposed by the author in [15]. The color sensor was designed by using a photoresistor (LDR), and three LEDs (RGB), interfacing with Arduino Uno. LDR will capture the incident light that is reflected from the object and RGB LEDs were used as an output to generate lights of RGB colors. The author proposed a Graphical User Interface (GUI) in MATLAB as a color sensor panel that consists of the calibration panel, color model values, and display the swatch color. The development of this colorimetry-based color sensor is to detect the different colors for various biomedical applications. This project does not implement a mobile application to monitor the color of the objects.

The author in [16] focuses on developing a low-cost colorimetric detector for glucose biosensor in a real-time. This project has been used inexpensive electronic components such as LDR, TCS230 color sensor, and webcam in order to analyze the best color recognition components for detecting glucose. TCS230 color sensor has been chosen as it has the best sensitivity among the others and showed good linearity in glucose detection. Arduino Uno is used as a microcontroller to control, generate and send the data of color recognition components connected to a notebook computer. The data has been collected in a real-time.

Results, Analysis & Discussion

The data collection has been conducted through the survey.

A. Statistical Analysis of Market Survey

As a basis of the device development, the market survey was conducted to analyze the user's preferences of the cyanosis detection device.

1) Analysis of Market Research:

The market survey is to determine the viability of the device. There are four types of relevant questions have been discussed. The percentages of the respondents from the questionnaires are shown in Table I.

In summary, almost all respondents 84.2% agreed to have the device that capable to quantify cyanosis color on newborn baby accurately by using the color sensor. 94.7% were agreed with the implementation of IoT into the device

will improve the monitoring and analysis data. 89.5% think this device need pulse oximetry sensor to measure the oxygen saturation in baby's blood and 94.7% think this device need heart rate sensor to measure the heart rate of baby.

Table 1. Percentages of respondents for market research

Market Research	Percentage (%)	
	Yes	No
Capable to quantify cyanosis color accurately	84.2	15.8
IoT will improve monitoring & data analysis	94.7	5.3
Need pulse oximeter sensor	89.5	10.5
Need heart rate sensor	94.7	5.3

2) Analysis of Product Specifications

The aims are to get the opinions about the specifications for the design of an IoT based cyanosis detection device for cyanosis recognition in medical training purpose. There are four relevant questions have been discussed. In this part, a basic statistical test such as finding the mean, median, and mode for data analysis were applied. The percentages of respondents from the selected questions is shown in Table 2.

Table 2. Percentages of Respondents for Product Specifications

Product Specifications	Percentage (%)				
	1	2	3	4	5
Have LCD screen for display measurement	0	0	8.8	45.6	45.6
Have buzzer to notify user	3.5	1.8	7	40.4	47.4
Using color, pulse oximeter and heart rate sensor	0	0	12.3	38.6	49.1
Implementation of IoT for monitoring and analysis data	0	1.8	8.8	42.1	47.4

To summarize, 45.6% of the scalar 4 and 5 were agreed and strongly agreed to have LCD screen for display the values of measurements. 8.8% were slightly agreed to have a LCD screen for display measurement. 47% were strongly agreed and 40.4% were agreed to have a buzzer to notify the user for the detection. 7% were slightly agreed to have a buzzer to notify user. 1.8% were disagreed and 3.5% were strongly disagreed to have a buzzer on the device. 49.1% were strongly agreed, 38.6% were agreed, and 12.4% were slightly agreed with the cyanosis detection device that capable to diagnose cyanosis baby by using color sensor, pulse oximetry and heart rate sensor. 47.4% were strongy agreed and 42.1% were agreed with the implementation of IoT is easy for monitoring and analysis data. 8.8% were slightly agreed and 1.8% were disagreed with the implementation of IoT for monitoring and analysis data.

Hence, the prototype is designed based on the user's preferences which will include color sensor, pulse oximeter and heart rate sensor, screen for display, and the implementation of IoT.

B. Analysis of the Different Color Sensors

The approach in measurement setup for testing the different color sensors is to get an accurate range of RGB values.

1) Sketch of Tip Area for the Different Color Sensor

The tip area for different color sensors such as TCS3200, TCS34725, and TCS230 have been sketched with the dimension. All sketches are labeled properly with the correct measurements.

