Developing Child Drowning Alert Prototype System using IoT PPG Sensor

Farid Zakwan Noorul Anhar[1], Zakiah Ayop[2], Irda Roslan[2], Syarulnaziah Anawar[2], Nur Fadzilah Othman[2], Norharyati Harum[2]

Fakulti Teknologi Maklumat dan Komunikasi, Universiti Teknikal Malaysia Melaka, Malaysia[1]
Center for Advanced Computing Technology, Fakulti Teknologi Maklumat dan Komunikasi, Universiti Teknikal Malaysia Melaka, Malaysia[2]

ABSTRACT— The death rate of drowning among children have been increasing lately in peninsular Malaysia. It may cause by the lack of attention from the parents in keeping their eyes of their children in the swimming pool. An IoT based system is proposed in avoiding this unintended death from happening as well as helping parents in taking care of their children in the swimming pool. Child Drowning Alert System is introduced to assist parents in paying attention to their children in the swimming pool. This system consists of NodeMCU and heart rate sensor. The heart rate sensor is used to detect heart rate the children in the swimming pool while NodeMCU is where the code is implemented in developing an algorithm to differ the normal heart rate and drowning heart. This system uses Wi-Fi to connect to the smartphone through Blynk application. If the designated threshold of heart rate is surpassed, the parents will get an alert signal from the microcontroller. From the testing, the prototype was able to detect the early symptom of drowning condition using our video simulation. This prototype not only help parents in monitoring one child but also enable to monitor more than one with the NodeMCU technology.

KEYWORDS: Child Drowning Alert, PPG sensor, NodeMCU, IoT.

1. INTRODUCTION

Drowning is defined as the "act of having trouble breathing as a result of excess liquid entry into the mouth or nostrils leading to lightening of the lungs' blood". The blood then easily loses its capacity to efficiently carry oxygen. This can contribute to death [1]. Drowning is the leading cause of unintentional injury death in toddlers aged 1–4 years old. Infants left unsupervised or alone with another child near water are one of the reasons associated with the rising incidence of drowning [2]. In public or private swimming pool, it can be difficult for parents to keep an eye on their children. This is where the children become vulnerable to danger and might lead to drowning as their parents are unaware of their children. A lifeguard can look over the water in a public swimming pool for several days without a big incident, which is a prescription for boredom, but a single moment of inattention when a swimmer experiences distress can mean the difference between life and death [3]. Even for experienced lifeguards, especially the cases that occur among children and inexperienced swimmers, the identification of a drowning person still seems to be a challenge, as there is no consistent behavior expressed by all people in near-drowning experiences [4]. The consequence of this problem would be a high risk of drowning among children. A wearable device attached to the swimmer capable of detecting anomaly in their behavior is needed as an early detection might help to overcome this problem. The IoT is a modern concept that provides the next generation of technical advances of new services. IoT applications have a collection of features and capabilities that can be grouped into four areas according to the domain of use: monitoring (device status, environment status, alarms, etc.), control (device function control), optimization (device output, diagnostics, repair, etc.) and autonomy (autonomous operations). Several IoT technologies have already been successfully developed for smart traffic networks, solutions for fleet management, logistic chain management, smart cities, smart metering, industrial automation, automotive collision detection systems, energy management, smart buildings/homes/ offices, environmental monitoring, etc [5].

2. Related Works

2.1 Background of Heart Rate Sensor

PPG/Heart beat sensor are functional through two main components which are the LED and photodiode. Both of the component are placed next to each other and along with circuit [6]. The circuitry consists of Ground, VCC and Signal which in charge for any amplification and noise cancellation. The LED must be place on top of the vein of human body such as fingers to detect the blood flow (refer Figure 1).

