DEVELOPMENT OF INTERNET OF THINGS (IOT) BASED ANTI-DROWNING DEVICE

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ABSTRACT
This study focused on the development of an IoT-based anti-drowning device to reduce the loss of lives to drowning. Agile methodology was adopted for this work. The design and its implementation created a wristband transmitter strap and lifeguard alert modules with a pulse reader, a GPS tracker, Arduino Nano and Pro Mini, and a red liquid substance to locate a drowning person precisely. The device schematic was simulated on Proteus software and coded using Arduino IDE. The components were coupled and tested, and the results showed that abnormal heartbeats between 0-60 and above 120 triggered an alert for assistance. The system needs a stable internet connection for its operations and is deployed to immediate monitoring, real-time tracking, and quick location of victims.

Keywords:
Anti-drowning, Arduino kits, Internet of Things, Lifeguard alert, Transmitter strap

1. INTRODUCTION

The challenge of discovering a drowning individual for experienced lifeguards remains daunting. Underage and amateur swimmers are affected by the near-drowning incidents [1]. Victims are confused, gasp for breath and try to avoid passage of water through their nostrils or mouth, which is far the most devastating form of death. Lakes, rivers, beaches, and man-made water bodies are common areas where drowning occurs. Domestic cases of the drowning of young infants are mostly recorded during recreational activities such as swimming and diving into the deep. Investigations confirmed that life-vest is the safest option to avert drowning; even if a swimmer floats on the cold-water surface, the probability of him dying of hypothermia remains imminent [2].

World Health Organization (WHO) asserts that people under 25 years account for the average of 372,000 young people who die annually from drowning [3], which becomes one of the leading causes of death among this age group. Also, the drowning incidents among children under age 15 accounts for 135,585 deaths globally. In the African continent, drowning is rated twenty times higher than other continents in the globe. In 2019, a drowning incident, which led to the Death of a graduate of the Federal University of Technology, Owerri, encouraged the invention of an IoT-based safety device to be worn by individuals before gaining access to the water. The device, in turn, alerts the lifeguards or passersby immediately a swimmer encounters danger.

1.2 Problem Statement

There is a need to deploy an IoT - based device to monitor, discover, track and locate anyone in danger of drowning in a water body and alert lifeguards to save them. The effective application of the IoT–based device will help reduce the number of deaths by drowning.

1.3 Objectives

Its primary objective is to develop an IoT-based anti-drowning device. The specific objectives are to:

i. Identify existing system weaknesses necessitating the proposed system.
ii. Design the device input-output modules using IoT Technology.
iii. Code, construct and integrate the software and the hardware using Arduino.
iv. Validate the proposed system development through testing.

2. LITERATURE REVIEW

2.1 The Reviewed Works

Technological advancement, with the invention of wearable devices, prevented the occurrence of emerging drowning occurrences. Swimmers remain selective in adopting suitable drowning prevention system. Most swimmers crave for swimming cap since it's the most acceptable in some public pools [1]. An increase in the nervous activities and heartbeats as a result of pugnacity are signs of danger for drowning swimmers.

It is unfortunate to note that trained lifeguards are not readily available at the pool sides where children try to amuse themselves in their leisure time, making them susceptible to the danger of drowning as a result of carelessness or inexperience of swimmers. The challenging task that requires an accurate system is the real-time detection of a drowning person. In 2014, WHO noted that US patents from a database search identified inventions aimed at averting drowning and the dissemination of its information among various stakeholders [3]. The findings identified some devices for preventing drowning, and other exceptional inventions. Cost-effective devices are required to prevent drowning re-occurrence in underdeveloped and developing countries, most especially the African continent. Most inventions need a critical evaluation of their effectiveness in averting drowning, most especially the cost-effective devices.