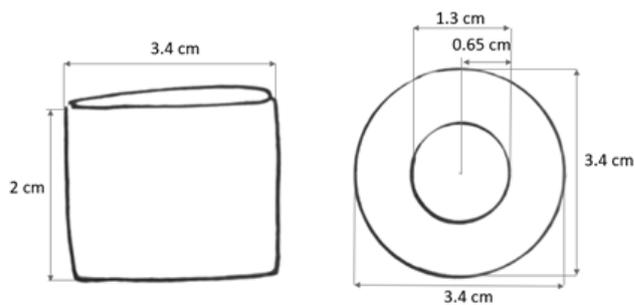


Fig. 1. Sketch of tip area for TCS3200

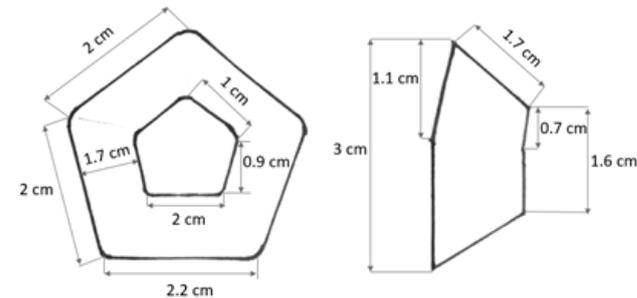


Fig. 2. Sketch of tip area for TCS34725

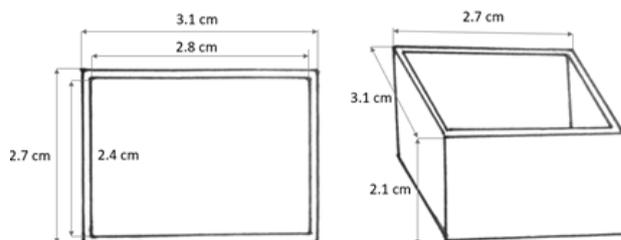


Fig. 3. Sketch of tip area for TCS230

The prototype of tip area for each color sensor has been made and set up properly. Therefore, the measurement setup for color sensor is more easier by using these prototype of tip area.



Fig. 4. Setup of tip area for TCS3200

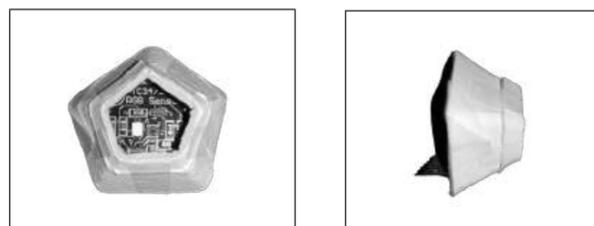


Fig. 5. Setup of tip area for TCS34725

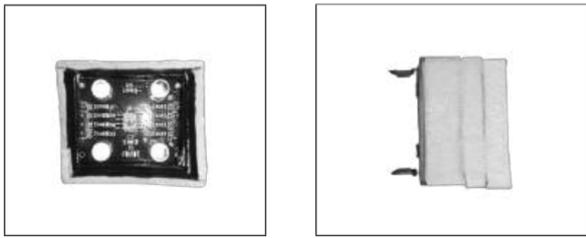


Fig. 6. Setup for tip area for TCS230

2) Data Analysis of the Different Color Sensors

The data analysis of color error for TCS34725 and TCS3200 color sensor was calculated. The color measurement from the TCS230 color sensor cannot be determined due to the Macbeth ColorChecker [17] is small with the dimension of each patch color is 1.2 cm x 1.2cm. While the dimension of TCS230 color sensor is about 3.1 cm x 2.7 cm.

Table 3. Data Analysis of TCS3200 Color Sensor

Patch Colors	Theoretical			Measured			Color Error
	R	G	B	R	G	B	
Dark Skin	115	82	68	93	93	77	26.19
Light Skin	194	150	130	204	147	130	10.44
Blue Sky	98	122	157	89	118	144	16.31
Foliage	87	108	67	93	119	87	23.60
Blue Flower	133	128	177	142	163	182	36.48
Bluish Green	103	189	170	158	205	190	60.67
Orange	214	126	44	217	131	89	45.38
Purple Red	80	91	166	97	119	168	32.81
Moderate Red	193	90	99	204	99	109	17.38
Purple	94	60	108	102	77	103	19.44
Yellow Green	157	188	64	179	192	117	57.52
Orange Yellow	224	163	46	203	154	78	39.32
Blue	56	61	150	46	81	142	23.75
Green	70	148	73	103	145	85	35.24
Red	175	54	60	173	43	47	17.15
Yellow	231	199	31	223	187	100	70.49
Magenta	187	86	149	187	119	150	33.02
Cyan	8	133	161	93	154	174	88.52
White	243	243	242	255	253	248	16.40
Black	52	52	52	52	49	57	5.83

