Implementation of a prototype to prevent childhood accidents in dangerous domestic environments using ESP 32 Wi-Fi module

Jenner Lavalle-Sandoval[1], Paul Córdova-Cardenas[1], Sheyla Rivera-Quispe[2], Laberiano Andrade-Arenas[3]
[1]Facultad de Ingeniería y Negocios, Universidad Privada Norbert Wiener, Lima, Perú
[2]Facultad de Ciencias de la Comunicación Social, Universidad Jaime Bausate y Meza, Lima, Perú
[3]Facultad de Ciencias e Ingeniería, Universidad de Ciencias y Humanidades, Lima, Perú

Article Info

Article history:

Received Apr 12, 2024
Revised Oct 10, 2024
Accepted Oct 30, 2024

Keywords:

Accidents
ESP 32 Wi-Fi module
Prototype model
Robotics
Sensors

ABSTRACT

Robotics has significantly advanced human evolution by optimizing tasks in fields such as medicine, engineering, and mechanics, enhancing daily life through various robotic prototypes. These innovations help prevent accidents and injuries, whether at home or in hazardous environments. For instance, sensors can detect gas leaks, fires, and other potential disasters. This research aims to design a prototype adaptable to any home environment that poses risks to infants, such as kitchens, bathrooms, or stairs. The proposed prototype incorporates gas, motion, and sound sensors connected to a Wi-Fi ESP 32 module, which alerts parents to any potential danger to their children. The research is developed in six phases: component selection, circuit simulation, prototype design, three-dimensional (3D) printing, code programming, and final testing. The results demonstrate a positive impact, improving the control and care of infants by alerting parents to hazards such as gas leaks, crying, or movement in risky areas. The conclusion confirms the effectiveness of the prototype in providing timely alerts to safeguard infants in potentially dangerous situations.

Corresponding Author:

Laberiano Andrade-Arenas
Facultad de Ciencias e Ingeniería, Universidad de Ciencias y Humanidades
Lima, Perú
Email: landrade@uch.edu.pe

1. INTRODUCTION

Worldwide, injuries resulting from unintentional accidents are the leading cause of death in children of pediatric age [1]. Most of these situations almost always occur within the home and in the context of child development activities [2], such as crawling, running, jumping, and climbing, which represent a major public health problem for different countries. According to figures from the World Health Organization (WHO), around 100 children die every hour in the world, of which 90% of these deaths are the result of unintentional injuries, thus indicating a high level of morbidity and mortality. Several studies have revealed that morbidity and mortality rates derived from unintentional injuries occur more frequently in low- and middle-income countries, which pay less attention to this type of problems, as opposed to developed countries, where the numbers are not so high.

Meanwhile, in the Region of the Americas, six children or adolescents under 20 years of age die every hour from unintentional injuries caused mainly by drowning and suffocation [3]. According to the WHO world report on childhood injury prevention, other causes of unintentional injury deaths are associated with brain injuries, falls and poisoning [4], insufficient supervision by parents or caregivers, as well as traffic, thermal injuries and fire burns [5]. In some American countries, the socioeconomic level is a contributing factor that contributes to provide a higher accident and mortality rate in unintentional injuries involving all ages of children.

In the case of Peru, the most common unintentional accidents in minors are falls, exposure to toxic substances, ingestion of foreign bodies, fires, burns, explosions, and electrocutions. In terms of the physical nature of the injury, these accidents can also be the most serious, because they can limit the activities of infants, either in the short or long term. In relation to this, [6] and [7] state that, the kitchen of all areas of the home, turns out to be the most risky area, and where children should not enter, especially those under 2 years of age, because there are usually dangerous elements, some sharp objects and others related to gas and electricity home environments that may represent a danger. This will be achieved using gas, sound and motion sensors, along with an ESP 32 Wi-Fi module.

Hence, nowadays, technological advances offer innovative solutions for monitoring children, such as sensors [8], [9] that have become valuable tools in this field, because these intelligent devices monitor and control the welfare and safety of children, providing peace of mind to parents by improving the efficiency and quality of parenting [10], [11]. This situation motivated the development of an electronic safety system for children of pediatric age, capable of warning and preventing possible accidents, especially when the infant begins to move independently [12]. In this sense, this prototype will serve as a support for the care and prevention of children in different home environments that may represent a danger. This will be achieved using gas, sound and motion sensors, together with an ESP 32 Wi-Fi module.

Based on the problems raised, the objective of the proposed prototype will seek to reduce the number of accidents and unintentional injuries among children, such as falls, burns, blows, cuts, and poisoning in spaces within the home identified as prone to risks. All this together with the fact that as children grow older, they develop greater mobility. The aim is to prevent future accidents or injuries, and at the same time, to offer a better quality of life and peace of mind to parents and caregivers.

2. MATERIALS AND METHODS

The sensors integrated in the prototype will be in charge of detecting the child's movement, especially if the child enters areas considered as dangerous inside the house. The prototype will facilitate the detection of sounds in situations where the child cries or screams due to a blow or fall. In addition, it will also identify possible toxic gas leaks in the kitchen, responding to any anomaly in the environment [13]. It should be noted that all these sensors will be controlled by an ESP 32 development board with a Bluetooth Wi-Fi module [14], [15].

