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DESIGN OF A DROWNING RESCUE ALERT SYSTEM

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ABSTRACT

Dating back in time, drowning has been a significant ground for death worldwide; it accounts for the third cause of unplanned death globally, with about 1.2 million cases yearly. Characteristically it affects swimmers, accident victims, children and recreational seeking individuals. Although there have been various provisions put in place from drowning in some countries, it still accounts for the primary cause of unplanned death. Eradication rather than cure has been able to minimize the number of individuals who drown generally, except in developing nations, who lack adequate educational facilities and enforcement of safety measures on the dangers of drowning, thereby making the burden of drowning to escalate. The proposed drowning rescue system aims to curb deaths from drowning by observing the rise and fall of the heart rate and blood pressure of a swimmer or non-swimmer in water and if endangered, sends signals from the wearable device attached to the wrist of the victim who maybe undergoing a near-drowning experience to the receiver or rescuer who could be a lifeguard, parent or neighbour, in order to enable the rescuer render immediate help.

Keyword words: Drowning, Rescue, Alert system, Swimmer, Heart rate, Blood pressure

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1. INTRODUCTION

Drowning is by far the most devastating form of death till date, as it puts the victim in a confused state of trying to gasp for breath and at same time trying not to allow the passage of water in the nostrils or mouth. According to the International Lifesaving Federation [ILS], 2007, Drowning is defined as the "act of experiencing difficulty in breathing as a result of excess entry of liquid into mouth or nostrils leading to a lightening of the blood in the lungs. The blood then rapidly loses its ability to carry oxygen effectively. This can lead to death [1].

Drowning is one of the most painful and unforeseen cause of death today in the world not only among children but also adults. As swimming pools, bathtubs, seas, lakes, and oceans constitutes the agents of drowning, mortality rates are said to have increased drastically over the years due to this agents. Agents are widely used for leisure, sports and temperature relief especially during hot climates which possess drowning risks on the groups of individuals who are attracted by it. Drowning also occurs when the victim had no intention of going into the water. For instance, accidents which results in collapsing into the water body or boats colliding with objects thus bringing about sinking which in turn affects passengers. About 1.2 Million individuals die by drowning every year, indicating that more lives are lost from drowning than from natural disasters annually [2].

2. OVERVIEW OF THE EXISTING DROWNING RESCUE SYSTEMS

Identification of a drowning individual still seems to be a challenge even for the experienced lifeguards, especially the cases which occur among children and amateur swimmers, as there is no specific behavior which is expressed by all individuals in near -drowning experiences [3]. With technological advancement, wearable devices for reduction of drowning are rapidly emerging. Two systems which are wearable and used for anti-drowning have already been put in place:

2.1. *Sen*TAG

Established in Australia, is an anti-drowning system that offers a safety solution for swimming pools which helps to check individual swimmers via a wristband given to the individual, it is used to monitor the individual's depth in water, motion and time. Sensors are mounted on the wall of the pool to check if any swimmer wearing the wristband is approaching the preset limits for depth and time. It then evaluates whether the swimmer is spending a lot of time in water under a pre-set depth of field. If so the wristband then sends a wireless alert signal through a radio or by an ultrasonic transmission frequency to a control unit alarm. At this point the alarm which is situated on the wristband begins to sound and then the LED lights comes on, which is used to indicate that the swimmer is to return back to a safe point. If the swimmer fails to respond as demanded, the unit then sends a full emergency alert to the authorized personnel only. This really cuts down the probability of false alarms [4]. The alarm system is a wrist band that triggers an alarm when a swimmer has been motionless under water for twenty seconds.

2.2. WAHOOO

[5] A headband was used to send an alarm to a receiver in the event that a swimmer stays too long under water. The system did not take into cognizance, the complexities of the near-drowning experience.

Video based drowning monitoring systems have been proposed [6], but the technology is very prone to visual and sensor disturbances especially when the pool or water-body is crowded [7]. A lot of other electronic drowning prevention systems like the swimming cap have also been proposed, especially those that make use of physiological features. A lot of users are very selective about the drowning prevention system to adopt [8]. Many swimmers opt for the swimming cap because it is a must in certain public water pools [7].

A drowning person usually panics [3]. This causes an increase in nervous activities and heartbeat.

To effectively differentiate the near drowning symptoms of increased nervous activity and faster heartbeat from those of the swimming activity itself, people in near-drowning situations tend to struggle vertically in one position for an unusually long time, indicating that there is probable drowning danger [3].