From the data analysis, the comparison between both color sensors can be calculated. The TCS3200 color sensor is chosen as the color error is low and more stable compared to the TCS34725 color sensor. The average color error for TCS34725 color sensor is 49.50 while the average color error for TCS3200 is 33.80. So that it can be concluded that the TCS3200 color sensor has lower color error than the TCS34725 color sensor.

C. Analysis of Cyanosis Detection Device

All sensors and components such as TCS3200 color sensor, MAX30100 pulse oximeter sensor, 1.3 Inch SH1106 OLED display, push-button and tactile switch are embedded and permanently connected to the NodeMCU ESP8266 and attached to the final prototype. The Blynk application is used to monitor and analyze the collected data.

1) Sketch of Final Prototype

The final prototype of cyanosis detection device has been sketched with the dimension and labeled properly with the correct measurements.

The final prototype of cyanosis detection device is shown in Fig. 8. The final prototype has been developed by modifying the available casing from the thermometer infrared. The

design of the circuit connection need is focused on keeping the cable arranged neatly on the prototype.

Table 4. Data Analysis of TCS34725 Color Sensor

Patch Colors	Theoretical			Measured			Color Error
	R	G	B	R	G	B	
Dark Skin	115	82	68	64	46	39	68.83
Light Skin	194	150	130	223	147	142	31.53
Blue Sky	98	122	157	71	106	142	34.79
Foliage	87	108	67	53	67	44	58.02
Blue Flower	133	128	177	117	134	191	22.09
Bluish Green	103	189	170	140	242	228	86.84
Orange	214	126	44	248	107	68	45.75
Purple Red	80	91	166	45	79	153	39.22
Moderate Red	193	90	99	193	70	85	24.41
Purple	94	60	108	41	36	60	75.43
Yellow Green	157	188	64	183	221	107	60.12
Orange Yellow	224	163	46	255	179	90	56.15
Blue	56	61	150	20	47	110	55.61
Green	70	148	73	71	126	72	22.05
Red	175	54	60	134	36	39	49.46
Yellow	231	199	31	255	255	120	107.86
Magenta	187	86	149	175	84	137	17.09
Cyan	8	133	161	57	134	182	53.32
White	243	243	242	255	255	255	20.78
Black	52	52	52	14	18	19	60.74

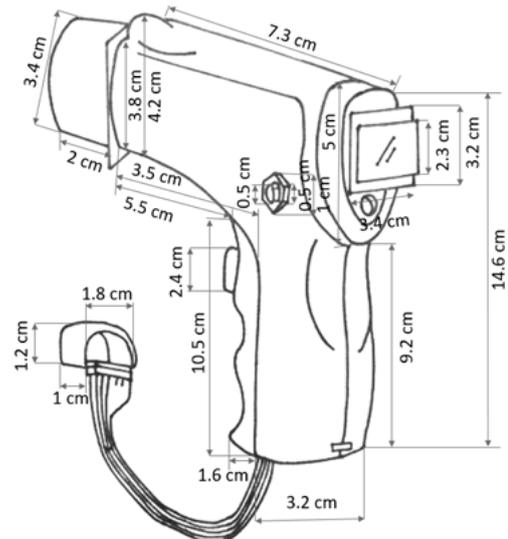


Fig. 7. Sketch of final prototype



Fig. 8. Final prototype

2) Final Prototype Testing

The measurement setups have been carried out in the room with low ambient light. These photos have been captured by using a smartphone with a model of OPPO A37fw and the camera has been set to auto mode.

The quantification of cyanosis and non-cyanosis color is measured by using the dataset of babies lips from [18]. The data is the real color values of the baby, captured in the operation theatre just after the baby was born. The color swatch of all datasets are printed on two type of paper which are plain paper and ivory paper. The plain paper with a thickness of 70 gsm is chosen and used for color quantification because it give more accurate result compare to the ivory paper that has significant color different.