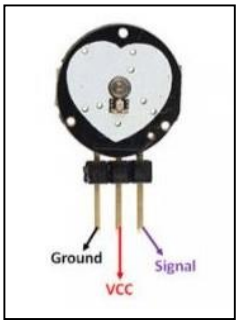

Figure 1: Components of PPG Sensor [7]

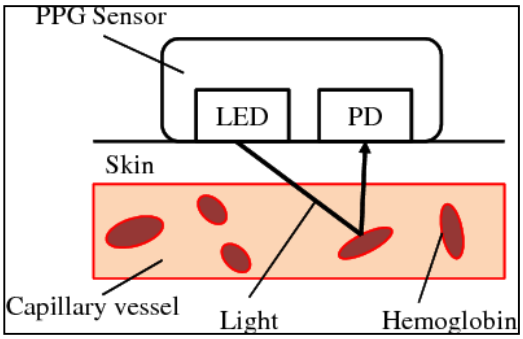

Figure 2: Mechanism of PPG Sensor [8]

The LED will emit light and pass through the vein directly. This is where the heart beat is detected because the blood flow only when the heart is pumping. The photodiode will absorb light since there will be light reflected red by the blood. The changes in receiving light will be analyzed per minute to determine the heart rate. Based on Figure 2, the light reflected from the red of the blood vary depending on how fast the blood is pumped from the heart. The faster the blood going through the vein, the lighter will be reflected to the photodiode [8]. Therefore, it will indicate how fast the heart rate of the human is.

2.2 Human Heart Behavior When Drowning

Drowning is known as damage to the respiratory system due to being in or under a liquid [1], [4]. A person that are drowning tend to have a higher heart rate since the heart will pump faster in order to get the oxygenated blood travel to all part of the body. A drowning person tend to be panic and will have their physical activity to increase. Movement from drowning increases the heart rate. Therefore, this will cause the person to be lack of oxygen since there will be difficulty to gasp for air when being under the water. Continuous lack of oxygen causes a person to be unconscious typically when the blood partial pressure is between 25 mmHg to 30 mmHg [9]. For children ages 6 to 15 years old have a normal heart rate of 70 to 100 bpm. Human heart pathology when drowning starts from the increase of heart rate from 130 bpm to 137 bpm. The heart rate somehow drops to 43 bpm and maybe cause from cardiac arrest [10].

2.3 Previous System

Previous studies have implemented drowning detection system using video surveillance [11], [12], [13]. Automated video monitoring systems are an effective mechanism of real-time identification of striking incidents. Generally, these systems consist of a computer vision unit that identifies segments and keeps track of objects submerged in motion and an analysis module that interprets the motions detected. Despite its success, these systems face a number of problems; this involves the issues related to the identification and monitoring of objects, for example, coping with shadows, changes in lighting and the effects of moving items that might appear in the background, etc. and the analysis of the movements of monitored objects into a summary of perceived behavior and interactions [14]. Recent development in the field of IoT have led to a renewed interest in using sensors to identify and alert the event of drowning. AlMahmoud developed a device composed of sonar sensors to identify a drowning person inside a body of water to form a three-dimensional sonar wave grid within the water body. A microcontroller is connected to the sensors for tracing a movement path of a person. The system will analyze the movement path of the person. An alarm will be issued if the movement path is indicative of a drowning person [15]. Several attempts have been made to detect drowning behavior based on heart rate [14], [16]. A work by [16] proposed the idea to save a person's life who is drowning in the water by informing heart rate to the lifeguard using a transmitter and receiver RF module. The transmitter unit consists of heart rate sensor, LCD, switch and regulator connected to the microcontroller powered by a 12V battery. The heart rate sensor is mounted on the hand or the head of the swimmer to track the person's heart rate. The LED and buzzer will be turn on if the heart rate of the swimmer increased or decreased. The receiver unit consist of a RF module, buzzer, microcontroller, transformer, rectifier and regulator will be hold by the lifeguard. Upon the detection of a drowning symptom, the buzzer will be ON to alert the lifeguard. On the other hand, system proposed by [14] measure and record the normal pulse pressure of the swimmer before they were made to wear the wristband watch and enter the pool. A low and high threshold is set to account for variation in the heartbeat, suggesting that the swimmer began to drown. The pulse rate is transmitted through the RF module. The Arduino Uno microcontroller will have received the signal and triggers an alarm signal through the buzzer. The microcontroller will also display an emergency text on the LCD in order to get the attention of the lifeguard for help to the swimmer. A similar wristband system has been proposed but a GSM module is used to communicate to the receiving unit [17]. Based on [11]- [17] studies, their projects do not involve any Wi-Fi to connect between the microcontroller to get an alert notification through mobile phone. Wi-Fi technology enable multiple devices to be connected simultaneously. This will enable multiple wristband to be connected to the mobile phone which the previous work used one-to-one connection. Mobile phone is widely use and always be kept close to the person. Thus, this will enable parents to get a quick alert notifications and information of their children in the swimming pool where lifeguard is distracted or unavailable.