For the programming of these electronic components, use was made of the Arduino platform, which facilitated the development, integration of sensors and ESP 32 module. As for the design, the prototype was designed in Blender software in order to locate all the aforementioned components [16]. Similarly, use was made of Tinkercad, a free online tool [17] where electronic circuit simulations were performed to get an idea of the operation and location of the electronic components used in this project. During the course of this study, it was proposed to carry out the research in six stages or phases in order to understand the process of component selection, circuit simulation, followed by prototype design, three-dimensional (3D) printing, code programming and final testing of the prototype, which can be seen in Figure 1, which together will help prevent child accidents in high-risk home environments.

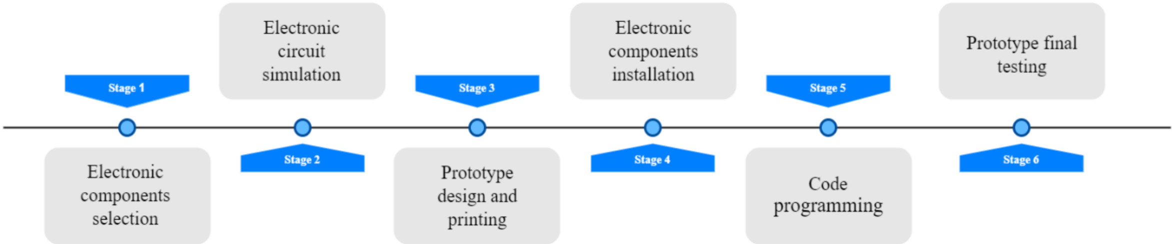

Figure 1. Prototype development phases

2.1. Electronic components selection phase

In Table 1, we find a list of electronic components selected for the construction of the prototype designed to prevent accidents involving children in hazardous home environments. The components include a passive infrared (PIR) sensor HC-SR501, a sound sensor KY-038, a gas sensor MQ-6, and an ESP32 development board with Bluetooth and Wi-Fi module. These components have been chosen to ensure the prototype effectively monitors and alerts parents to potential dangers in various home settings.

Table 1. List of electronic components

Electronic components	Quantity
PIR sensor HC-SR501	1
Sound sensor KY-038	1
Gas sensor MQ-6	1
Esp32 development board with Bluetooth Wi-Fi module	1

2.2. Electronic circuit simulation

As previously mentioned, TinkerCad, an intuitive and easy to use software [18], was used to simulate the electronic components, allowing to obtain an understanding of the design and operation of the electronic components, as well as the Arduino coding and programming process. In this simulation, a PIR sensor, a gas sensor and a temperature sensor and two resistors, one of them of 1k ohm and the other of 10k ohm, were considered. Also, a liquid crystal display (LCD) screen was used that allowed the visualization of the information emitted by the sensors, also a protoboard was used in which all the electronic components were connected, including an Arduino one board [19].

Additionally, the use of this software made it possible to program the code in blocks, which contributed to achieve a complete simulation during the testing of all the sensors. However, it is important to point out that the tests were not carried out with all the original electronic components of the project because the software lacked some elements, such as the ESP 32 development board with Bluetooth Wi-Fi module and a sound sensor. That is why the tests were performed with some alternate components such as a temperature sensor and a 16×2 Figure 2 LCD screen.