Table 5. The values of *L *a *b for dataset of babies lips

*L	*a	*b
50.45	20.95	19.91
49.1	22.48	24.29
51.53	24.66	27.21
55.41	28.52	31.05



Fig. 9. Status of cyanosis color measurement



Fig. 10. RGB values of cyanosis color measurement



Status of non-cyanosis color measurement

In getting data of RGB values, the device is put directly to the surface of color and press the button switch as shown in Fig. 9 and Fig. 10 for cyanosis color measurement while in Fig. 11 and Fig. 12 for non-cyanosis color measurement. The color values of the measured data is shown in Table 6.

Table 6. Cyanosis and Non-Cyanosis Status

Theoretical			Measured			Status	Figure
R	G	B	R	G	B		
104	68	54	102	67	63	Cyanosis	Figure 9, 10
207	118	83	195	125	109	Non-Cyanosis	Figure 11, 12



Fig. 11. RGB values of non-cyanosis color measurement

In getting the data of SpO2 or the level of oxygen saturation, the finger is put directly to the detection part of sensor as shown in Fig. 13. The velcro tape is used in prototyping the pulse oximeter sensor in order to keep the finger properly fit with the sensor. The test is carried out by youth in the category age of around 23 to 24 years old. The measured value of SpO2 is shown in Table 7.



Fig. 12. SpO2 measurement

Table 7. SpO2 Data

Condition α	Measured-Value α	Description α
Without-put-the-finger α	0.00% α	Initial-State α
With-put-the-finger α	98.00% α	Normal α

3)

4) Data Analysis of Cyanosis Detection Device

The color conversion and see the color swatch of the measured color has been determined and identified by using Wolfram Alpha website [19]. From the analysis, the color error is calculated by using Euclidean distance to determine the difference between the actual data and measured data.

Dataset Lip 1			Actual			Measured			Color Error (%)
*L	*a	*b	R	G	B	R	G	B	
32.82	14.78	15.18	104	68	54	100	69	67	13.64
41.71	18.84	18.64	134	86	69	129	86	77	9.43
39.10	22.35	25.49	133	77	52	124	71	63	15.43
50.45	20.95	19.91	161	106	87	154	100	95	12.21
49.10	22.48	24.29	160	101	77	161	103	91	14.18
51.53	24.66	27.21	171	106	78	169	106	95	17.12
55.41	28.52	31.05	188	112	80	180	115	99	20.83

Fig. 13. Color error of dataset lip 1

Dataset Lip 2			Actual			Measured			Color Error (%)
*L	*a	*b	R	G	B	R	G	B	
48.60	24.79	27.34	163	98	70	162	100	89	19.13
44.85	20.20	23.07	145	93	69	143	96	85	16.40
43.18	20.34	24.79	141	88	62	137	87	77	15.56
57.63	25.87	20.64	188	120	104	186	122	121	17.23
59.36	32.97	35.03	207	118	83	198	126	109	28.65
57.62	28.19	33.13	194	118	82	193	126	111	30.10
47.44	22.98	27.69	157	97	67	157	100	89	22.20
56.50	30.54	32.95	194	113	80	193	106	73	9.95

Fig. 14. Color error of dataset lip 2

Table 8. Comparison of color switch for dataset lip 1

Measured			Measured			Status
R	G	B	*L	*a	*b	
100	69	67	32.79	13.53	6.83	Cyanosis
129	86	77	41.23	17.50	12.89	Cyanosis
154	100	95	48.28	21.99	12.33	Cyanosis
143	96	85	45.7	18.66	14.48	Cyanosis
180	115	99	55.28	25.00	20.08	Non-Cyanosis
198	126	109	60.29	27.31	21.53	Non-Cyanosis
193	126	111	59.69	25.45	19.47	Non-Cyanosis
193	106	73	54.66	33.33	34.37	Non-Cyanosis

Table 9. Comparison of color switch for dataset lip 2

Actual Dataset Lip 1			Measured Dataset Lip 1		
*L	*a	*b	*L	*a	*b
32.82	14.78	15.18	32.79	13.53	6.83
41.71	18.84	18.64	41.23	17.50	12.89
39.10	22.35	25.49	36.56	22.57	15.1
50.45	20.95	19.91	48.28	21.99	12.33
49.10	22.48	24.29	49.84	22.93	16.97
51.53	24.66	27.21	51.67	24.95	17.29
55.41	28.52	31.05	55.28	25.00	20.08