Authors in [4] developed an automatic drowning rescue device for humans using Radio Frequency Identification (RFID) scheme. Due to the difficulty in detecting a drowned person in a pool using conventional methods, the deployment of an RFID-based system is employed as a sensor to detect the human body underwater. With the use of the Global Position System (GPS) and Global System of Mobile Communication (GSM), the location of the person can be easily tracked. The RFID consists of two components: the reader and the tag. A tag is applied to one's hand while the reader is inserted in the deep of the pool. The reader generates a Radio Frequency (RF) signal constantly with a unique serial number as soon as the tag gets close range with the reader. Simultaneously, the Programmable Integrated Circuit (PIC) identifies the tag resulting in the activation of GPS and tracking down the drowning victim for rescuing.

Drowning Detection and Automated Pool Security was employed by authors in [5] using wearable technology in the form of a wristband to detect drowning automatically. To detect such errors early on, the gadget used a differential pressure method. This system included an RF module, a pressure sensor, and a motor driver, among other things.

A video-based device for drowning detection that operates on automatic mode was developed by authors in [6]. Active contours were employed to notify lifeguards of drowning scenario. This study detects and tracks the person swimming in the pool using the HSV color space properties and contour-based method. Where a moving target remains underwater for more than a predetermined period, an alarm is triggered to the lifeguard. The HSV color space is preferred over others because it segments the swimmer more effectively in varied light conditions in the background.

2.2 The Established Research Gap

The proposed system is a wristband with pressure sensor that measures water pressure continuously and transmits it on a Radio Frequency module [5], and it needs a high voltage source. With respect to the existing Automatic Drowning Rescue System for Humans Using RFID, it could be observed that, the obtained result was inconsistent with established standard; while the use of a single RFID reader is not significantly sufficient because the dangerous locations could be more than one [4]. The Video-based drowning detection system proposed by authors in [6] has a problem of the technology being susceptible to sensor and visual disorders especially when the water-body is jam-packed. From these findings, it could thus, be inferred that a more reliable system that operates and integrates IoT features is the desirable and robust solution to prevents, as well as, salvage the users of water ways and pools for recreation.

3.0 MATERIALS AND METHODOLOGY

3.1 Materials Requirement: Component and Tools.

a. Node MCU ESP 8266 Uno

The ESP8266 is TCP/IP stack and microcontroller-based Wi-Fi low-cost chip developed by a Chinese manufacturer based in Shanghai. The chip was announced in August 2014 with the ESP-01 module, made by Ai-Thinker - a third-party manufacturer. This module allows the interconnection of microcontrollers with a Wi-Fi network. With this, simple TCP/IP links using Hayes-style commands are made possible. However, at the time, there was almost no English-language documentation on the chip and the instructions it could receive for processing. The low cost of the module often attracted hackers to explore. The ESP8285 is an ESP8266 with 1 MB of built-in flash, allowing for single-chip devices capable of connecting to Wi-Fi [7]. The successor to these microcontroller chips is the ESP32; its features are summarized as follows:

i. Processor: L106 32-bit RISC microprocessor core based on the Tensilica Xtensa Diamond Standard 106Micro with a speed of 80 MHz.
ii. 96KB of data RAM and 64 KB of instruction RAM.
iii. Supports external QSPI flash-up to 16 MB (512 KB to 4 MB typically included).
iv. IEEE 802.11 b/g/n Wi-Fi.
v. Integrated matching network with transmitting switch, balun, LNA, power amplifier.
vi. WEP or WPA/WPA2 authentication, or open networks.
vii. 16 GPIO pin.
viii. Transmit-only UART on dedicated pins to be enabled on GPIO2.
ix. 10-bit successive approximation Analog-to-Digital Converter.
x. Support STA/AP/STA+AP operation modes.
xi. Support both Android and iOS devices Smart Link task

The hardware connections required to connect to the ESP8266 module are usually easy to use, however, a few issues are necessary to consider, especially, as it relates to power usage. ESP8266 module is shown in figure 1, and it operates on requires 3.3V power. The ESP8266 communicates via serial port at 3.3V.

