TELKOMNIKA, Vol.16, No.4, August 2018, pp. 1870~1876
ISSN: 1693-6930, accredited First Grade by Kemenristekdikti, Decree No: 21/E/KPT/2018
DOI:10.12928/TELKOMNIKA.v16i4.9046

An Early Drowning Detection System for Internet of Things (IoT) Applications

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Abstract

Drowning is the leading cause of injury or death for children and teenagers. Designing a drowning detection device by implementing an Internet of Thing (IoT) is needed. An Early Drowning Detection System (EDDS) is a system that gives an early alarm to the guardians (parents and lifeguard) if the detector triggered an abnormal heartbeat and the victims are submerged under the water for a long time. A microcontroller was used to control the signal received from a pulse sensor and time for the signal lost under the water before it is transmitted to the access point. The access point acts as a data forwarding to the database via an internet connection. Universal Asynchronous Receiver/Transmitter (UART) 433MHz radio frequency transceiver has been used to create the wireless communication between drowning detection device and monitoring hub. A triggered warning signal will be transmitted to the guardians via Android apps and web page.

Keywords*: Internet of thing (IoT), Early drowning detection device (EDDS), Universal asynchronous receiver / transmitter (UART)*

1. Introduction

The World Health Organization (WHO) define the drowning as a process of experiencing respiratory impairment effect of submersion or immersion in the liquid such as water [1]. The blockage of the human respiratory system may suffer the lung and the brain (hypoxia) due to lack of oxygen flow inside the human bloodstream [1]. WHO statistics in 2014 shows that 372,000 people die globally every year due to drowning [2]. Children and young adults were the main contributors to this drowning cases especially boys [2], [3]. Usually, drowning happened in open space such as streams, lakes, bathtubs and swimming pool [3]. Lack swimming abilities among the victims andless effective methods of the water safety monitoring around the swimming pool are the key point for this situation. The wide area of swimming pool and congestion of visitors at the swimming pool may create many blind spots. The lifeguard's view of the swimming area is obscured [4]. It is the lifeguard's responsibility to seek out every blind spot in the swimming area and to take the necessary action to reduce the amount of area that the lifeguard cannot see from his/her lifeguard station [4], [5]. It might give difficultiesfor lifeguards to monitor all the swimmer's safety inside the swimming pool [4]. The chance of drowning among the children is high will be the outcome of this issue.

The additional water safety system for detecting drowning situation might help to overcome the problem. The technology has improved human capabilities days by days. Implementation of theInternet of Things (IoT) in daily lifestyle has received a lot of attention by the researcher and industries recentlyespecially for safety monitoring purposes. The IoT establishes a connection between all things, and internet via detection of devices and smart tools identification and management [6]. The IoT is able to work with any type of sensor nodes such as Wi-Fi network adapters, motion sensors, cameras, microphones and other types of electronic instrumentation. The integrations of all these nodes can form a useful devices or system that can improve human lifestyle. Wearable computing devices like watches and glasses are also envisioned to be key components in future IoT systems [7]. The same wireless communication protocols like Wi-Fi, Radio Frequency (RF) and Bluetooth are naturally extended to the IoT also. It is a network or chain of objects or sensors, which contain embedded

Received February 23, 2018; Revised June 27, 2018; Accepted July 10, 2018

technology, can communicate and interact with each other via that technology. These gadgets like smart devices can be remotely accessed and controlled through the graphical user interface (GUI) from far, thereby benefitting users. Wireless Sensor Network (WSN) is currently one of the most develop and research field in electronics as its potential to create an impact on our society through its application. WSN integrates various interdisciplinary technologies, such as sensor technology, embedded computing technology, distributed information processing technology and wireless communication technology [8]. WSN able to act as a bridge between physical and virtual world [9]. A few industrial companies have initiatives to build a system/product to reduce the risk of drowning especially for children. Table 1 below shows the three products that special design for drowning cases.

Table 1. Other Products for Detecting Drowning.

Products	Drowning Detection	Output
SEAL	Detecting the time of submerge using a wearable device.	Central hub will sound the alarm when the victims submerge under the water for a long time.
I-Swimband	Detecting the time of submerge using the wearable device.	It will send an alert to a parent's smartphone if a swimmer is submerged for a long time.
Coral	Using the camera to monitor the strange behavior inside the water	Sound the alarm to lifeguard office to take actions.

The SEAL and I-Swimband were implementing the short-range Bluetooth that operate at 2.4 GHzas aninterconnection between thewearable band and the monitoring device. These two systems use the samemechanism for detecting drowning which detects a long submersion of the victims underwater. The contrast between this two systemis the SEAL use portable monitoring hub as a monitoring device, while I-Swimband were using a smartphone as a monitoring device. The Coral using the camera to monitor the strange of swimmer's behavior inside the water. This system required high cost and usually, these products installed in a private swimming pool. This system used image processing technique to detect drowning.