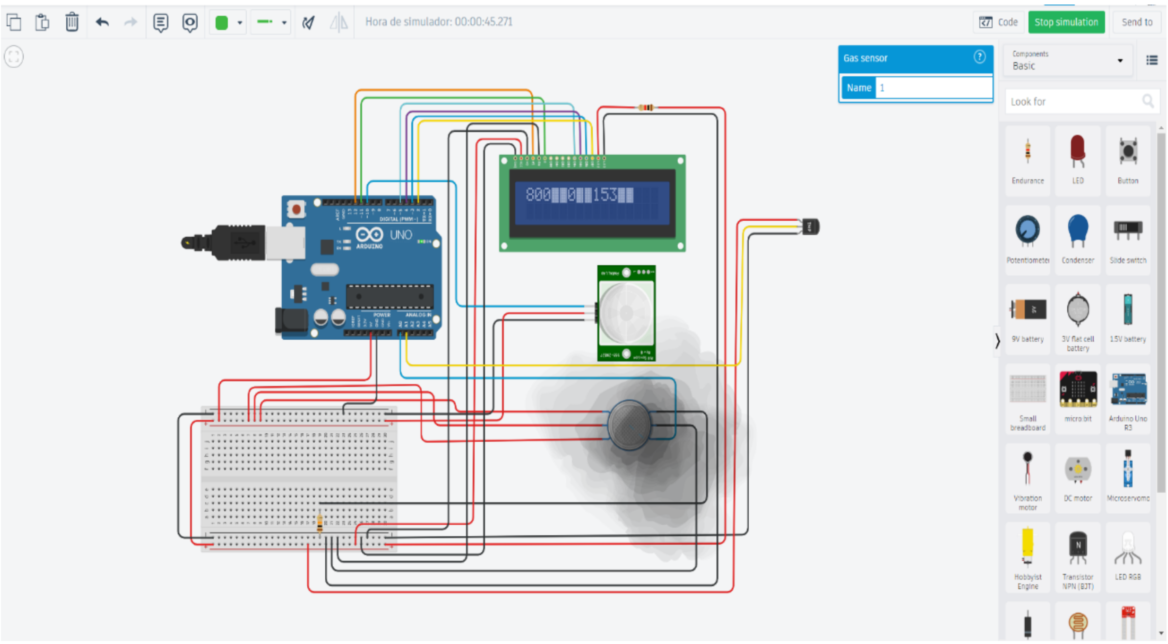

Figure 2. Electronic simulation of components

In the code section of the TinkerCad web application, the programming of all the electronic components was performed, as a first action the LiquindCrystal.h library was installed [20], which facilitates the Arduino board to control the LCD display, as shown in Figure 3. Likewise, as part of the code, the integer variables were defined and the configuration of columns and rows of the LCD display was performed. Additionally, the input pins were established in order to guarantee all compatibilities. The commands to be executed while the Arduino board is enabled were also incorporated. Finally, the value of the variables or text indicated as parameter that each sensor will display on the LCD screen was printed.

```
#include <LiquidCrystal.h>

int pirPin = 10;
int  pir  =  0 ;
int gas;
int  temp ;

LiquidCrystal lcd(12, 11, 5, 4, 3, 2);

void setup() {
  pinMode(pirPin,INPUT);
  lcd.begin(16, 2);
}

void loop() {
  gas = analogRead(A0);
  pir = digitalRead(pirPin);
  temp = analogRead(A1);
  lcd.home();
  lcd.println(gas);
  lcd.println(pir);
  lcd.println(temp);
}
```

Figure 3. Simulation programming code

2.3. Prototype design and printing

The design of the case and hook of the prototype was worked in Blender software [21], a free open source tool that allows the creation of 3D content through which the object can be shown in different contexts [22], thus speeding up and improving the efficiency in the creation of the prototype [23]. As well as offering a wide range of essential tools, including modeling, rendering, animation, among other functions that helped in the whole process of elaboration of the design. On the other hand, being a multiplatform application, it is compatible with various operating systems, such as Linux, MacOS and Windows.

Regarding the development of the case design, as shown in Figure 4, first the measurements of the electronic components were taken, such as the PIR sensor HC-SR501 [24], the sound sensor KY-038, the gas sensor MQ-6 and the ESP 32 development board with Bluetooth Wi-Fi module in order to design the partitions where each electronic component should be located. Then, the cover of the case was made and as a last step, the hook that will hold the case was designed. This specific design of the hook has been planned to allow the case to adapt more effectively to different home environments, thus ensuring its versatility and usefulness in different situations.

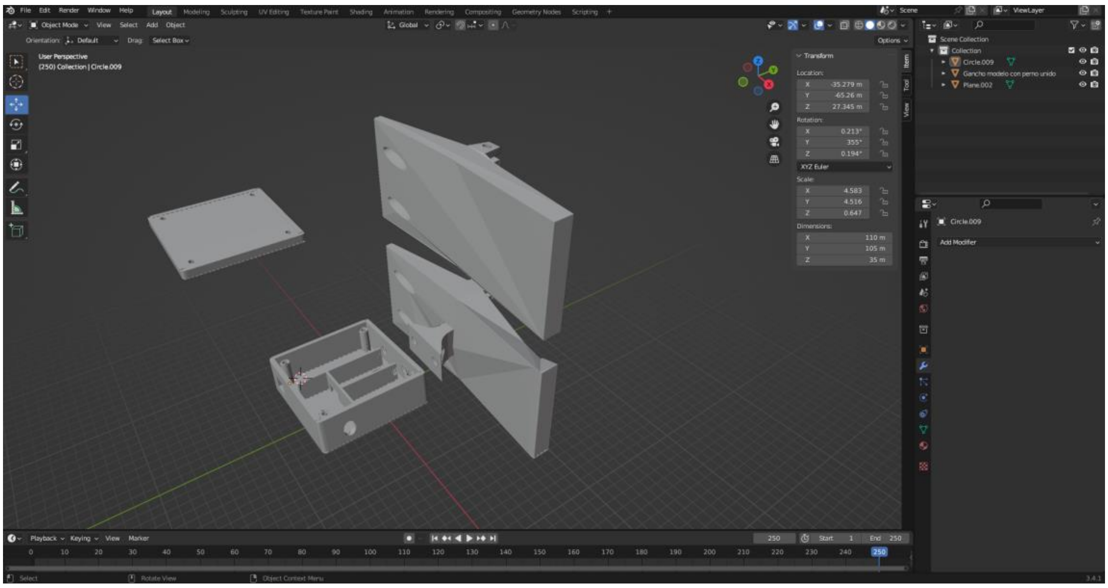

Figure 4. Design and modeling of prototypes in blender

After completing the design phase of the case and the hook, both elements were printed [25]. As shown in Figure 5, initially, the case and its lid were printed using a 3D printer. Then the hook part was printed, as illustrated in Figure 6. The entire process ensured precise fabrication of each component, leading to a successful assembly of the prototype.