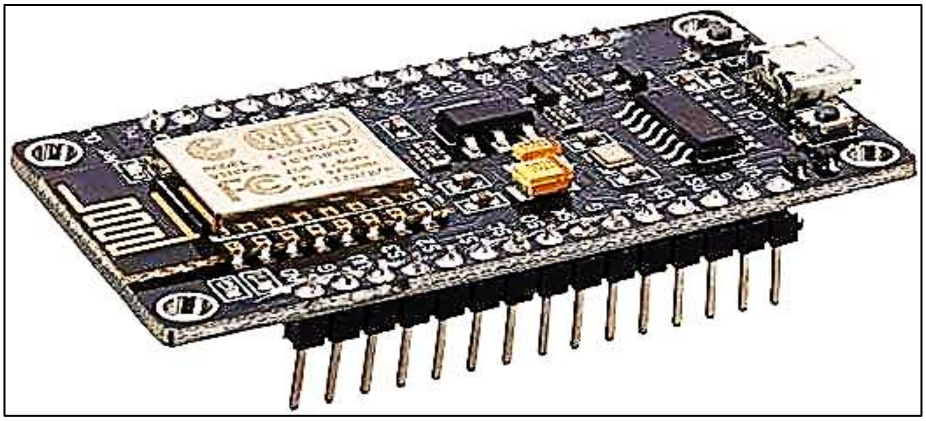

Fig. 1: Node MCU ESP 8266 (Node mcu esp 8266 Uno Rev3).

The connection point details and the terminals of the ESP8266 Wi-Fi module are described in Figure2.

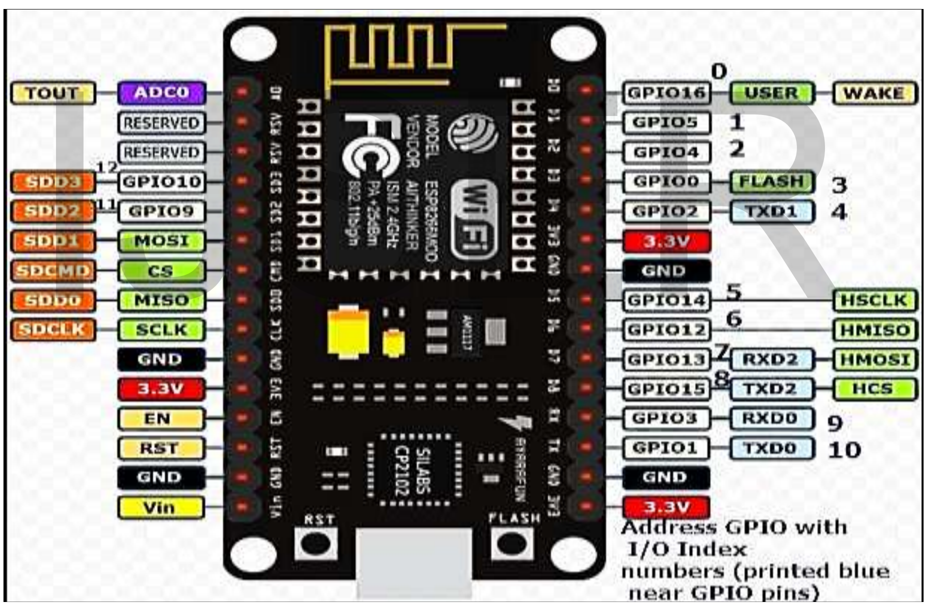

Fig. 2: ESP8266 Wi-Fi module.

b. Heartbeat Sensor

An electronic device that works on the principles of photo-plethysmography is used to measure heart rate. Typical examples are shown in figure 3. The device measures the change in the blood volume from any body part, and the blood flow varies with the heart pulses. It has LED and light detecting resistor. When the LED light focuses on a tissue, the light is transmitted or reflected. Some rays are absorbed by the blood, while the rest are absorbed by the detector. The light absorption depends on the volume of blood in the tissue. According to authors in **[7],** the heartbeat rate is directly proportional to the electrical signal output of the detector device. The heartbeat rate calculation is given by:

$BeatsPerMinute = 60 \text{ x } f$
where f, is the pulse frequency.