This paper is focusing on the development of a system based on IoT technology that gives an early warning to the parents and lifeguard if the drowning incident happen. Implementationof IoT inside this drowning detection system will givelong-range monitoring method to monitor the children's conditions inside the swimming pools in real time. This system is based on the biological symptoms of drowning that can be detected by electronic sensors. Before the victims start drowning, they usually will experience a near-drowning (panic situation). In that particular situation, their heartbeat rhythms will be abnormal (cardiac dysrhythmias) and most of their body temperature will drop below 35degree Celsius (hypothermia) [10]. All in all, the paper outcome is mainly focused to improve water safety at the swimming pool and to reduce the percentage drowning accidents among children and young adults. The system needs to be waterproof to ensure that all components are not damaged.

2. Research Method

Near drowning is the situation that occursbefore drowning and it happens very quickly. Within 3 minutes of submersion, most of the victims are unconscious, and the brain starts to suffer within 5 minutes of submersion effect from lack of oxygen. During near drowning, a human usually fights to survive. The victim starts to give a panic reaction with violent struggling to save their lives.Their head is low in water and mouth at water level. Hyperventilating and gaspingis the common behavior during drowning. The heartbeat rhythm may become abnormal. Abnormal heart rhythms (cardiac dysrhythmias) often occur in near-drowning cases, and the heart may stop pumping (cardiac arrest) when the victims start to drown.

The heartbeat may increase drastically during panic situations (Hyperventilating). Therefore the abnormalities of heart rhythm are suitable for detecting an early drowning situation.The second parameter is the loss of radio frequency signal between thewearable device and access point. When the signal loss for more than 30 seconds, it means that the swimmer start submerges deep into the water. RF attenuation is high underwater, therefore, the deeper the swimmer submerge, the higher attenuation of RF signal.433MHz UART transceiver used due to theabilitytoestablishing long-range wireless transmission.

PPG sensor used a light source to measure heartbeat. PPG is seen as an alternative method to identify the condition of an individual [11]. This light will travel through biological tissue. It can be absorbed by different substances such as pigments in the skin, bone, and arterial and venous blood. Most changes in blood flow occur in the arteries and arterioles. PPG sensors optically detect changes in the blood flow volume (changes in the detected light intensity) in the microvascular bed of tissue via reflection from or transmission through the tissue. The green light is suitable for the measurement of blood flow in the skin. The green light in PPG sensors has minimized the motion of artifacts. However, better accuracy and reproducibility of real environments are required to eliminate motion artifacts [12].

Web page and mobile app were used to view the heartbeat signal from the sensor [13]. Heartbeat signal converts to the electrical signal by using PPG sensor. Then this analog signal was converted to the digital signal using a microprocessor. RF transceiver act as RF module for communicating between microprocessor and access point. Mobile app and monitoring web page have been developed to display heartbeat information and time domain waveform to users for healthcare monitoring. The data from the access point can be sent to monitoring computer using existing available networks (3G, 4G, Wi-Fi, etc.) for health database logging purpose [13].

3. Design Architecture

The main objectives of the paper are to improve the water safety in swimming pool and reduce the statistic of drowning accident among children by developing a system that can use to detect the early symptoms of drowning, which are an abnormal heartbeat and long submerge timing of the swimmers. This system can be monitored wirelessly far from swimming pools.

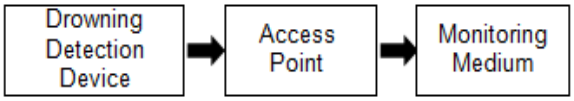


Figure 1. Block diagram of the full system

Based on block diagrams in Figure 1, the system divided into three sub-systems which are drowning detection device, access point/server, and monitoring system. The whole system was designed using the suitable size of components to make the device smaller and easier for installation. The components need to be affordable and long last. The EDDS were used a simple 433Mhz Radio Frequency (RF) communication protocol between drowning detection device and access point. The microprocessor analyzes the algorithm of the drowning symptoms before it triggers the warning alarm through monitoring medium.