2.4 Proposed System

The aim of this project is to develop a system for smart drowning detection using heart rate sensor and high detection accuracy. Heartbeat is the only parameters that are analyzed to detect the drowning condition. A drowning person intend to panic [18]. Thus, this causes nervous activities and heartbeat to slightly increase. Detecting heartbeat can be done by using a heart rate PPG sensor which will record the heartbeat detected per minute. An accurate heart rate detection is significant in providing precise data. When the heartbeat has been recorded, the data needs to be delivered to the parents. The parents can monitor their children heartbeat even when the parents are not in the area of the pool. This will somehow increase the safety of the children in the pool. The sensor is attached as wristband which will not impede the child activity. The system will feature a microcontroller, NodeMCU which is used to read data from heart rate sensor to detect heartbeat then sends the information to a cloud storage platform. Analog-to-Digital Converter will be implemented to convert data from analog to digital to make the data readable. The data will be sent to smartphone and available to user

online. If the signal of heart rate surpasses the designated threshold, the system will send an alert notification to the smartphone. The parents will get alert signal from the smartphone and take necessary action to save the drowning child. With the NodeMCU ESP 8266 WiFi module, more than one child can be monitored to the parent mobile phone.

3. Methodology

Rapid Application Development (RAD) methodology is used in this study. This method is suitable as it requires less time to complete compared to Waterfall Model. RAD consists of four (4) phases: Requirements Planning, User Design and Construction, Testing and Cut Over as illustrated in Figure 3. This paper focuses up to Testing phase.

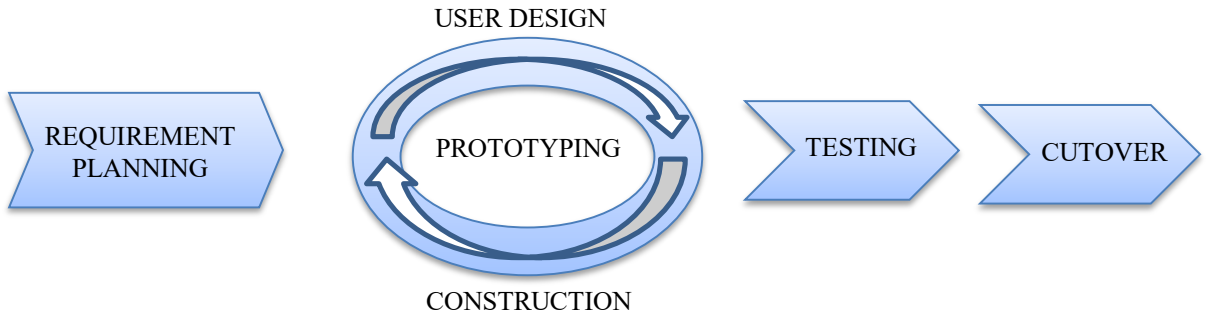

Figure 3: Rapid Application Development Methodology [19]

The activities in each phase are summarized in Table 1.

Table 1: Development Activities

Phase	Activities
Requirement Planning	• Identify required hardware (NodeMCU, ESP8266, Heart Rate Sensor and LiPo battery) and software (Blynk, ThinkSpeak, Arduino IDE) • Identify data requirement of the system.
User Design	• Determine overall design of the prototype as shown in Figure 4 • Determine the flow of the system of the proposed system as shown in Figure 5 • Determine PPG Heartbeat Circuit Design as shown in Figure 6
Construction	• Develop the hardware as shown in Figure 7 • Develop the mobile apps using Blynk application as shown in Figure 8
Testing	• Funtionality Testing