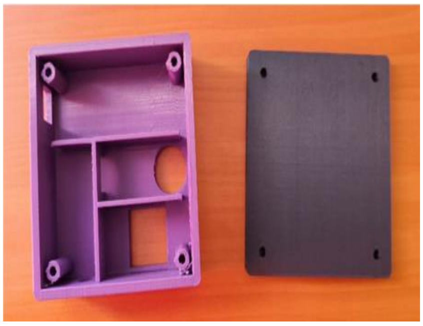

Figure 5. Case printing

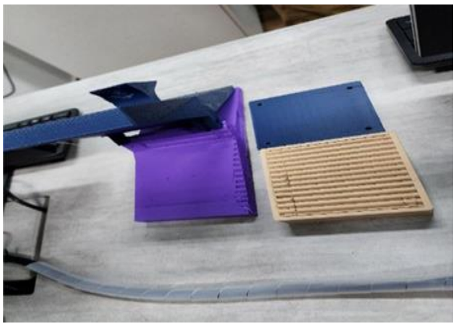

Figure 6. Hook printing

2.4. Electronic components installation

Once the prototype parts were ready, the electronic components were soldered and placed in their respective places inside the case, as shown in Figure 7. At this point, the sound sensor, the gas sensor and the motion sensor were also installed, followed by the installation of the ESP 32 development board with Bluetooth Wi-Fi module. Culminating with the realization of some tests with all the components installed.

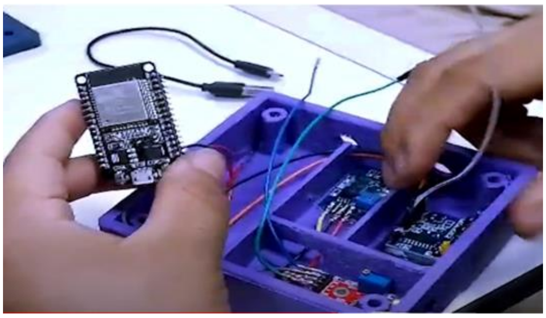

Figure 7. Installation of sensors and ESP32

2.5. Code programming

In the development of the programming code for the electronic components, the ESP32-WROOM-32E [26] is considered as a high performance and low power consumption microcontroller, which stands out for its wide range of integrated functionalities. One of the most outstanding features is its wireless connectivity capability, as it incorporates a dual-band (2.4 GHz/5 GHz) Wi-Fi system, making it possible for the device to function as an access point (AP), station (STA) or both simultaneously. In addition to providing a solid foundation for internet of things (IoT) projects by facilitating wireless connectivity with local networks or Internet connection.

The development of the prototype programming for the ESP 32 module, which incorporates motion (PIR), sound (KY-038) and gas (MQ-5) sensors, was carried out in the Arduino IDE development environment in its version 1.8.18 [27]. Subsequently, to enable the ESP 32 programming, the board manager provided by Espressif Systems in its version 2.0.11 was installed and an additional URL for board management was configured in the Arduino IDE interface: https://dl.espressif.com/dl/package_esp32_index.json. As can be seen in Figure 8, manual installations of the required libraries were then performed, including ESPAsyncTCP, AsyncTCP and arduinoWebSockets, essential to facilitate asynchronous communication and WebSockets implementation on the ESP32.

Figure 9 shows how the code was structured for the interaction with the sensors, such as the motion sensor (PIR), the gas sensor (MQ-5) and the sound sensor (KY-038). In the setup function (), the initial configurations were carried out, such as the definition of the sensor pins, the initialization of the serial communication and the configuration of the ESP32 as a Wi-Fi access point.

The SPIFFS file system was also started, which is essential for storing and accessing the HTML file, which represents the device's control interface. At this stage, the web server and WebSockets servers for communication with the clients were also configured. By initializing the root path (/), it was established that, when accessing this path, the server will respond by sending the main HTML file that has been previously loaded, allowing the visualization and interaction with the device through a web browser, as shown in Figure 10.

The HTML file, as the central element of the control interface, incorporates HTML tags, JavaScript scripts and CSS styles. This interface enables the visual presentation of sensor data by configuring a communication with the device server, allowing the transmission of information in real time through a web browser. Next, there is the loop function (), which is the core of the program and is executed continuously. In each iteration of the loop, the values of the motion, gas and sound sensors are read. If a change is detected in any of the sensors, an alert message is sent through WebSockets with the text corresponding to the detected event. It is worth mentioning that this development has been optimized to avoid the repetition of alerts from the same sensor in short time intervals, thus facilitating real-time monitoring of the sensors, as shown in Figure 11.

```
#include <WiFi.h>
#include <ESPAsyncWebServer.h>
#include <SPIFFS.h>
#include <WebSocketsServer.h>
```

Figure 8. Installation of libraries

```
int motionPin = 23; // D23
int gasPin = 27;    // D27
int soundPin = 32;  // D32

AsyncWebServer server(80);
WebSocketsServer webSocket(81);

unsigned long lastMotionTime = 0;
unsigned long lastGasTime = 0;
unsigned long lastSoundTime = 0;
const unsigned long alertInterval = 5000;
const int gasThreshold = 3175;

void handleWebSocketMessage(uint8_t num, WStype_t type, uint8_t *payload, size_t length)
{
}

void setup()
{
  pinMode(motionPin, INPUT);
  pinMode(gasPin, INPUT);
  pinMode(soundPin, INPUT);
  Serial.begin(115200);

  WiFi.softAP("ESP32", "123456");
  delay(5000);
  Serial.println("softAP");
  Serial.println(WiFi.softAPIP());
```

Figure 9. Source code programming

```
  if (!SPIFFS.begin(true))
  {
    Serial.println("Error al montar SPIFFS");
    return;
  }
  server.on("/", HTTP_GET, [](AsyncWebServerRequest *request)
            { request->send(SPIFFS, "/index.html", "text/html"); });
  server.begin();
  webSocket.begin();
  webSocket.onEvent(handleWebSocketMessage);
}
```