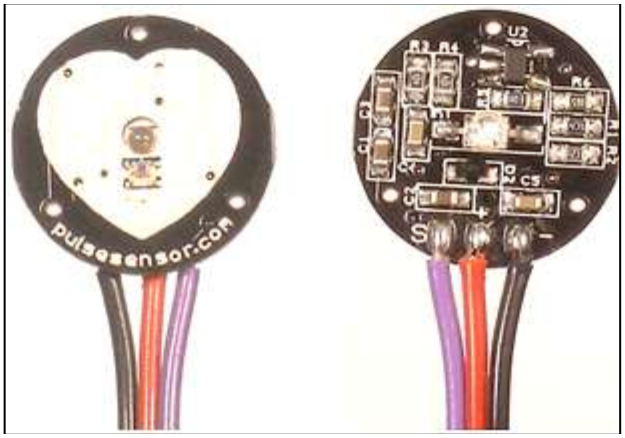

Fig. 3: Sensor Module for Heart-beat

An important kit, which aids the efficient performance of the sensor module for heart-rate measurement is shown in the figure 4.

Fig. 4: Related components for Heart-beat sensor.

The kit of the Pulse Sensor is integrated with the following items:

i. A connector Color-Coded Cable (24-inch with male headers) that easily connects Arduino and embeds sensors into projects without soldering.
ii. An earlobe-sized clip-sensor hot-glued and easily worn on the ear.
iii. 2 roughly sized sensor Velcro Dots on the 'hook' side useful to making fingertip wearable fabric (or Velcro strap).
iv. Sensor for pulse with finger wearable Velcro strap to wrap it.
v. 3 Stickers made transparent to prevent oil on the finger and sweat on the earlobes from reaching the front of the sensor for pulse.
vi. 3 holes around the edge of the Pulse Sensor to make it easy to sow onto almost anything.

Table 1 contains the datasheet of the heartbeat sensor module. It indicates the giving the pin numbers, names, wire colours and their descriptions.

Table 1: Heartbeat sensor module datasheet

Pin Number	Pin Name	Wire Colour	Description
1	Ground	Black	Connected to the ground of the system
2	Vcc	Red	Connect to +5V or +3.3V supply voltage
3	Signal	Purple	Pulsating Output signal

c. LED

The Light Emitting Diode (LED) transforms energy from electrical to light (See Figure 5). They need few volts to turn on and are energy efficient. Electric current in LEDs flow in one direction from anode to cathode to light it up, and does not turn on when current flows in opposite direction. The anode and the cathode are represented by its two pins that power it.

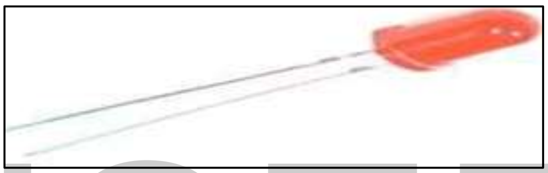

Fig. 5: Light Emitting Diode

d. Battery

Battery stores direct current electricity and produces power from chemical sources. It has basic units called cells with two electrodes marked positive and negative, and chemical between them is called electrolyte. Where the terminals are connected in an electrical or electronic circuit, chemical reactions cause electrolytic activity to start and ions are formed as current is delivered [8]. Metallic or plastic casing is used to package it conveniently and safely for use.

Fig. 6: Li battery

First, the required components for the systems design like the Heart rate sensor, power source, Push button, Arduino promini etc. were carefully selected. Modules and their data sheet for all the components were obtained from relevant sources. To meet up with the recommended operating conditions, additional measures were taken. For example, LED works at about 3V and the module of the heart rate sensor was handled with great caution with appropriate voltage levels applied, considering its sensitive nature.