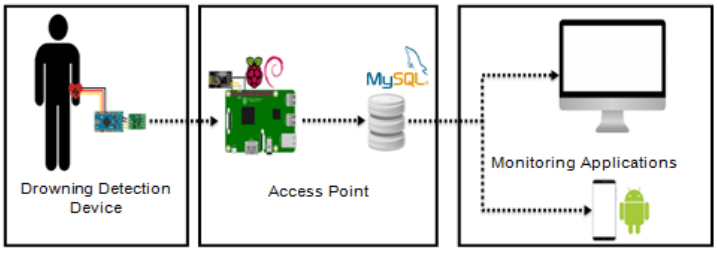


Figure 2. Architecture diagram for EDDS

Figure 2 shows the architecture diagram for the whole system of EDDS. The first part of the EDDS is wearable drowning detection device. This device consists of pulse sensor to detect the heartbeat rhythm from the swimmer. This heartbeat signals from pulse sensor were analyzed by the microcontroller- Arduino Pro Mini 328. 433MHz (UART) transceiver module was

used as a transmitter for the device to transmit the data to the access point. The second part of this system is known as “Access Point”. The function of this part is to establish the communication between the wearable drowning detection device and access point. This part was used the same 433MHz (UART) transceiver module as a receiver at the access point.

The access point was developed by using Raspberry Pi 2 because it can be connected to the internet easily by plug in the internet cable or Wi-Fi adapter. It also acts as a gateway to store the received data from the drowning detection device to database (MySQL) via an internet connection. The last part of the system is monitoring applications. The access point will establish the cloud network to allow the user to monitor the system through android application and web page by connecting it to the internet connection. These applications have extracted the data from the database for display it to end user. It will show the real-time application of the system. It can help lifeguard and parents to monitor the children in real time.

4. Experimental Results and Discussions

The main parameter for EDDS is a heartbeat. Drastic rises in heartbeat changes were the main triggering point for the panic attack before drowning. The development of heartbeat algorithm from the sensor requiredthesignal processing technique to get an exact reading of heartbeat. The raw signal needs to be filtered first to remove all the noise before identifying the actual heartbeat per minute of the swimmer.

The filtered signal was used to calculate how many beats that can be fitted in one minute (BPM). But to have one minute delay to read heartbeat reading per minute is quite long and it seems to be not really practical to wait for a minute to get one BPM reading. Therefore, the algorithm used in the system is sliding window technique to perform continuous heartbeat reading without having a delay. The system counts first 10 seconds of heartbeat samples and times it by 6 to give a heartbeat reading per minutes (BPM) and continuously shifted a second to give a new reading of heartbeat. The red LED will blink based on swimmer heart beat’s rhythm. Figure 3 and Figure 4 shows the full figure of drowning detection device with 433 MHz UART transceiver module. This transceiver module does not need any additional coding if used with Arduino Pro Mini because it uses the same protocol as USB serial port which is serial.

Figure 3. Drowning Detection Device

Figure 4. Drowning Detection Device wear as a headband

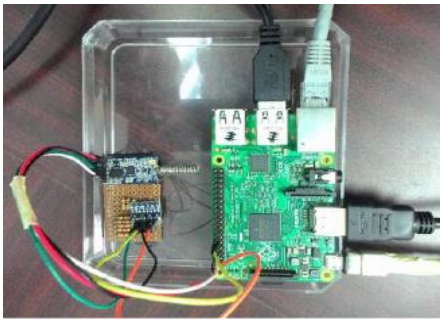


Figure 5. Hardware of the Access Point

The access point allows the user to monitor the system using the mobile app. Figure 5 shows the hardware of access point. Internet connection needs to be established at the access point to allow the system to push the data to the database. To enable the connection between drowning detection device and the access point, both of the baud rates need to be synchronized at the same baud rate, which is 115.2 Kbps. This baud rate has been chosen to eliminate or minimize the delay in terms of data transfer from the transmitter and the receiver, in order to make this system effective. The swimmer's submerging timing is calculated for this access point. This access point will calculate how long the RF signal between the drowning detection device and access point are lost. If the lost signal is more than 30 seconds, its mean that the swimmer is already submerged for 30 seconds. This access point will analyze and categorize the symptoms into several categories which are normal, active, panic and drowning.

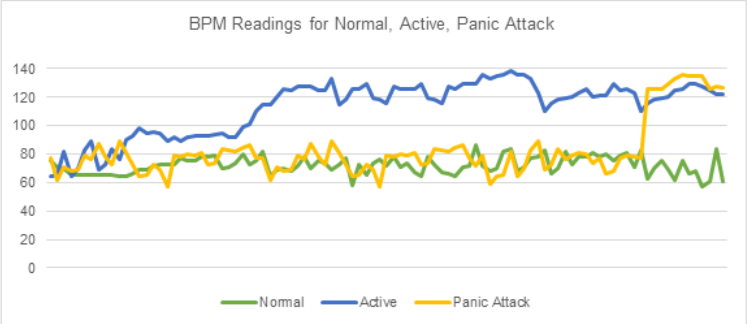


Figure 6. Average of BPM reading for normal, active and panic attack

Figure 6 shows a set of data for an average of BPM after EDDS been tested. The tests only cover for normal, active and panic attack situation only. The near drowning situation can be assumed as panic attack situation. During panic attack situation the BPM reading increased drastically from normal BPM reading. If the condition of the swimmer is critical (either drowning or panic attack), the monitoring web page and mobile app will give a warning alarm to warn the lifeguard about swimmer condition. The drowning condition happens when the signal between drowning detection device and the access point is lost more than 30 seconds. This can be assumed that the swimmer is already unconscious due to low of oxygen level to brains. The swimmer starts to submerge and RF signal starts to distort due to high attenuation underwater.