The heart rate can be analyzed by the use of electrocardiography (ECG) or photoplethysmogram (PPG) signals. A flexible and small piezofilm polymer sensor that can be placed inside a swimming cap and around the location of the superficial temporal artery to measure the heart rate was proposed by [9]. An accelerometer or gyroscope was used to measure perpendicularity [7]. The measurements from the piezofilm sensor and gyroscope were used as the basics for triggering a drowning danger alarm. Laboratory experiments carried out on the piezofilm polymer sensor showed that the sensor was susceptible to noise due to motion and electromagnetic interferences [10]. The Weight Factor Mode (WFM) which employs Ensemble Empirical Mode Decomposition (EEMD) was used to solve the noise problem of the piezofilm polymer sensor [8], [11]. A system prototype was also presented [7].

In several drowning cases, a white, ample, coriaceous and tenacious fizz displays at the nostrils, mouth and trachea which increases the compression of chest and leads to the squeezing of lungs. The lungs then become voluminous and cover the chest wall and the impressions of the ribs are found. On dissection the lungs, white fizz with blood oozes out with a crackling sound [12]

Some drowning detection systems are built around video surveillance. Automated video surveillance systems are an effective means of detecting striking events in real-time [13-16]. These systems consist typically of a computer vision component which detects segments and keeps track of objects in motion underwater and an inference module that interprets the detected motions. The challenges faced by these systems are divided into two-folds; this includes the problems which are related to object detection and tracking (e.g. dealing with the shadows, lighting changes and the effects of moving elements that may appear in the background etc.) and the interpretation of the objects' motions into a description of detected actions and interactions [17].

In general, automated video-based surveillance system is used for real-time human behaviour analysis and helps to provide an effective way of monitoring any unusual activity in any surrounding. Due to the rapid lighting evolvement in the environment, there are high dynamic backgrounds and thus vague visibility of targets is a major difficulty and this continues to be faced by most advanced systems [18].

In yet another study, a camera sensor system was introduced for early detection of drowning incidents, this study presented a camera-centered approach to spot drowning incidents or the potential for one occurring in a swimming pool [19]. The study's motivation was because of a lack of timely efforts to initiate rescue to drowning victims which leaves them at risk to irreversible brain injuries. The study was carried out in order to provide some on the job assistance to lifeguards and therefore improve the safety of public pools with no lifeguards. In another study on the detection of human fall incidents for enhanced safety in indoor environments (like a swimming pool), an intelligent video surveillance system was utilized [20].The major parts of this system were a vision component for the detection and track movement of individuals who are in the view of the camera and for the analysis of the observation sequence of individuals features. An event inference module is used for possible falling behavioral signs. Thus the system could be used to robustly detect human falls in real time [20].

Amazingly, some camera based drowning detection systems have been reported. To identify stationary bodies at the base of pools, this systems use underwater cameras. None of this systems involves the detection of physiological or early drowning behavioral signs, such as wrestle on the water surface, which is mandatory for on time rescue and reliable drowning detection. The use of underwater cameras does not only incur high level and protected installation and maintenance cost but also it has the problem the underground cameras have which is being easily obstructed by nearby swimmers. So the aim is to build a camera-based system which would have the capability of detecting potential cases of drowning at the incubator stage using only off-the-shelf overhead cameras [11]. In another study related to a robotic arm project, a robotic arm was designed to rescue a person automatically from the water. A microcontroller was programmed with the capability of driving basically three stepper motors designed to form an anthropomorphic structure, an essential part of the robotic arm. The study also detailed the way in which the robotic arm is interfaced with the programmed 8051 micro-controller that is used to control its operations [21].

In order to find the exact position of the person drowning, sonar method was employed, it is also a technique used to detect the presence of computer users [22]. This technique already exists on laptop computers and other kinds of electronic devices. It employs the fact that all human bodies have a unique effect on sound waves than on air waves and other objects [22]. A user study was conducted in which 20 volunteers were made to use computers equipped with ultrasonic sonar software. The results then brought to the realization that just after ten seconds of measurement; it is achievable to sense the presence or absence of users with efficient accuracy [22].