3.1 Data Requirement

This prototype is interacting using a hardware hence it needs to have an input to the system and output to the user. The input for this project will be the heartbeat sensor which will collect an input from the heartbeat of a person and send it to the microcontroller to be converted into a digital signal. The heart rate sensor has a light source and photodetector. Photodetector measures the reflected light from the tissue which is proportional to the blood volume variation. The incident light received is converted into voltage. The signal on heart rate sensor is a DC signal that relates to the tissues and blood volume. The AC components synchronous with the heartbeat that caused by changes in arterial blood volume is overlaid on the DC signal. Basically, the heart rate sensor receives the input as an analog signal and NodeMCU convert it to digital signal. This process is called Analog to Digital Converter (ADC). If the heart rate exceeds 140 bpm, it is considered as panic and when it is considered as drowning when the heart rate is below 40 bpm [10]. Then the signal will be sent to

the microcontroller for the calculation thus display the data through a Blynk application. The formula on how the analog signal is converted into digital signal which gives the value of the bpm is as follows [20]:

$$\frac{Resolution\ of\ the\ ADC}{System\ Voltage} = \frac{ADC\ Reading}{Analog\ Voltage} \quad (1)$$

Whereby,
System voltage = for NodeMCU is 3.7V
Resolution of ADC = 0-1023
ADC Reading = Digital value converted from Analag value

4. Prototyping

4.1 User Design

The architectural design of the child drowning alert system is shown in Figure 4. This system use NodeMCU as microcontroller which will programmed to read the data of heart rate sensor to obtain the heart rate of the child. The data will be sent to the user online through ESP8266 Wi-Fi module to the smartphone. This system also features a notification alert on a designated condition of the heart rate if the threshold value is surpassed using Blynk application. This system will use a power bank as a power supply.

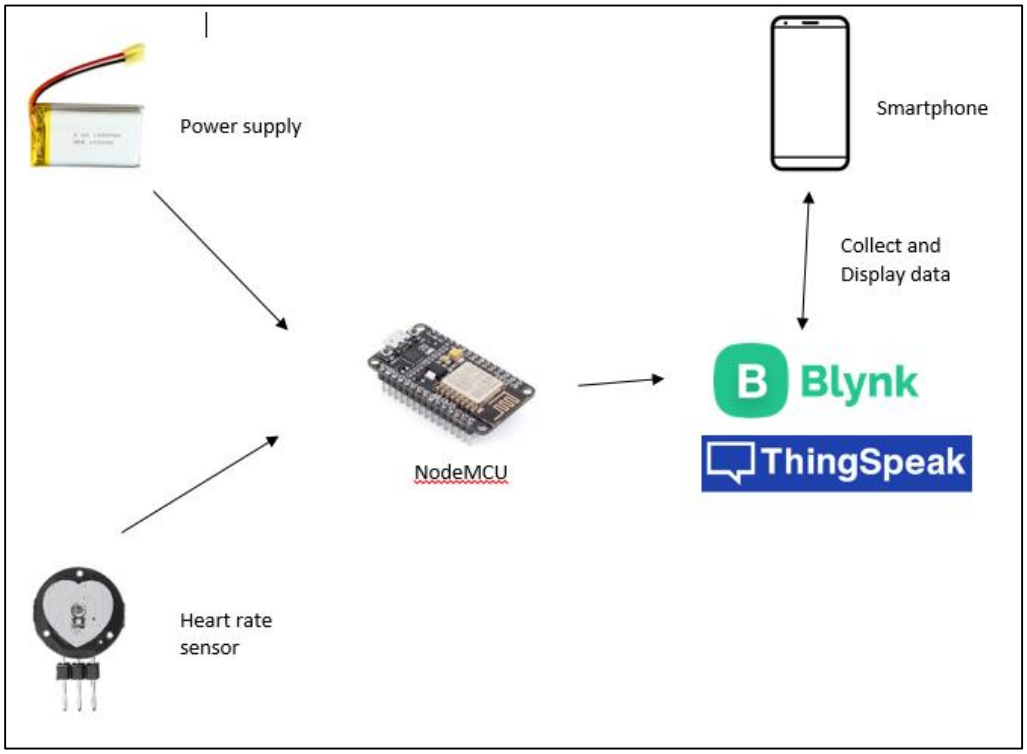

Figure 4: Design of the Proposed System

Based on the data requirement, the basic workflow of the proposed system is illustrated in Figure 5. The circuit design of the proposed system is shown in Figure 6.