Figure 10. SPIFFS file system startup code

```
void loop()
{
  int motionValue = digitalRead(motionPin);
  int gasValue = analogRead(gasPin);
  int soundValue = digitalRead(soundPin);
  unsigned long currentMillis = millis();
  if (motionValue == HIGH && (currentMillis - lastMotionTime >= alertInterval))
  {
    webSocket.broadcastTXT("motion_detected");
    lastMotionTime = currentMillis;
  }
  if (gasValue > gasThreshold && (currentMillis - lastGasTime >= alertInterval))
  {
    webSocket.broadcastTXT("gas_detected");
    lastGasTime = currentMillis;
  }
  if (soundValue == HIGH && (currentMillis - lastSoundTime >= alertInterval))
  {
    webSocket.broadcastTXT("sound_detected");
    lastSoundTime = currentMillis;
  }
  webSocket.loop();
}
```

Figure 11. Loop function code

3. RESULTS AND DISCUSSION

Prototype final testing: At this point, the installation and testing of the sensors with all the electronic components has been completed. Figures 12 and 13 show the complete prototype, with all its integrated parts and the programmed code to guarantee its correct operation. Also, Figure 13 shows that the prototype has a hook that facilitates its adaptation to different environments, seeking to improve the user's experience. It is crucial to highlight that its design was focused on enabling the user to use it in areas of the home that could pose a risk to the child, such as the kitchen, since the prototype is equipped with a gas sensor that can detect possible leaks. As previously mentioned, the prototype has a motion sensor, which acts as a preventive measure in case the child approaches the kitchen or other potentially dangerous areas. This versatility can also be used in rooms where children may be exposed to risks such as bumps or falls. In addition, a sound sensor alerts family members in case the infant cries, requiring attention or help.

Figure 12. Prototype A

Figure 13. Prototype installed B

Figure 14 shows the start of the application, where the default IP address (192.168.4.1) is displayed when configuring the access point. At this point, the information detected by the sensors is shown. This feature improves the control of the prototype’s operation, allowing for real-time monitoring and adjustments. The web interface provided by the ESP32 Arduino offers an intuitive way to interact with the prototype and view the sensor data.

In Figure 15, it is evident that the prototype is working properly due to the motion detected by the PIR sensor HC-SR501. This confirms that the user will be able to have more effective and careful control of the child in the area where the prototype has been installed, along with the motion, gas, and sound sensors. The precise detection of motion allows for quick alerts about any unexpected activity. Additionally, the integrated system contributes to greater safety and peace of mind for parents by monitoring potentially dangerous areas.