A database search from the US patent was used to identify inventions which are aimed at preventing drowning, so as to disseminate the information among various classes of stakeholders. The survey was able to identify inventions that could be broadly classified into: physical barriers (e.g. pool fences, gates, etc.) [23], detection and signaling devices [24], floatation devices [25], water rescue devices [26], devices for emergencies involving watersport events [27], devices for preventing drowning in home sanitary wares (e.g. pools, spas, bathtubs etc.) [28], devices for preventing scuba diving related drowning [29], and other assorted inventions [30]. However there are many inventions that require the systematic evaluation of the invention's effectiveness in prevention of drowning, especially, the cost effective devices, which can be affordable for deployment in under developed and developing countries. This should receive particular attention, as these countries endure about 97% of deaths through drowning globally [31] [32] [33] [34].

3. CLASSIFICATION OF DROWNING DETECTION SYSTEMS

3.1. Video Based Drowning Systems

Drowning monitoring systems in swimming pools which are based on video technology is becoming quite common. The drowning monitoring system is classified into three kinds according to the different positions of the camera. One of which is when the camera is mounted on an underwater swimming pool wall, then made to monitor underwater swimmer status. The drawback to this is that if the swimmers are much, then there would be a problem of congestion. Another is when the camera is placed in the water, and this tries to monitor the Swimmer's motion in the pool. Although the reflection and refraction of light in air-water interference may affect the image quality, and thus when an individual begins to drown, such an individual may not be easily detected and it is also quite difficult to distinguish between swimmers and divers. The third encapsulates of the two mentioned above. It is also important to note that this system requires constant supervision which is also seen as its major drawback.

3.2. Light Dependent Resistor Based Automated Drowning Detection System

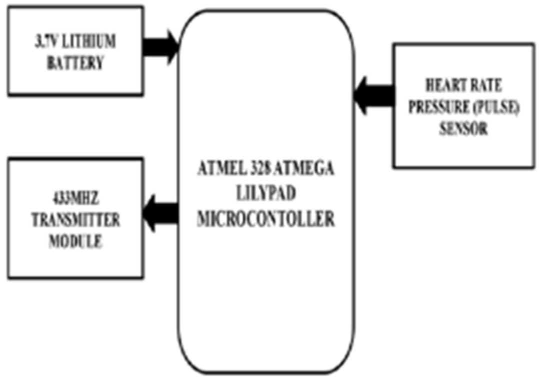

Figure 1 Functional Diagram of the Transmitter Module

In this system, the LDR and laser handles human identification in the pool. The data gotten from a water pressure sensor is used for checking if the human body is in the water, when the human body is submerged in water, then it begins to initialize the checking process. Its configuration includes an iron metal plate being kept on the poo floor, while the LDR and the laser source are kept on the sides of the pool wall. The entire process is being controlled by the microcontroller. The laser source spreads itself over the entire pool, at same time the LDR senses the laser light and then produces a resistance value; the process depends on the resistance value produced when the process was taken. At a time when the LDR value is constant, the alarm will then become activated. The value of the resistance becomes altered with respect to the human motion. The message is sent to the administration with the GSM service help. After half a minute without any visible change, the plate will ten lift automatically using the motor and motor driver.

4. SYSTEM DESIGN AND METHODOLOGY

The design of the drowning alert system works on the principle of heart rate pressure. The system contains two basic modules: to begin with, the wristband which looks like a watch consisting of heart rate pressure sensors on the transmitter side and a microcontroller while at the receiver end which would be with the lifeguard, consist of another microcontroller, a buzzer, and an LCD display. The individuals entering the pool territory would be made to wear the wristband which would be left on at all times. The heart rate pressure would be set at a particular high and low levels which would be used as threshold levels to indicate when there is actual danger. Once the individual gets into the pool, the individual's heart rate pressure is continuously measured and monitored by the heart rate sensor connected to the microcontroller. When the current value surpasses the threshold limits an alerting signal is sent to the receiver which is the lifeguard on duty. The wireless transmission and reception of signals is done through an RF module. On receiving the valid signal microcontroller sets the buzzer ON, the system aims to curb deaths from drowning by signaling the lifeguard of an eminent danger so as he can go and render help to such victims before the drowning.