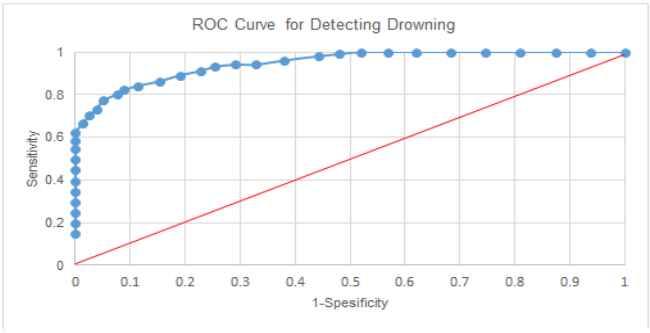


Figure 7. ROC curve for detecting drowning

Figure 7 shows the ROC curve for EDDS algorithm for detecting the drowning situation. The result of ROC curve for this algorithm was above the linear line. It shows that the possibility of getting false alarm was low compared to the possibility of sensitivity for this algorithm. The area under the graph is 0.94 which is good. The accuracy of the EDDS defined by the area

under the curve. An area of 1 represents a perfect test; an area of 0.5 represents a worthless test [14]. Mobile app and monitoring web page are used to display the status of the swimmer to the parent and lifeguard. Monitoring web page is designed purposely for the lifeguard to monitor the current status of the swimmer's condition. The monitoring web page will be refreshed automatically for every one second. The monitoring web page contains the time, BPM, current status, and history. Figure 7 and Figure 8 shows the view of monitoring web page for EDDS, which is to show all the heartbeat record for the swimmer. This will make it easier for lifeguard and parents to monitor the current condition of the swimmer.

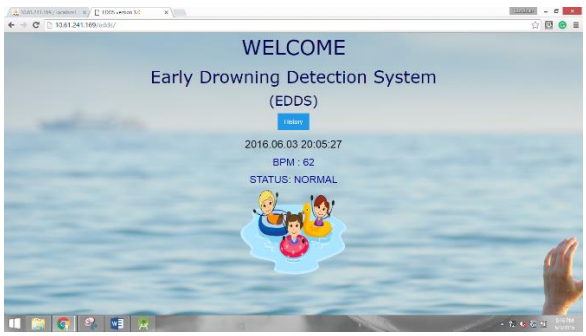
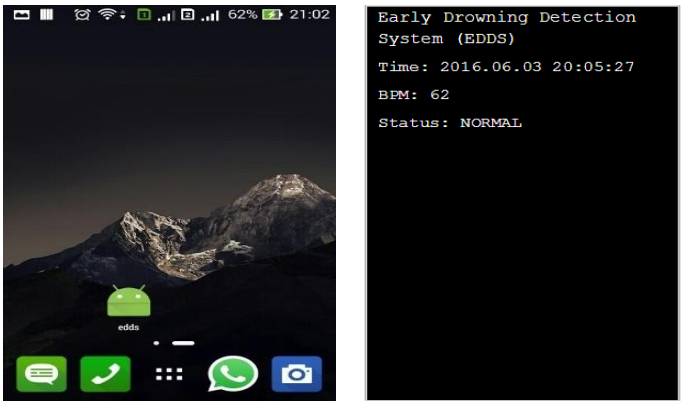


Figure 7. View of web page interface (main page)

Figure 8. View of web page interface (history page)

This mobile app is a user interface specially designed for the parents. With this mobile app, it is easier for parents to monitor their children while they are not with them. This app works as monitoring web page, it will give a warning alarm when their children are in danger (tired, drowning and panic). Figure 9 shows the view of mobile app interface for EDDS.



(a) (b)

Figure 9. Mobile App Interface for this EDDS

5. Conclusion

The Early Drowning Detection System device has been successfully built and tested. The area under the curve for ROC is 0.94. The system used PPG types of pulse sensor to measure the abnormalities in heartbeat of the swimmer. The data have been updated and transmitted to the monitoring system in real-time. The lifeguard and parents able to monitor the condition of the swimmer and alerted in real-time when the panic attack, which is drowning symptom detected. Therefore the swimmer especially children safety in the swimming pool can be monitored remotely by parents and lifeguard.

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