3.2 Methodology Adopted.

Towards the design of an IoT-based anti-drowning device, the methodology adopted was the Agile system. The Agile methodology was introduced in 2001 by a small group of researchers who were tired of the traditional method of developing a software project. Consequently, the group advanced the Agile manifesto. Agile is considered the latest system's development methodology most suitable for electronic projects. Both project module design and testing in Agile are concurrent, unlike most other models. Its core value includes:

i. Individual and team communications over processes and tools;
ii. Working software over an all-inclusive records;
iii. Customer partnership over contract negotiation; and
iv. Response to changes in line with the set-out plan for the system.

With the developing process going on with Agile methodology, its testing methods include Scrum method, Lean Software design scheme, Kanban method, Feature Driven Development Method (FDM), Dynamic Software Development Method (DSDM), Crystal method, and eXtreme Programming (XP). Figure 7 depicts the steps involved in the Agile development process.

Fig. 7: Agile methodology system development life cycle [6]

The Agile system has a System Development Life Cycle (SDLC) which works like a train wheel. Figure 7 depicts a pictorial sample succinctly. Each wheel rotation represents a sprint. During each sprint, new needs emerge from the back log through the Agile project planning and designing, implementation and building, testing and evaluation, and deployment phases.

1. Requirement Analysis: In this phase after the initiation process of conceptualizing the idea, a list of all the things you and your team needs to do is produced, this is usually called the "backlog". List out all the requisites needed for the achievement of the project. The project goals will help to ascertain what is required for the project.
2. Project Design: In this phase, a project's main features, composition, condition for accomplishment and key deliverables are all planned out. The essence is to build up one or more designs which can

be used to achieve the desired goal of the project. The project is split into sprints and assigned to different units and teams with clear understanding of their task and duty.

3. Construction/building phase: In this stage, it is ensured that the system under study is built to reflect the features identified during the design stage of the agile methodology.
4. Testing and debugging phase: during this phase, there is the verification of the product functions that were designed during building stage. Testing of the integrated unit(s) and system is carried out, even before the process is completed.
5. Release phase: This is the phase where the system is released for use and to end users by the developers after it must have been tested and debugged. As customers interact with them and discover new requirements, then it will give rise to the next iteration. This helps the methodology to be very fast in responding to changes.
6. Maintenance: This is the last phase in the cycle which involves carrying out maintenance measures on the system developed. In agile, the user is carried along in the system development, hence, there is usually not much need for rigorous maintenance except in cases of system upgrade and addition of a new requirement.

3.2.1 System Design and Analysis

The main hardware components employed for the device system consist of the heart rate sensor, battery, push-button, Arduino pro mini, buzzer, shock, GPS tracker, temperature sensor, etc. The design and function of the IoT-based anti-drowning device are based on the pressure principle of heart rate. The device has two basic modules: (1) the wrist band resembling heart rate pressure watch sensor on the transmitter side, the microcontroller and at the receiver end, and (2) a buzzer to be with the lifeguard. The wristband will be issued to individuals who adventure to enter a pool at a time. The band will be on ON-state all the time. The rate of the heart pressure would be set at a threshold level to indicate when a wearer is prone to danger. As soon as a wearer enters the pool, the pressure rate of the heart is sensor-measured and continuously monitored through connection to the microcontroller. On exceeding the set thresholds, an alarm is triggered by the receiver to signal the lifeguards. The signal transmission and reception are wirelessly done through an inbuilt RF module. On valid signal receipt, the microcontroller turns ON the buzzer. The GPS tracker and the red liquid substance help the diver to know the exact location of the person about to drown, and adequate help is rendered to rescue such victims. Figure 8 depicts the block diagram of the IoT-based anti-drowning device.