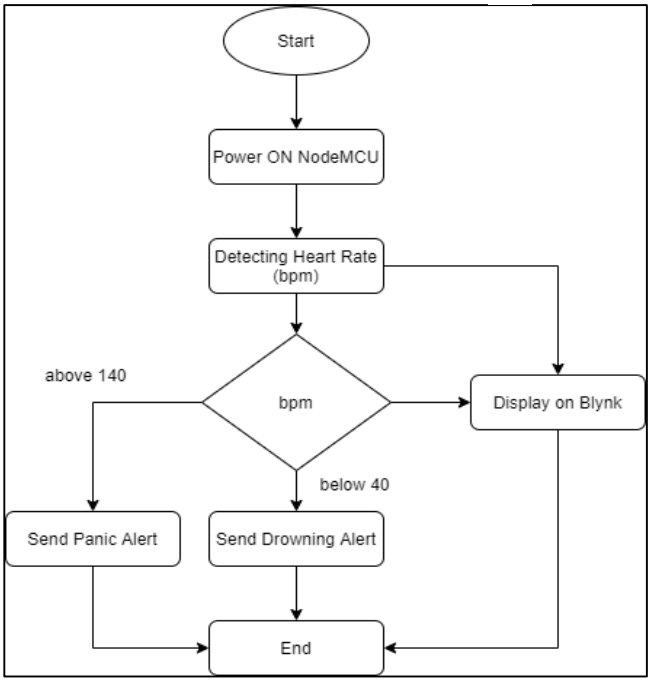

Figure 5: Workflow of the Proposed System

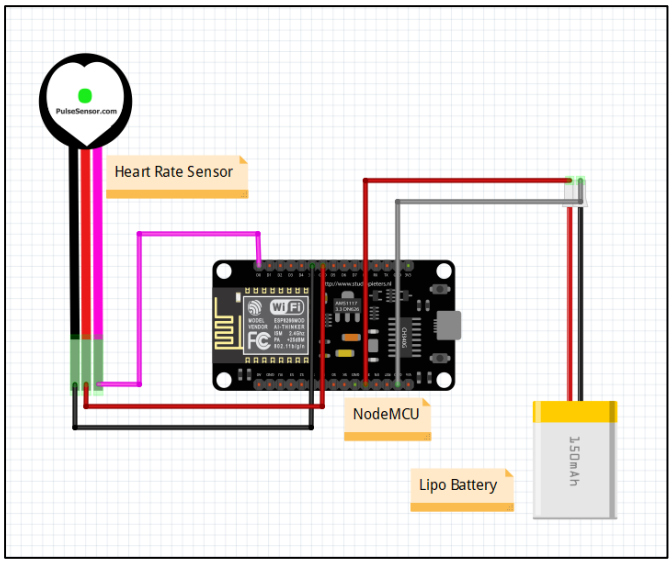

Figure 6: PPG Heartbeat Sensor Circuit Design

4.2. Construction

This phase is where all the codes written will be implement on NodeMCU by using Arduino IDE which control C++ development environment. The connection between the sensor and microcontroller are then tested to obtain an accurate reading. Once an accurate reading has been achieved, Blynk application installed in a smartphone will be configured to make sure that the connection between microcontrollers has been setup. The application should receive all the upcoming data from the microcontroller and display it on the smartphone. The complete development of the prototype is shown in Figure 7. The complete construction of the heart rate interface on mobile application is shown in Figure 8.