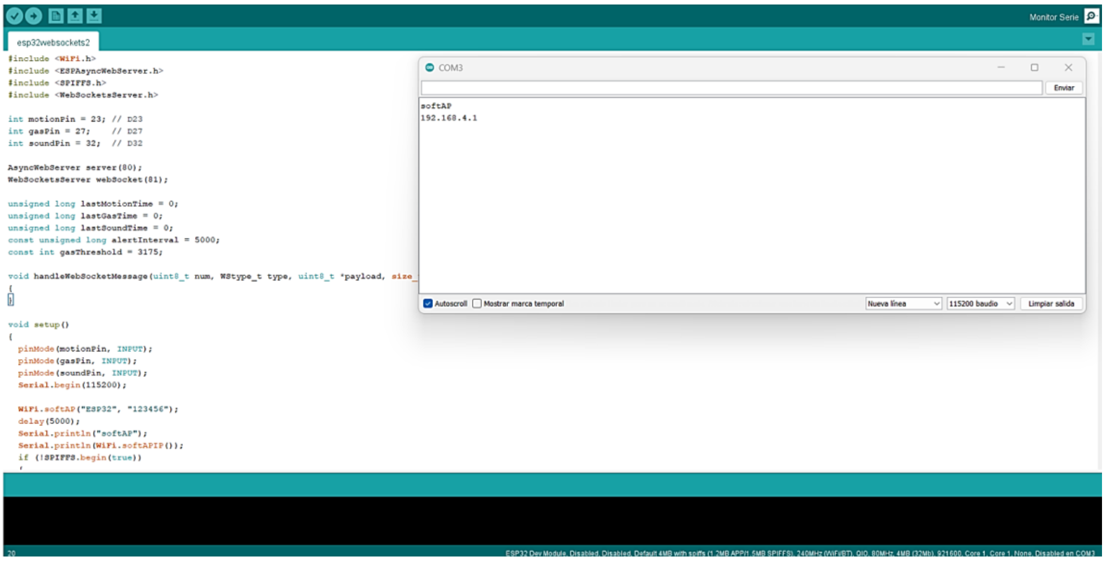

Figure 14. ESP 32 Arduino web interfaces

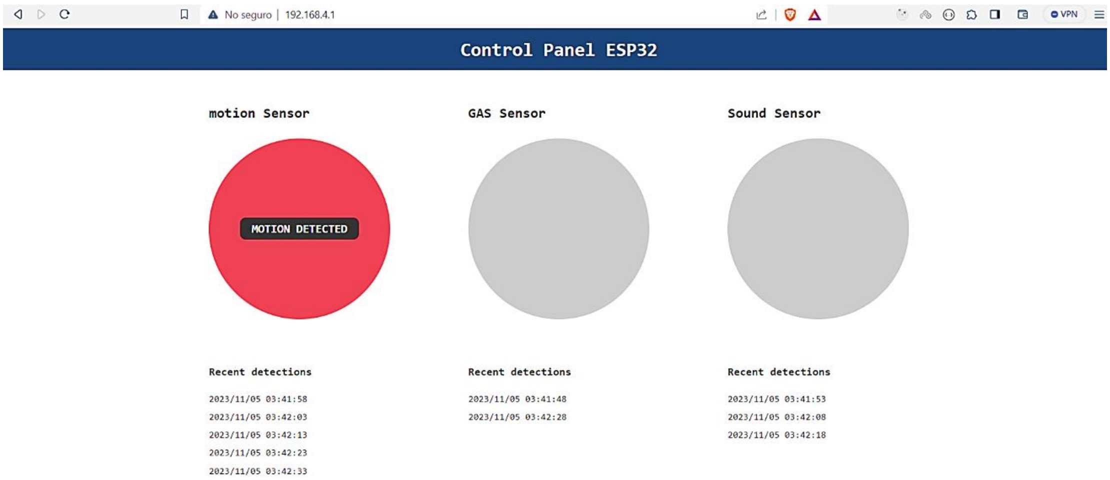

Figure 15. Motion detected in the motion sensor

Similarly, the prototype was tested with the MQ-6 gas sensor, as shown in Figure 16, where the system was able to detect the presence of a gas leak in a room of the house. This allowed the user to make immediate decisions to prevent future accidents that could harm people's health, either by poisoning or fire. The sensor's ability to detect leaks in real time is crucial for home safety. Additionally, the early warning system facilitates prompt intervention to mitigate risks and protect occupants from potential hazards.

The same procedure was performed when evaluating the prototype with the KY-038 sound sensor. In Figure 17, it is evident that the sensor has detected a sound, possibly from the infant's cry or some other noise. This functionality allows the user to be alert and prepared for any eventuality in the home or environment where the prototype is installed. The sensor's ability to identify and differentiate various sounds adds an extra layer of security. Additionally, the system facilitates timely intervention by generating alerts for unexpected noises that could indicate an emergency situation.

Figures 15 to 17, show that the implementation of a prototype designed to prevent children accidents in risky areas of the home using gas, sound, motion sensors with ESP 32 Wi-Fi module has had a positive impact, according to the results of the present research. Following the author's recommendation [27], the importance of using the ESP32 module in the development of similar prototypes, as it highlights its versatility and the various opportunities for expansion of the application by incorporating other sensors to improve the monitoring and care of people.

Figure 16. Gas leak detection

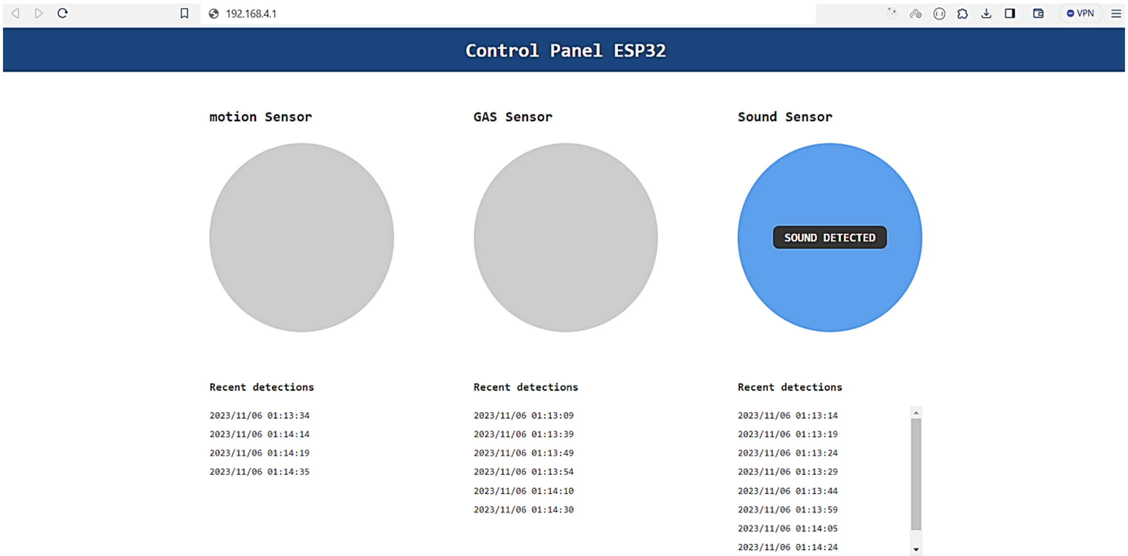

Figure 17. Noise detection

4. CONCLUSION

From the implementation of a prototype to prevent children's accidents in hazardous home environments, it is concluded that this device incorporates a preventive strategy by allowing early detection of potential domestic risks, especially those related to the safety of infants, who are more susceptible due to their natural curiosity to explore their environment. Considering the above, it can be added that the incorporation of technology and the integration of motion, sound and gas sensors offer a versatile and flexible solution to improve home security. This approach is materialized through a prototype that includes a user interface designed with an emphasis on functionality and efficiency, thus facilitating agile and well-informed decision making on the part of the user. This comprehensive system not only covers the detection of potential accidents, but also has the ability to send instant alerts to parents or caregivers in case of risky situations.