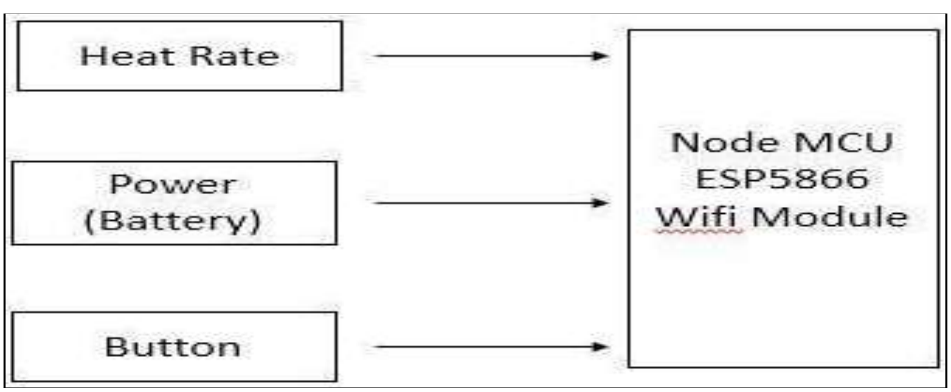

Fig. 8: Block representation of pro the IoT-based anti-drowning device.

A Node, MCU ESP 8266 Wi-Fi module, may be linked to other components through a wired or wireless scheme. The driving instructions are stored in this node. The concise details about the functions of the node will be given in the latter part of the paper. The module is powered by the supplied voltage from the battery connected to it. The buttons are connected to provide manual commands. The Wi-Fi module is enabled to connect to the internet and send signal to the blink app through GSM.

The flowchart in Figure 9 describes the sequence of functions associated with the various units incorporated for the design of the IoT-based anti-drowning device.

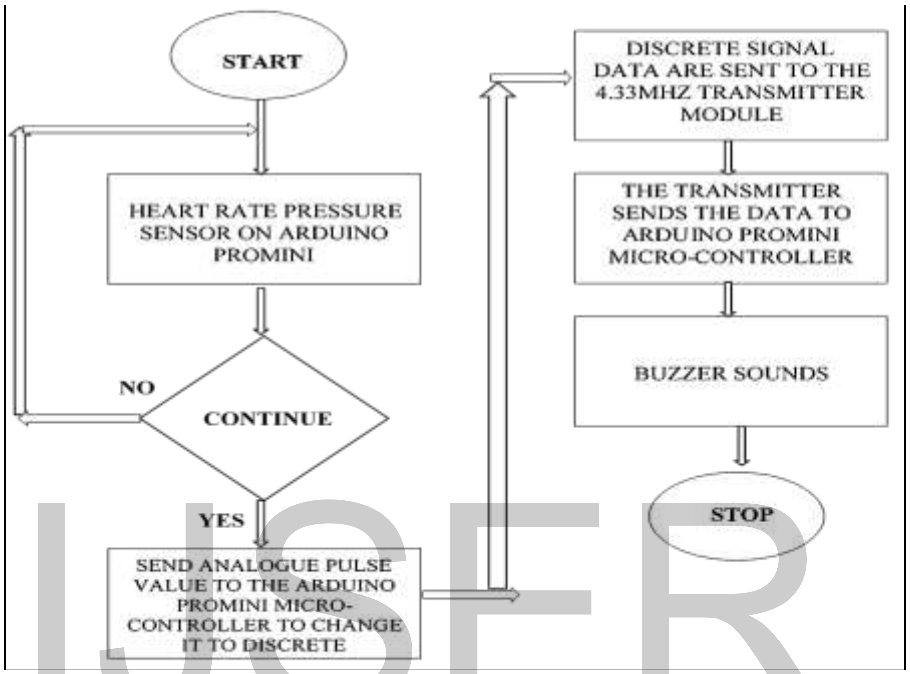

Fig. 9: The flowchart of the Anti-drowning system.

3.2.2 System Codes Simulation

The simulation of the system's component connection and performance was carried out with the Proteus circuit simulator. Necessary driving codes were written and burned into the microcontroller. However, Proteus software is limited in that it lacks the package or schematic support for the Node MCU originally used in the project implementation. Thus, during the project simulation phase, Arduino UNO was used instead. Key features of the embedded program are shown in Arduino IDE as in Figure 10.