4.1. Mode of Operation

The drowning rescue alert system functions on the principle of differential heart rate pressure. The system is made up of two major modules; the first module is transmitter side which consists of a wristband-watch like device that houses the heart rate pressure sensor and then second module is the receiver side which contains the buzzer and LCD which signifies the lifeguard on duty in case of an emergency. Swimmers entering into the pool are made to wear the wristband watch. It is observed that before drowning occurs individuals begin to panic, and as the individual panics, the rate of the heart beat changes which in turn affect the individual's pulses, which would bring about a reduction or increase in the pressure of the individual's pulses as the case may be. Thus, the normal pulse pressure of each swimmer is taken and recorded before the individual is required to wear a wrist band which is set to a particular low and high threshold in order to consider alterations from the heartbeat, when the threshold values are surpassed which indicates that the swimmer began to drown. The analogue pulse signals are converted to discrete signals by the Atmega328 chip on the Arduino Lilypad microcontroller and transmit the signal via a 433MHZ transmitter module to a 433MHZ receiver. The received signal is then sent to the Arduino Uno microcontroller that triggers an alarm signal through the buzzer and then displays an emergency text on the LCD in order to get the attention of the lifeguard for help to the swimmer. The Figure1 below shows the functional module of the transmitter containing the pulse sensor, transmitter and the Arduino Lilypad microcontroller while Figure 2 shows the functional module of the receiver showing the Arduino Uno, the receiver, the LCD and the buzzer. The flowchart in Figure 3 shows the algorithm for the drowning alarm system.

Figure 2 Functional Diagram of the Receiver Module

5. IMPLEMENTATION AND TESTING

The ATmega328p chip was used for the control of the entire drowning rescue system. The ATmega328 chip used for this particular project was embedded on two separate Arduino which was used for the transmitter and receiver sides of the project respectively. Thus the Arduino 1.8.5 IDE is used which is open-source Arduino software (IDE) that its environment written with java, it makes it possible to write programs in C-language and easily upload it to any Arduino board.

5.1. Acceptance Testing

After the construction of the Drowning rescue device, the transmitter strap module was placed on an individual's wrist and it took a little while to stabilize, but after which it started beating in accordance to the individuals pulse. Immediately there was irregularity of pulse beat (above or below the threshold) noticed by the transmitter strap module, it sends an alert to the receiver or lifeguard module, which is displayed on the LCD and sounded on the buzzer.

5.2. Program Testing

After developing the program codes, it was then compiled to ascertain that there were no build errors or bugs. The areas where there were errors, such as the RF module header not being called properly was corrected and built again, after which it was compiled successful.

5.3. Unit Testing

Each of the drowning rescue system components were tested using a digital multimeter to ascertain that the components were actually working before soldering took place on the Veroboard.

5.4. Subsystem testing

This test was carried out during the gradual development of the Drowning rescue device, as the pulse sensor device was testing with the Arduino to confirm that it was responsive and also on the RF module on the Arduino's to confirm if the data being sent was also being received. After these all the components were all soldered to the Veroboard and were still tested to confirm regularity. Although the circuit design was tested first on breadboards to determine if there were any errors, correct placement or positioning of components and subsystem, and to determine its current and voltage consumption.

5.5. System testing

This test involved the testing of the drowning rescue system as a whole and a lot of errors were discovered here as this was when it was discovered that the RF transmitter needed a higher voltage source in order for it to be able to transmit, as initially it shared source with the pulse sensor and the microcontroller. Thus the voltage source of the RF transmitter was differentiated from that of the pulse sensor.