In conclusion, this prototype stands out for its adaptability and portability, which allows it to be easily moved between different home environments. Likewise, the accessibility of its components in the market highlights the ease with which any person or researcher can acquire them. In addition to the relative simplicity of programming, it reinforces the idea that incorporating solutions of this type in the home does not require a considerable investment. Therefore, it is recommended that users or parents invest in technological solutions that enable them to prevent falls, injuries, gas leaks, among other accidents that occur frequently in the home.

Finally, despite certain limitations presented during the process, such as the absence of a 3D printer to print various designs or prototypes with different electronic components that facilitate the test of adaptability in various domestic environments, and the difficulty of incorporating additional sensors such as humidity or temperature to improve daily usability, this research is presented as a valuable contribution providing a parative point for future research interested in developing prototypes for domestic use, thus stimulating progress in this particular field.

REFERENCES

[1] B. A. West, R. A. Rudd, E. K. Sauber-Schatz, and M. F. Ballesteros, "Unintentional injury deaths in children and youth, 2010–2019," *Journal of Safety Research*, vol. 78, pp. 322–330, Sep. 2021, doi: 10.1016/j.jsr.2021.07.001.

[2] I. J. Chico Morales, S. K. Narváez Pupiales, A. C. Umaquinga Criollo, and P. D. Rosero Montalvo, "Embedded system oriented to babies in crawling stage for accident prevention applied in an intelligent textile (in Spanish: Sistema embebido orientado a bebés en etapa de gateo para prevención de accidentes aplicado en un textil inteligente)," *Enfoque UTE*, vol. 9, no. 1, pp. 217–225, Mar. 2018, doi: 10.29019/enfoqueute.v9n1.281.

[3] Y. Endo and C. Premachandra, "Development of a bathing accident monitoring system using a depth sensor," *IEEE Sensors Letters*, vol. 6, no. 2, pp. 1–4, Feb. 2022, doi: 10.1109/LSENS.2021.3139636.

[4] J. Prego and J. Prego, "Lights and shadows of unintentional injury prevention (in Spanish: Luces y sombras de la prevención de lesiones no intencionales)," *Archivos de Pediatría del Uruguay*, vol. 94, no. 2, 2023, doi: 10.31134/AP.94.2.2.

[5] T. Kanchan, R. G. Menezes, and F. N. P. Monteiro, "Fatal unintentional injuries among young children – a hospital based retrospective analysis," *Journal of Forensic and Legal Medicine*, vol. 16, no. 6, pp. 307–311, Aug. 2009, doi: 10.1016/j.jflm.2008.12.017.

[6] K. C. Ramya, M. Nivetha, R. Marithai, and S. Hemanth, "LPG Leakage detector with smart SMS alert using microcontroller," in *2021 6th International Conference on Communication and Electronics Systems (ICCES)*, Jul. 2021, pp. 58–62, doi: 10.1109/ICCES51350.2021.9489037.

[7] N. N. Mahzan, N. I. M. Enzai, N. M. Zin, and K. S. S. K. M. Noh, "Design of an Arduino-based home fire alarm system with GSM module," *Journal of Physics: Conference Series*, vol. 1019, p. 012079, Jun. 2018, doi: 10.1088/1742-6596/1019/1/012079.

[8] M. Javaid, A. Haleem, S. Rab, R. Pratap Singh, and R. Suman, "Sensors for daily life: a review," *Sensors International*, vol. 2, p. 100121, 2021, doi: 10.1016/j.sintl.2021.100121.

[9] J. D. Torres Bonilla and J. E. Largacha Hinestroza, "Centralized variable measurement and monitoring system using IoT for home accident prevention (in Spanish: Sistema centralizado de medición y monitoreo de variables utilizando IoT para la prevención de accidentes en el hogar)," Institución Universitaria Antonio Jose Camacho, 2022.

[10] G. Poon, K. C. Kwan, W.-M. Pang, and K.-S. Choi, "Towards using tiny sensors with heat balancing criteria for child care reminders," *International Journal of Semantic Computing*, vol. 10, no. 03, pp. 365–378, Sep. 2016, doi: 10.1142/S1793351X16400146.

[11] A. García-Domínguez *et al.*, "Children's activity classification for domestic risk scenarios using environmental sound and a bayesian network," *Healthcare*, vol. 9, no. 7, p. 884, Jul. 2021, doi: 10.3390/healthcare9070884.

[12] H. Na, S. F. Qin, and D. Wright, "A smart vision sensor for detecting risk factors of a toddler's fall in a home environment," in *2007 IEEE International Conference on Networking, Sensing and Control*, 2007, pp. 656–661, doi: 10.1109/ICNSC.2007.372857.

[13] J. B. A. Gomes, J. J. P. C. Rodrigues, R. A. L. Rabêlo, N. Kumar, and S. Kozlov, "IoT-enabled gas sensors: technologies, applications, and opportunities," *Journal of Sensor and Actuator Networks*, vol. 8, no. 4, p. 57, Dec. 2019, doi: 10.3390/jsan8040057.

[14] R. B. Salikhov, V. K. Abdrakhmanov, and I. N. Safargalin, "Internet of things (IoT) security alarms on ESP32-CAM," *Journal of Physics: Conference Series*, vol. 2096, no. 1, p. 012109, Nov. 2021, doi: 10.1088/1742-6596/2096/1/012109.