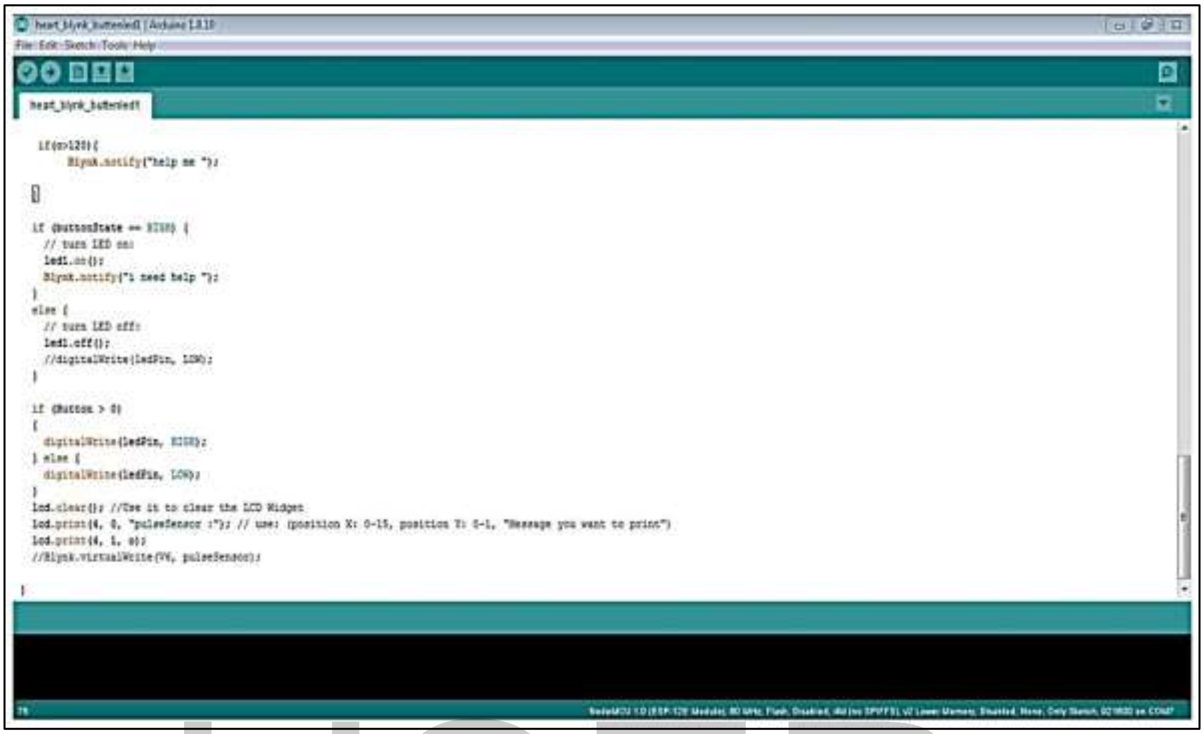

Fig. 10: Project code in Arduino IDE for simulation in Proteus

3.2.3 System Schematic Simulated

The packages and libraries required for simulating and sketching the schematic circuit were imported and installed. Figure 11 shows the schematic diagram of the simulation.