Table 10. Cyanosis and non-cyanosis status

Actual Dataset Lip 2			Measured Dataset Lip 2		
*L	*a	*b	*L	*a	*b
48.60	24.79	27.34	49.23	24.80	17.35
44.85	20.20	23.07	45.70	18.66	14.48
43.18	20.34	24.79	42.53	20.38	14.86
57.63	25.87	20.64	58.07	25.61	11.40
59.36	32.97	35.03	60.29	27.31	21.53
57.62	28.19	33.13	59.69	25.45	19.47
47.44	22.98	27.69	48.57	22.72	16.33
56.50	30.54	32.95	54.66	33.33	34.37

5) Data Analysis of Blynk Testing

The Blynk application as shown in Fig. 16 is used as the IoT platform for real-time monitoring and analyzing the collected data from the cyanosis detection device.

The values display is displayed the values of RGB and SpO2. The SpO2 value also appeared on the gauge display and the reading is labeled as a percentage. The data analysis of SpO2 is shown in Table 11.



Fig. 15. Blynk application

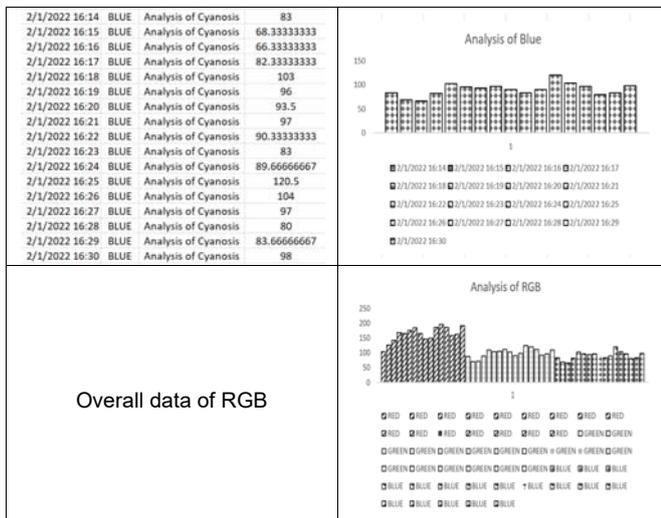
Table 11. Data analysis of SpO2 on Blynk application

Parameter	Graph Analysis	Condition
		Initial
		Normal

The reading showed 98% of oxygen saturation which is normal when the finger is put on the detection part. The normal blood oxygen level is more than 95%. For cyanosis, the oxygen level saturation is below than 85% or reaches approximately 67%. The data will report by using the report widget on Blynk. The data report is configured and customized in Comma-Separated Values (CSV) format which is in Microsoft Excel and sent through the personal email that is used to create the project on the Blynk application.