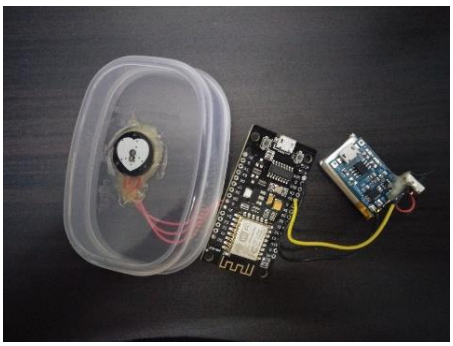

Figure 7: Complete Project Prototype

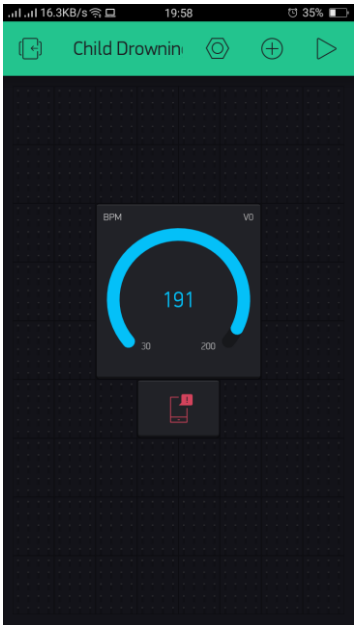

Figure 8: Heart Rate Interface on Mobile Application

5. Testing and Discussion of the Result

5.1 Test Environment

The environment of the testing will depend on the location and the preparation needed to be done to carry out this project. To understand the device limitations, the location of the project must be identified. The connection between the device and Blynk application need to be successful through ESP8266. The data collected must be monitored and controlled to detect any issues on the device during testing. To obtain a drowning heart rate condition is very difficult so a video simulation that act like an actual heartbeat will be used in the testing. The link of the video is accessible at [21] as shown in Figure 9.

Figure 9: Screen Capture of the Video Simulation

In this video, the normal heart rate is being simulate as the beginning of a normal heart rate condition. On the 00:47 of video is where the heart rate to increase and on the 01:23 the heart rate starts to exceed 140 bpm which indicate that the child is panic. After a few seconds the heart starts to decrease until it reaches below 40 bpm and that is where the child is consider drowning (Figure 10).

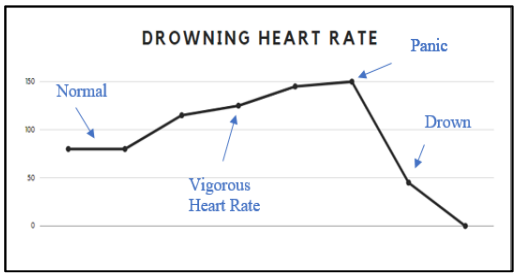

Figure 10: Chart for Simulation of Drowning Heart Rate

5.2 Accuracy Test of the System

This test is done to measure the accuracy of the heart rate sensor when measuring the heart rate. The heart rate can also be measured by calculating the pulse per minute using the radial pulse method as shown in Figure 11. The method to do it is by putting two fingers on the wrist between bone and the tendon over radial artery. The researcher starts to calculate the pulse for 60 seconds. Figure 7 shows how the method is done.

Figure 11: Radial Pulse Method

Based on Table 2, it can be seen that the both method are producing similar reading. This conclude that the sensor can detect the heart rate of a person.

Table 2: Comparison between Two Methods of Calculating Heart Rate

With Heart Rate Sensor (bpm)		Without Heart Rate Sensor (bpm)	
Rest	**Exercise**	**Rest**	**Exercise**
87	118	85	120

5.3 Testing Device in the Water

The device is put in to the water to test the efficiency of the device to detect heart rate in the water and the durability of the device under the water. The setup for the testing is shown below in Figure 12.

Figure 12: Setup for Testing

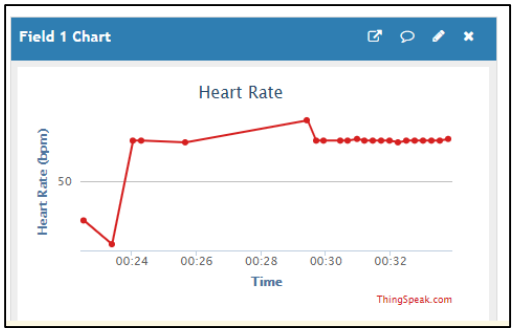

Figure 13: Reading of the Testing

Based on Figure 13, the device can detect the heart rate in the water. The reading is obtained from Thing Speak when the device was tested a few minutes under the water. The durability of the device in the water is excellent as it could detect the heart rate without any damage on the components of the device.