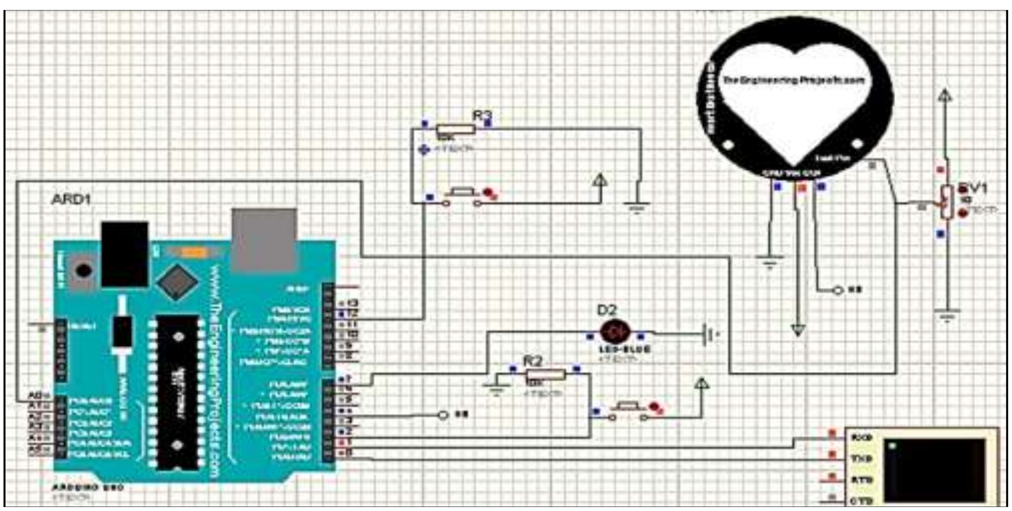

Fig. 11: Diagram of the simulation circuit.

The IoT-based anti-drowning device operates on the differential heart rate pressure principle. Of the two major system modules, the first is the transmitter device in a watch-like wristband housing the pressure sensor for heart rate. The receiver is the second module comprising the alarm and the display that sends signals during emergencies to the lifeguard on duty. Swimming pool users are encouraged to wear wristband watches. Usually, before drowning occurs, individuals begin to panic; this leads to changes in the heartbeat rate. In turn, the individual's pulses rise. The normal pulses of individual swimming are taken and recorded before wearing the wristband. The band is preset to low and high thresholds to easily detect a differential of the of the outmatched heartbeat threshold values, indicating danger for a swimmer. The chip (Atmega328) on the Lily-pad Arduino microcontroller converts analogue pulse signals to discrete signals and a transmitter of 433MHZ frequency transmits the signal to a receiver of 433MHZ frequency. The Arduino Uno microcontroller receives the signal and triggers a buzzer and also displays an SOS text indicating a swimmer in danger and needs help from lifeguards.

4.0 Test Results

Towards the control of the entire drowning rescue system, an Arduino pro mini chip was employed. The chip (ATmega328) was deployed on two Arduino boards, one for the transmitter and the other for the receiver. The open-source software Independent Development Environment (IDE) of Arduino 1.8.5, was enabled for concise coding and uploading of the hardware compatible C-language to on its board. The developed program codes were compiled to ensure error-free. The areas where errors occurred, especially when the header of RF module was not properly called, were rectified, thereafter the codes were successfully compiled.

Following the integration of the various device units, the strap transmitter worn around the wrist by an individual took 5 seconds to stabilize, after which synchronized with the individual's pulses. Once the threshold range is crossed above or below, the transmitter module sends out alert to the lifeguard through the receiver module.

A Digital meter was utilized to test each component incorporated in the designing of the anti-drowning system. This was to confirm their functional status before they were soldered on the Vero board. The test was done during the development phase of the IoT-based system. The pulse sensor was tested to confirm that it was responsive. The RF module on the Arduino also confirmed that there was data transmission and reception from the expected modules. The integrated components for the various sub-units of the design were first outlaid on the breadboard before they soldered on the Vero board. Another important test carried out was that of continuity. Table 2 displays the results of the testing.

Table 2: Result outcome from testing

Heartbeats Per Minute	Display	Meaning
0-60	LED turns ON	Help Needed
60-120	Normal	No ActionNeeded
120+	LED turns ON	Help Needed
Put Button ON	LED turns ON	Help Needed

5.0 CONCLUSION

The anti-drowning device was developed and implemented using IoT technology to alert lifeguards for action on detection of heartbeat above or below the threshold. Besides, the system aids easy discovery of victims' location. In this work, both the transmitter strap, as well as, lifeguard alert modules was developed and test-run. The modules communicate wirelessly over a transmitter. Its appropriate deployment will help provide adequate measures of safety and death prevention for all waterway users; whether as traders or travelers. This way, the system assures the safety of life and support for adventure in waterways without anxiety in the society.

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