Table 12. Data Analysis of RGB on Blynk Application

Data in Excel Sheet	Graph Analysis																																																																				
<table border="1"> <tr><td>2/1/2022 16:14</td><td>RED</td><td>Analysis of Cyanosis</td><td>120</td></tr> <tr><td>2/1/2022 16:15</td><td>RED</td><td>Analysis of Cyanosis</td><td>104.3333333</td></tr> <tr><td>2/1/2022 16:16</td><td>RED</td><td>Analysis of Cyanosis</td><td>126.6666667</td></tr> <tr><td>2/1/2022 16:17</td><td>RED</td><td>Analysis of Cyanosis</td><td>142.6666667</td></tr> <tr><td>2/1/2022 16:18</td><td>RED</td><td>Analysis of Cyanosis</td><td>168.6666667</td></tr> <tr><td>2/1/2022 16:19</td><td>RED</td><td>Analysis of Cyanosis</td><td>166</td></tr> <tr><td>2/1/2022 16:20</td><td>RED</td><td>Analysis of Cyanosis</td><td>175.5</td></tr> <tr><td>2/1/2022 16:21</td><td>RED</td><td>Analysis of Cyanosis</td><td>184</td></tr> <tr><td>2/1/2022 16:22</td><td>RED</td><td>Analysis of Cyanosis</td><td>165.3333333</td></tr> <tr><td>2/1/2022 16:23</td><td>RED</td><td>Analysis of Cyanosis</td><td>146.2</td></tr> <tr><td>2/1/2022 16:24</td><td>RED</td><td>Analysis of Cyanosis</td><td>149.3333333</td></tr> <tr><td>2/1/2022 16:25</td><td>RED</td><td>Analysis of Cyanosis</td><td>186.625</td></tr> <tr><td>2/1/2022 16:26</td><td>RED</td><td>Analysis of Cyanosis</td><td>197</td></tr> <tr><td>2/1/2022 16:27</td><td>RED</td><td>Analysis of Cyanosis</td><td>186.4</td></tr> <tr><td>2/1/2022 16:28</td><td>RED</td><td>Analysis of Cyanosis</td><td>158.1666667</td></tr> <tr><td>2/1/2022 16:29</td><td>RED</td><td>Analysis of Cyanosis</td><td>162.6666667</td></tr> <tr><td>2/1/2022 16:30</td><td>RED</td><td>Analysis of Cyanosis</td><td>192.25</td></tr> </table>	2/1/2022 16:14	RED	Analysis of Cyanosis	120	2/1/2022 16:15	RED	Analysis of Cyanosis	104.3333333	2/1/2022 16:16	RED	Analysis of Cyanosis	126.6666667	2/1/2022 16:17	RED	Analysis of Cyanosis	142.6666667	2/1/2022 16:18	RED	Analysis of Cyanosis	168.6666667	2/1/2022 16:19	RED	Analysis of Cyanosis	166	2/1/2022 16:20	RED	Analysis of Cyanosis	175.5	2/1/2022 16:21	RED	Analysis of Cyanosis	184	2/1/2022 16:22	RED	Analysis of Cyanosis	165.3333333	2/1/2022 16:23	RED	Analysis of Cyanosis	146.2	2/1/2022 16:24	RED	Analysis of Cyanosis	149.3333333	2/1/2022 16:25	RED	Analysis of Cyanosis	186.625	2/1/2022 16:26	RED	Analysis of Cyanosis	197	2/1/2022 16:27	RED	Analysis of Cyanosis	186.4	2/1/2022 16:28	RED	Analysis of Cyanosis	158.1666667	2/1/2022 16:29	RED	Analysis of Cyanosis	162.6666667	2/1/2022 16:30	RED	Analysis of Cyanosis	192.25	
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<table border="1"> <tr><td>2/1/2022 16:14</td><td>GREEN</td><td>Analysis of Cyanosis</td><td>88.5</td></tr> <tr><td>2/1/2022 16:15</td><td>GREEN</td><td>Analysis of Cyanosis</td><td>70.33333333</td></tr> <tr><td>2/1/2022 16:16</td><td>GREEN</td><td>Analysis of Cyanosis</td><td>71.66666667</td></tr> <tr><td>2/1/2022 16:17</td><td>GREEN</td><td>Analysis of Cyanosis</td><td>89.33333333</td></tr> <tr><td>2/1/2022 16:18</td><td>GREEN</td><td>Analysis of Cyanosis</td><td>109.6666667</td></tr> <tr><td>2/1/2022 16:19</td><td>GREEN</td><td>Analysis of Cyanosis</td><td>104.5</td></tr> <tr><td>2/1/2022 16:20</td><td>GREEN</td><td>Analysis of Cyanosis</td><td>105.25</td></tr> <tr><td>2/1/2022 16:21</td><td>GREEN</td><td>Analysis of Cyanosis</td><td>112</td></tr> <tr><td>2/1/2022 16:22</td><td>GREEN</td><td>Analysis of Cyanosis</td><td>102</td></tr> <tr><td>2/1/2022 16:23</td><td>GREEN</td><td>Analysis of Cyanosis</td><td>90.6</td></tr> <tr><td>2/1/2022 16:24</td><td>GREEN</td><td>Analysis of Cyanosis</td><td>98</td></tr> <tr><td>2/1/2022 16:25</td><td>GREEN</td><td>Analysis of Cyanosis</td><td>123.875</td></tr> <tr><td>2/1/2022 16:26</td><td>GREEN</td><td>Analysis of Cyanosis</td><td>120</td></tr> <tr><td>2/1/2022 16:27</td><td>GREEN</td><td>Analysis of Cyanosis</td><td>112</td></tr> <tr><td>2/1/2022 16:28</td><td>GREEN</td><td>Analysis of Cyanosis</td><td>92.83333333</td></tr> <tr><td>2/1/2022 16:29</td><td>GREEN</td><td>Analysis of Cyanosis</td><td>96.66666667</td></tr> <tr><td>2/1/2022 16:30</td><td>GREEN</td><td>Analysis of Cyanosis</td><td>110.5</td></tr> </table>	2/1/2022 16:14	GREEN	Analysis of Cyanosis	88.5	2/1/2022 16:15	GREEN	Analysis of Cyanosis	70.33333333	2/1/2022 16:16	GREEN	Analysis of Cyanosis	71.66666667	2/1/2022 16:17	GREEN	Analysis of Cyanosis	89.33333333	2/1/2022 16:18	GREEN	Analysis of Cyanosis	109.6666667	2/1/2022 16:19	GREEN	Analysis of Cyanosis	104.5	2/1/2022 16:20	GREEN	Analysis of Cyanosis	105.25	2/1/2022 16:21	GREEN	Analysis of Cyanosis	112	2/1/2022 16:22	GREEN	Analysis of Cyanosis	102	2/1/2022 16:23	GREEN	Analysis of Cyanosis	90.6	2/1/2022 16:24	GREEN	Analysis of Cyanosis	98	2/1/2022 16:25	GREEN	Analysis of Cyanosis	123.875	2/1/2022 16:26	GREEN	Analysis of Cyanosis	120	2/1/2022 16:27	GREEN	Analysis of Cyanosis	112	2/1/2022 16:28	GREEN	Analysis of Cyanosis	92.83333333	2/1/2022 16:29	GREEN	Analysis of Cyanosis	96.66666667	2/1/2022 16:30	GREEN	Analysis of Cyanosis	110.5	
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From the data analysis of RGB, the output frequency of red, green, and blue represents the ratio of the respective measured color by using a cyanosis detection device. The red data is higher among the RGB data. As the transformation of measured colors is from the dark brown to orange-red, the ratio of RGB showed the highest more to red. The red color can be seen as the highest responsivity for photodiode spectral in the TCS3200 color sensor.