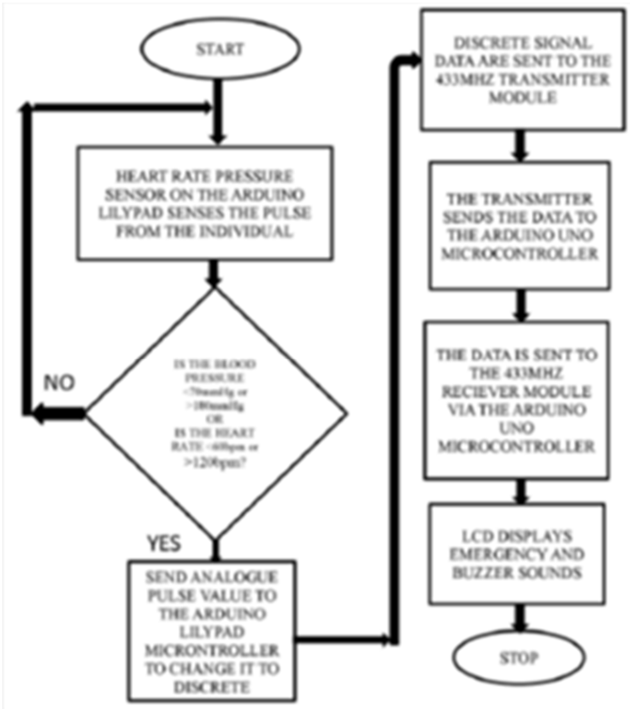

Figure 3 Drowining Rescue Device Flowchart

5. CONCLUSION

Drowning has been a significant ground for death Worldwide as it accounts for the third cause of unplanned death; it affects swimmers, accident victims, children and recreational seeking individuals. Although there have been various provisions put in place from drowning in some countries, it still accounts for the primary cause of unplanned death. Eradication rather than cure has been able to minimize the number of individuals who drown generally, except in developing nations, who lack adequate educational facilities and enforcement of safety measures on the dangers of drowning, thereby making the burden of drowning to escalate. Thus the drowning rescue system was designed to curb deaths from drowning by observing the rise and fall of the heart rate and blood pressure of a swimmer or non-swimmer in water and if endangered, sends signals from the wearable device attached to the wrist of the victim who maybe undergoing a near- drowning experience to the receiver or rescuer who could be a lifeguard, parent or neighbour, in order to enable the rescuer render immediate help.

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REFERENCES

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

[2] I. Macintosh, “EDA Linker,” pp. 397–401, 2013.2017.

[3] F. Pia, “OBSERVATIONS ON THE DROWNING OF,” 1974.

[4] “Drowning Detection System from Sentag - Sentag Pool Safety & Drowning Detection.” [Online]. Available: https://www.sentag.com/. [Accessed: 23-Oct-2018].

[5] “The Wahoo Swim Monitor: A high tech solution to keep kids safe in the water | Cool Mom Tech.” [Online]. Available: https://coolmomtech.com/2013/07/wahoo-swim-monitor-water-safety-alarm/. [Accessed: 23-Oct-2018].

[6] H. Eng, K. Toh, S. Member, W. Yau, and S. Member, “IEEE Xplore - DEWS: A Live Visual Surveillance System for Early Drowning Detection at Pool,” vol. 18, no. 2, pp. 196–210, 2008.

[7] M. Kharrat, A. Y. Wakuda, and A. S. Kobayashi, “Near drowning detection system based on swimmer’s physiological information analysis,” vol. 17, no. 201, p. 99635483, 2011.

[8] A. Pantelopoulos and N. G. Bourbakis, “A survey on wearable sensor-based systems for health monitoring and prognosis,” IEEE Trans. Syst. Man, Cybern. Part C (Applications Rev., vol. 40, no. 1, pp. 1–12, 2010.

[9] M. Kharrat, Y. Wakuda, S. Kobayashi, N. Koshizuka, and K. Sakamura, “Adaptive radial artery pulse rate measurement using piezo film sensor based on ensemble empirical mode decomposition,” Proc. IEEE/EMBS Reg. 8 Int. Conf. Inf. Technol. Appl. Biomed. ITAB, no. 1, pp. 3–6, 2010.

[10] Z. Wu and N. E. Huang, “Ensemble empirical mode decomposition: a noise-assisted data analysis method,” Adv. Adapt. Data Anal., vol. 1, no. 01, pp. 1–41, 2009.

[11] L. Mathew, A. Thomas, B. Baby, C. Stephen, J. E. Eldhose, and C. E. T. Koothattukulam, “Adrs (Automatic Drowning Rescue System for Human Using Rfid),” Int. Res. J. Eng. Technol., vol. 4, no. 4, pp. 2539–2542, 2017.

[12] N. Shrivastava, D. K. Satpati, and A. Kumar, “Easy Confirmation of Drowning By Detection of Diatoms in Trachea,” J. Indian Acad. Forensic Med., vol. 37, no. 4, pp. 352–354, 2015.

[13] H. Buxton and S. Gong, “Advance Visual Surveillance using Bayesian Networks,” Proc. ICCV’95 Work. Context. Vis., pp. 111–122, 1995.

[14] I. Haritaoglu, D. Harwood, and L. S. Davis, “W4: Real-time surveillance of people and their activities,” IEEE Trans. Pattern Anal. Mach. Intell., no. 8, pp. 809–830, 2000.

[15] D. Koller et al., “Towards robust automatic traffic scene analysis in real-time,” in Pattern Recognition, 1994. Vol. 1-Conference A: Computer Vision & Image Processing. Proceedings of the 12th IAPR International Conference on, 1994, vol. 1, pp. 126–131.