5.4 Drowning Simulation Video Test

The drowning simulation video test is done to simulate the heart rate condition when a person is drowning. The video as mention on section 5.1 was being used for the testing.

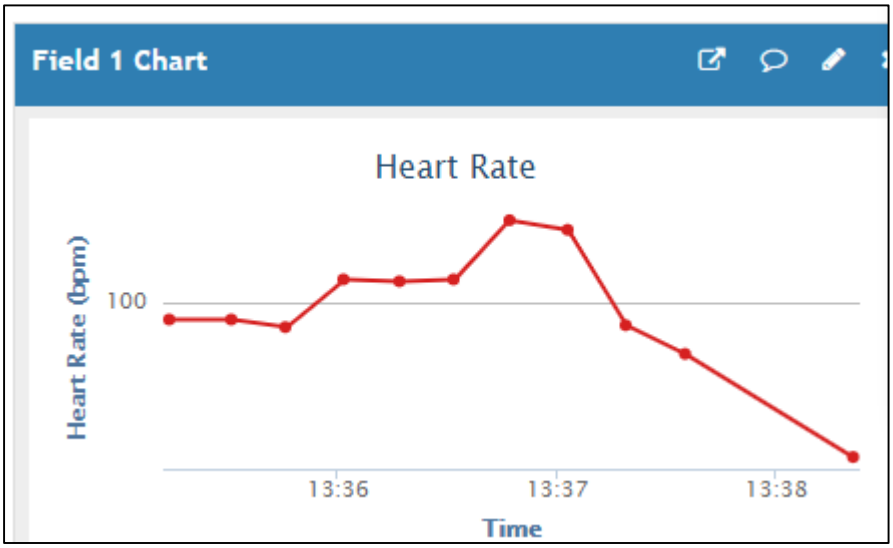

Figure 14: Full Video Simulation Chart

Figure 15: Panic Alert Notification

Figure 16: Drowning Alert Notification

Based on Figure 14, it shows the full simulation of the drowning condition. On the early of the video, the heart rate is between 87 bpm to 91 bpm which is a normal heart rate. A few seconds later, the heart rate increase to 112 bpm to 139 bpm. That simulates how fast the heart can generate pulse. 143 bpm is the maximum heart rate reached and that shows it is in panic condition. An alert is sent to the mobile app to indicate that the child is panic as shown in Figure 15. After that, the heart rate drops rapidly until it reaches below 40 bpm. This indicate that the child is drowning. A notification is sent to the mobile app to indicate the child is drowning as shown in Figure 16. This video simulate what will happen to a person's heart when drowning. The rapid drop from heart rate can be due to cardiac arrest or the lack of oxygen in the brain. This video simulation is done because it is difficult to simulate a drowning heart rate condition since it is very dangerous to test on live subject.

6. Conclusion and Future Works

The prototype is capable of detecting heart rate and differentiate between normal and drowning condition. However, during testing there is a few errors such as fluctuation of current in the device when it is using the LiPo battery. The power from direct USB connection to the device are shows much better connection. This shows that a better power supply is needed in providing better reading which will be the future works of this study. Overall, the objective of this study has been achieve where the device is able to detect the heart rate in an early drowning situation. By using ESP8266, device is connected through WiFi. Thus, the mobile phone can be connected with multiple heart rate device. This will enable parent with more than one child to monitor their children.

7. Acknowledgement

A high appreciation to Center for Advanced Computing Technology (C-ACT), Fakulti Teknologi Maklumat dan Komunikasi, Universiti Teknikal Malaysia Melaka (UTeM) for supporting the work done in this paper.

8. References

[1] International Life Saving Federation, “World Drowning Report,” p. 25, 2007.

[2] Ariscain, V. (2020, February 3). Drowning. Retrieved October 18, 2020, from https://www.who.int/news-room/fact-sheets/detail/drowning.