Conclusion

In conclusion, the objectives which is to develop the IoT based cyanosis detection device for newborn assessment in medical training application that can detect and evaluate a correct cyanosis color values have been achieved. Hence, it can be concluded that the developed cyanosis detection device provides almost accurate reading of cyanosis color values if we compare to the real color data. In analysis of cyanosis color, the complexity is more on the process to make a color sensor to get an accurate reading of color same as actual color. From the color printed paper for the dataset of babies lips, the color printed on plain paper with 70 gsm thickness is better than the color printed on ivory paper with 230 gsm thickness. The plain paper is chosen to analyze the cyanosis color because it gives more accurate result compare to the other one. The color printed on the ivory paper has a significant different. Therefore, it can be concluded that the colors are slightly different due to different of printing method.

The limitation of the project is the data from a Caucasian baby which is baby with the light skin color. From the result of analysis, the cyanosis status is showed more to the dark brown color. So, there is no indicator to recognize the baby with dark skin. In the future, when the data for Asean baby are available, the cyanosis color analysis can be carried out by using the developed device. Besides, the project can be extended in order to predict the baby got the cyanosis or not, by performing the prediction model using neural network or Artificial Intelligence (AI). The other limitation of the project is the data of measured color displayed in RGB values and the color conversion can be determined from the website. In a future, a device that can directly display CIELAB can be created. This is because CIELAB is the color space that is resemble most on how our eyes see colors. Then, the device can be expanded for multiple medical application such as jaundice detection and for covid application.