[16] C. Stauffer and W. E. L. Grimson, “Learning patterns of activity using real-time tracking,” IEEE Trans. Pattern Anal. Mach. Intell., vol. 22, no. 8, pp. 747–757, 2000.

[17] A. H. Kam, W. Lu, and W.-Y. Yau, “A Video-Based Drowning Detection System BT - Computer Vision — ECCV 2002,” 2002, pp. 297–311.

[18] N. Salehi, M. Keyvanara, and S. A. Monadjemmi, “An Automatic Video-based Drowning Detection System for Swimming Pools Using Active Contours,” Int. J. Image, Graph. Signal Process. vol. 8, no. 8, pp. 1–8, 2016.

[19] W. Lu and Y.-P. Tan, “A camera-based system for early detection of drowning incidents,” in Image Processing. 2002. Proceedings. 2002 International Conference on, 2002, vol. 3, pp. III–III.

[20] Ji Tao, M. Turjo, Mun-Fei Wong, Mengdi Wang, and Yap-Peng Tan, “Fall Incidents Detection for Intelligent Video Surveillance,” 2005 5th Int. Conf. Inf. Commun. Signal Process. pp. 1590–1594, 2005.

[21] O. D. Jegede, “The Design and Construction of a Robotic Arm Using an 8051 Microcontroller Development of a Microcontroller Based Robotic Arm,” in 2007 Computer Science and IT Education Conference Development, 2007, no. June 2007.

[22] S. P. Tarzia, R. P. Dick, and P. A. Dinda, “Sonar-based Measurement of User Presence and Attention,” Proc. Int. Conf. Ubiquitous Comput. (UbiComp ’09), pp. 89–92, 2009.

[23] World Health Organization, “Facts about injuries: Drowning,” World Heal. Organ. Geneva, Switz., no. 2, 2003.

[24] M. M. Peden and K. McGee, “The epidemiology of drowning worldwide,” Inj. Control Saf. Promot., vol. 10, no. 4, pp. 195–199, 2003.

[25] L. Quan and P. Cummings, “Characteristics of drowning by different age groups,” Inj. Prev., vol. 9, no. 2, pp. 163–168, 2003.

[26] D. T. Cass, “Preventing children drowning in Australia,” Med. J. Aust., vol. 175, no. 11, pp. 603–604, 2001.

[27] P. Lindholm and J. Steensberg, “Epidemiology of unintentional drowning and near-drowning in Denmark in 1995,” Inj. Prev., vol. 6, no. 1, pp. 29–31, 2000.

[28] J. Steensberg, “Epidemiology of accidental drowning in Denmark 1989–1993,” Accid. Anal. Prev., vol. 30, no. 6, pp. 755–762, 1998.

[29] R. A. Brenner, A. C. Trumble, G. S. Smith, E. P. Kessler, and M. D. Overpeck, “Where Children Drown, United States, 1995,” Pediatrics, vol. 108, no. 1, pp. 85–89, 2001.

[30] “Poseidon | Drowning Prevention Technology.” [Online]. Available: https://www.drowningprevention.com.au/. [Accessed: 23-Oct-2018].

[31] A. Gunatilaka and J. Ozanne-Smith, “A survey of inventions aimed at preventing drowning.,” Int. J. Inj. Contr. Saf. Promot., vol. 13, no. 2, pp. 119–121, 2006.

[32] Okokpujie, Kennedy, Etinosa Noma-Osaghae, Samuel John, and Prince C. Jumbo. "Automatic home appliance switching using speech recognition software and embedded system." In Computing Networking and Informatics (ICCNI), 2017 International Conference on, pp. 1-4. IEEE, 2017. https://ieeexplore.ieee.org/abstract/document/8123775/

[33] Kennedy Okokpujie, Etinosa Noma-Osaghae, Odusami Modupe, Samuel John, Oluga Oluwatosin “A Smart Air Pollution Monitoring System”. International Journal of Civil Engineering & Technology (IJCIET) - Scopus Indexed.

[34] Okokpujie, Kennedy, Etinosa Noma-Osaghae, Samuel John, Kalu-Anyah Grace, and Imhade Okokpujie. "A face recognition attendance system with GSM notification." In Electro-Technology for National Development (NIGERCON), 2017 IEEE 3rd International Conference on, pp. 239-244. IEEE, 2017. https://ieeexplore.ieee.org/abstract/document/8281895/