[15] K. Abouelmehdi, K. Elhattab, and A. El Moutaouakkil, "Smart agriculture monitoring system using clean energy," *International Journal of Advanced Computer Science and Applications*, vol. 13, no. 5, 2022, doi: 10.14569/IJACSA.2022.0130544.

[16] T. Hattori, R. Masuda, Y. Moritoh, Y. Imai, Y. Kawakami, and T. Tanaka, "Utilization of both free 3DCG Software 'Blender' and 3D printing for early STEM education," in *2020 IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE)*, Dec. 2020, pp. 879–882, doi: 10.1109/TALE48869.2020.9368379.

[17] R. Abburi, M. Praveena, and R. Priyakanth, "TinkerCad - a web based application for virtual labs to help learners think, create and make," *Journal of Engineering Education Transformations*, vol. 34, p. 535, Jan. 2021, doi: 10.16920/jeet/2021/v34i0/157209.

[18] L. P. Golubev, M. M. Tkach, and D. A. Makatora, "Using tinkercad to support online the laboratory work on the design of microprocessor systems at technical university," *Information Technologies and Learning Tools*, vol. 93, no. 1, pp. 80–95, Feb. 2023, doi: 10.33407/itlt.v93i1.4817.

[19] H. Yang, T.-C. Hsiao, K. Zhu, Y. Yang, and L. Guo, "An exploration of online teaching based on Arduino virtual simulation experiments," in *2021 IEEE 3rd Eurasia Conference on Biomedical Engineering, Healthcare and Sustainability (ECBIOS)*, May 2021, pp. 126–128, doi: 10.1109/ECBIOS51820.2021.9510339.

[20] J. Udvaros, N. Forman, and D. É. Dobák, "Application and impact of electronic solutions in teaching programming," *Annales Mathematicae et Informaticae*, vol. 57, pp. 78–91, 2023, doi: 10.33039/ami.2023.04.001.

[21] L. Soni, A. Kaur, and A. Sharma, "A review on different versions and interfaces of Blender Software," in *2023 7th International Conference on Trends in Electronics and Informatics (ICOEI)*, Apr. 2023, pp. 882–887, doi: 10.1109/ICOEI56765.2023.10125672.

[22] V. Bagaria, R. Bhansali, and P. Pawar, "3D printing- creating a blueprint for the future of orthopedics: current concept review and the road ahead!," *Journal of Clinical Orthopaedics and Trauma*, vol. 9, no. 3, pp. 207–212, Jul. 2018, doi: 10.1016/j.jcot.2018.07.007.

[23] M. S. Hosen, S. Ahmmed, and S. Dekkati, "Mastering 3D modeling in blender: from novice to pro," *ABC Research Alert*, vol. 7, no. 3, pp. 169–180, Dec. 2019, doi: 10.18034/ra.v7i3.654.

[24] R. Wahyuni, A. Rickyta, U. Rahmalisa, and Y. Irawan, "Home security alarm using Wemos D1 And HC-SR501 sensor based Telegram notification," *Journal of Robotics and Control (JRC)*, vol. 2, no. 3, pp. 200–204, 2021, doi: 10.18196/jrc.2378.

[25] V. Saggiomo, "A 3D printer in the lab: not only a toy," *Advanced Science*, vol. 9, no. 27, Sep. 2022, doi: 10.1002/advs.202202610.
[26] J. J. Mendoza Montoya, G. T. Penalva, E. A. Navarro, K. H. Zea, J. A. Rivera Suana, and J. Chilo, "IoT aroma sensor module to determine beverage alcohol grade," in *2021 11th IEEE International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications (IDAACS)*, Sep. 2021, pp. 43–48, doi: 10.1109/IDAACS53288.2021.9661006.
[27] M. Babiuch, P. Foltynek, and P. Smutny, "Using the ESP32 microcontroller for data processing," in *2019 20th International Carpathian Control Conference (ICCC)*, May 2019, pp. 1–6, doi: 10.1109/CarpathianCC.2019.8765944.

BIOGRAPHIES OF AUTHORS

Bach. Jenner Lavalle-Sandoval has a bachelor's degree in Engineering and Research in Systems and Computer Science from Norbert Wiener University, focused on development with the aim of making a continuous contribution to the problems that arise in society. With publications in journals indexed in Scopus. He can be contacted at email: lavas0428@gmail.com.

Paul Córdova-Cadernas is a student of Systems and Computer Engineering at Norbert Wiener University, focused on development with the aim of making a continuous contribution to the problems that arise in society. He can be contacted at email: paulcordova@gmail.com.

Bach. Sheyla Rivera-Quispe has a bachelor's degree in journalism from the Jaime Bausate y Meza University, focused on development with the aim of making a continuous contribution to the problems that arise in society. With publications in journals indexed in Scopus. She can be contacted at email: yheylarqdl@gmail.com.

Dr. Laberiano Andrade-Arenas has a doctor in Systems Engineering and Computer Science. Master in Systems Engineering. Graduated from the Master's Degree in University Teaching. Graduate of the Master's degree in accreditation and evaluation of educational quality. Systems Engineer. International ITILV3 Fundamentals Course (Zonngo-Peru/IMLAD-Mexico). Scrum Fundamentals Certificate, research professor with publications in Scopus indexed journals. He has extensive experience in the University Chair in face-to-face and blended classes at different undergraduate and graduate universities in Lima. He can be contacted at email: landrade@uch.edu.pe.