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REFERENCES

- [1] M. Kyavar and A. Sadeghpour, "Cyanosis," in *Comprehensive Approach to Adult Congenital Heart Disease*, Springer-Verlag London Ltd, 2014, pp. 37–43.
- [2] N. F. Azmi, F. Delbressine, and L. Feijs, "Conceptual Determination and Assessment of Cyanosis," *Int. J. Biosci. Biochem. Bioinforma.*, vol. 6, no. 3, pp. 75–83, 2016, doi: 10.17706/ijbb.2016.6.3.75-83.
- [3] D. Blake, "Do we assess 'colour' appropriately using the Apgar score?," *J. Neonatal Nurs.*, vol. 16, no. 4, pp. 184–187, Aug. 2010, doi: 10.1016/J.JNN.2010.03.002.
- [4] M. H. A. Rahim, M. A. H. M. Adib, M. Z. Baharom, I. M. Sahat, and N. H. M. Hasni, "Non-Invasive Study: Monitoring the Heart Rate and SpO₂ of the New Born using InfaWwrap Device," *Proc. - 2020 IEEE EMBS Conf. Biomed. Eng. Sci. IECBES 2020*, pp. 212–217, Mar. 2021, doi: 10.1109/IECBES48179.2021.9398749.
- [5] N. F. Azmi, *Designing Colour Changing Actuation for Realistic Cyanosis in a Baby Manikin*, no. 2021. 2021.
- [6] M. Tkaleie and J. F. Tasie, "Colour spaces - Perceptual, historical and applicational background," *IEEE Reg. 8 EUROCON 2003 Comput. as a Tool - Proc.*, vol. A, pp. 304–308, 2003, doi: 10.1109/EURCON.2003.1248032.
- [7] et al Chowdhary, Ajay Kumar, "Neonatal Jaundice Detection Using Colour Detection Method," *Iarjset*, vol. 4, no. 7, pp. 197–203, 2017, doi: 10.17148/IARJSET.2017.4733.
- [8] L. A. Greenawald, G. R. Boss, J. L. Snyder, A. Reeder, and S. Bell, "Development of an Inexpensive RGB Color Sensor for the Detection of Hydrogen Cyanide Gas," *ACS Sensors*, vol. 2, no. 10, pp. 1458–1466, 2017, doi: 10.1021/acssensors.7b00396.
- [9] L. C. Ku and N. S. M. Lazim, "Direct Photometry Non Invasive Bilirubin Device," *Int. Res. J. Eng. Technol.*, vol. 4, no. 5, pp. 401–404, 2017.
- [10] F. Drăgan, R. Holonec, and R. Copindean, "Digital Color Sensor based Solution for Recyclable material Sorting System," 2018.
- [11] A. A. S. Gunawan, D. Brandon, V. D. Puspa, and B. Wiweko, "Development of Urine Hydration System Based on Urine Color and Support Vector Machine," *Procedia Comput. Sci.*, vol. 135, pp. 481–489, 2018, doi: 10.1016/j.procs.2018.08.200.
- [12] A. Nasser, K. Zhu, and P. V. M. Rao, "Poster: Colortact: A Finger Wearable Audio-tactile Device Using Customizable Color Tagging," *UbiComp/ISWC 2018 - Adjunct. Proc. 2018 ACM Int. Jt. Conf. Pervasive Ubiquitous Comput. Proc. 2018 ACM Int. Symp. Wearable Comput.*, pp. 178–181, 2018, doi: 10.1145/3267305.3267583.
- [13] N. F. Ghazali, M. A. As'ari, M. N. Jamaludin, L. H. Ismail, H. F. M. Latip, and A. H. Omar, "Wearable device for Malaysian ringgit banknotes recognition based on embedded decision tree classifier," *J. Telecommun. Electron. Comput. Eng.*, vol. 10, no. 1, pp. 129–137, 2018.
- [14] M. Azrul, H. Mohd, M. Hanafi, A. Rahim, N. Hazreen, and M. Hasni, "Development of Bilirubin Jaundice (BiliDice) Device for Neonates," no. July, pp. 1–2, 2019.
- [15] P. K. Patnaik et al., *Development of a low-cost color sensor for biomedical applications*, no. 2018. Elsevier Ltd, 2019.
- [16] A. Fatoni, A. N. Aziz, and M. D. Anggraeni, "Low-cost and real-time color detector developments for glucose biosensor," *Sens. Bio-Sensing Res.*, vol. 28, no. November 2019, p. 100325, 2020, doi: 10.1016/j.sbsr.2020.100325.
- [17] "ColorChecker® Classic; X-Rite." <https://www.xrite.com/categories/calibration-profiling/colorchecker-classic> (accessed Jan. 10, 2022).
- [18] N. F. B. Azmi, F. Delbressine, L. Feijs, and S. B. Oetomo, "Color correction of baby images for cyanosis detection," *Commun. Comput. Inf. Sci.*, vol. 894, no. August, pp. 354–370, 2018, doi: 10.1007/978-3-319-95921-4_33.
- [19] "Wolfram|Alpha: Computational Intelligence." <https://www.wolframalpha.com/> (accessed Jun. 28, 2021).