[3] Brewster, B. C. (1999). Comment on: Prevention of drowning: visual scanning and attention span in lifeguards. Journal of occupational health and safety, Australia and New Zealand, 15(3), 208-210.

[4] Pia, F. (1974). Observations on the drowning of non-swimmers. Journal of Physical Education, 71(6), 164-167.

[5] Čolaković, A., & Hadžialić, M. (2018). Internet of Things (IoT): A review of enabling technologies, challenges, and open research issues. Computer Networks, 144, 17-39.

[6] Castaneda, D., Esparza, A., Ghamari, M., Soltanpur, C., & Nazeran, H. (2018). A review on wearable photoplethysmography sensors and their potential future applications in health care. International journal of biosensors & bioelectronics, 4(4), 195–202. https://doi.org/10.15406/ijbsbe.2018.04.00125

[7] Gitman, Y. (2018). The "GettingStartedProject". Retrieved October 27, 2020, from https://pulsesensor.com/pages/code-and-guide

[8] Fukushima, H., Kawanaka, H., Bhuiyan, M. S., & Oguri, K. (2012, August). Estimating heart rate using wrist-type photoplethysmography and acceleration sensor while running. In 2012 Annual International Conference of the IEEE Engineering in Medicine and Biology Society (pp. 2901-2904). IEEE, doi: 10.1109/EMBC.2012.6346570.

[9] Lindholm, P. (2007). Loss of motor control and/or loss of consciousness during breath-hold competitions. International journal of sports medicine, 28(04), 295-299.

[10] Lund, F. K., Torgersen, J. G., & Flaatten, H. K. (2009). Heart rate monitored hypothermia and drowning in a 48-year-old man. survival without sequelae: a case report. Cases journal, 2(1), 1-6.

[11] Kam, A. H., Lu, W., & Yau, W. Y. (2002). A video-based drowning detection system. Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 2353, 297–311.

[12] Lu, W., & Tan, Y. P. (2002, September). A camera-based system for early detection of drowning incidents. In Proceedings. International Conference on Image Processing (Vol. 3, pp. III-III). IEEE.

[13] Salehi, N., Keyvanara, M., & Monadjemmi, S. A. (2016). An Automatic Video-based Drowning Detection System for Swimming Pools Using Active Contours. International Journal of Image, Graphics and Signal Processing, 8(8), 1.

[14] John, S. N., Ukpabio, I. G., Omoruyi, O., Onyiagha, G., Noma-Osaghae, E., & Okokpujie, K. O. (2019). Design of a drowning rescue alert system. International Journal of Mechanical Engineering and Technology (IJMET), 10(1), 1987-1995.

[15] AlMahmoud, A.A., Khalifa University of Science and Research (KUSTAR), 2018. Sonar based drowning detection system, method and kit. U.S. Patent 9,972,188.

[16] Chaudhari, T., Kava, Y., Pandit, G., Gupta, P., and Kumar, P. M., (2018). Anti-Drowning system using remote alert, IOSR Journal of Engineering (IOSRJEN), vol. 1, pp. 38-42.

[17] Ramani, J. G., Gayathri, J., Aswanth, R., & Gunasekaran, M. (2019, March). Automatic prevention of drowning by inflatable wrist band system. In 2019 5th International Conference on Advanced Computing & Communication Systems (ICACCS) (pp. 346-349). IEEE.

[18] Webber, J. (2012). Surf Lifeguard Response to Drowning: The SENTINEL system revisited. Ophthalmic and Physiological Optics, 31(3), 216–224. https://doi.org/10.13140/RG.2.1.3844.3041

[19] Jamsheer, K. (2019, March 14). 12 Best Software Development Methodologies with Pros & Cons. Retrieved November 03, 2020, from https://acodez.in/12-best-software-development-methodologies-pros-cons/

[20] Lillis, W. J. (1976). Analog to digital conversion. In Digest of Technical Papers - IEEE International Solid-State Circuits Conference (Vol. 19, p. 143). https://doi.org/10.1109/ISSCC.1976.1155560

[21] Farid Zakwan, N.A (2020) Drowning Heart Rate Simulation. Retrieved September 4, 2020, from https://youtu.be/I4uSiNfka04