Mobile Application to Assist in the Evacuation of Blind or Visually Impaired People using IoT and Azure AI Computer Vision

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Abstract—**The vulnerability of visually impaired individuals to natural disasters constitutes a critical public health issue, particularly in Peru, where this demographic faces high exposure to seismic risks and fires lacking adequate assistive tools. Consequently, this study proposes a technological solution based on a mobile application integrated with an Internet of Things bracelet and Azure Artificial Intelligence services to assist in safe evacuation and navigation. The methodology encompassed the development of hybrid architecture combining an ESP32 microcontroller with ultrasonic and thermal sensors for reactive edge detection, and cloud-based computer vision services for preventive environmental analysis. Validation was conducted through three experimental scenarios: route analysis, object identification, and fire identification. Results demonstrated the system's efficacy, successfully classifying routes based on obstacle density and triggering immediate multisensory alerts in response to proximity and temperature hazards. This confirms that the IoT-AI integration balances preventive precision with the necessary reactive response in emergencies.**

Keywords— Blind and low vision people, Mobile application, IoT, Azure IA, Evacuation assistance, ESP32.

I. INTRODUCTION

A recent study published by the World Health Organization (WHO) has highlighted the growing and alarming problem regarding the vulnerability of blind and low-vision (BLV) individuals to natural disasters, particularly in developing countries [1]. This situation is of particular concern due to the multiple complications that may arise if not addressed in a timely manner, such as prolonged displacement, increased exposure to physical risks, and a severe impact on mental health. Furthermore, visual impairment has a direct and negative impact on quality of life and general well-being during emergencies [1].

In this context, a report by the Instituto Nacional de Estadística e Informatica (INEI) of Peru has corroborated the growing concern surrounding visual impairment, emphasizing the urgency of inclusive interventions [2]. The situation is even more critical in Peru, where 10.4% of the population presents some form of disability, with 48.3% of this group suffering from visual impairment. This vulnerability is exacerbated by high exposure to seismic events, floods, and landslides (huaicos), representing a serious global public health problem [3].

Addressing the growing challenge of the BLV population vulnerability in natural disasters, various studies have proposed innovative models. Solutions such as the *YOLOv5-based* fire warning system [4] and the smart glove equipped with *IoT* sensors [5] have emerged to detect fires and obstacles in real-world environments, focusing on specific patterns to achieve accurate alerts. In parallel, *IoT* infrastructures for evacuations [6] and evacuation simulations involving disabled pedestrians [7] seek to optimize emergency response, aiming to accurately predict risk areas and impact severity. However, despite these advancements, a gap persists regarding the integration of accessible solutions for seismic and fire disasters within the Peruvian context.

Therefore, this study proposes a technological solution based on a mobile application integrated with an *IoT* bracelet and *Azure AI* services to assist in the evacuation of BLV persons. The *IoT* component is used to provide inputs regarding environmental conditions; specifically, sensors able to register temperature and detect nearby objects via the bracelet. Conversely, *Azure AI* services are employed for real-time object detection using the mobile device's camera. Based on the data obtained, the system generates comprehensive reports on the route traversed. The proposal is articulated in four phases: (i) material definition, (ii) IoT device selection, (iii) construction of the *IoT* device, and (iv) mobile application construction.

The remainder of this paper is organized as follows: Section 2 presents the literature review. Section 3 explains the proposal based on the four phases. Section 4 presents the discussion of the study. Finally, Section 5 outlines the conclusions and potential future research directions in this field.

II. RELATED PROJECTS

In the literature, diverse approaches have been proposed to address the vulnerability of Blind and Low-Vision (BLV) individuals to natural disasters by integrating technologies such as *IoT* and *AI*. These include improved *YOLOv4-based* warning systems [8], evacuation models using *BHSFM* [7], smart glasses with *YOLOv8* [9], and tactile bracelets [10]. These approaches address various objectives, such as assessing socioeconomic vulnerabilities, assisting in navigation with obstacle detection [11], simulating inclusive evacuations [12], and optimizing physical safety using emerging trends like *IoHT* [13]. Investigations utilize datasets ranging from the Household Pulse Survey [14] to *COCO* [15] and *HAR* [16], covering everything from population surveys to simulations. Although many studies use proprietary data, there is evident variability in accuracy (up to 97%) and limitations regarding real-world validation, scalability, and accessibility.

Regarding the use of *IoT* in these inclusive contexts, [6] designed an infrastructure for self-evacuation in natural disasters, which reduced evacuation times via interconnected IoT nodes, demonstrating scalability in simulated scenarios. On the other hand, [5] utilized ultrasonic and *PIR* sensors alongside a classifier voting system to assist visually impaired individuals, achieving 95% accuracy in close-range obstacle detection, thus reinforcing its applicability in wearable devices. Furthermore, [10] evaluated a haptic bracelet with vibratory feedback, enabling over 80% of visually impaired users to complete physical tasks, such as reaching objects at a distance or moving between points, with greater safety. Similarly, a portable device was presented in [11] for visually impaired pedestrians that combined real-time object detection with tactile feedback, achieving accuracies exceeding 90% in urban environments. Additionally, a *TinyML* model [17] was proposed for obstacle detection on sidewalks, optimized for low-power devices, reaching an F1-score of 91%, which validates the viability of lightweight models. Likewise, the *SOMAVIP* system in [18] integrated IoT and cloud services to guide visually impaired people in road environments, achieving 97% effectiveness in field tests. Finally, [16] introduced an indoor monitoring scheme using deep learning ensembles in IoT for people with multiple disabilities, achieving 92% accuracy in anomaly detection, demonstrating the utility of multisensory fusion.

In the realm of artificial intelligence, an improved *YOLOv4* model [8] was proposed for automatic fire detection, achieving 97% accuracy and reducing false positives in simulated environments. Complementarily, [9] implemented an intelligent navigation system with *YOLOv8* for visually impaired individuals, achieving a latency of less than 0.5 s and a 95% accuracy in obstacle identification. Conversely, [15] developed a distance estimation and detection method for blind users that improved spatial accuracy by 92%, facilitating indoor guidance. Meanwhile, utilizing an optimized version of *YOLOv10* [19], which balanced performance and energy efficiency, researchers managed to reduce memory consumption by 30% without sacrificing accuracy in bus detection and *Point of View* (POV) classification for visually impaired persons. In parallel, models such as *YOLOv8* and its integration with *EfficientDet* [20] obtained accuracies of up to 96% in adverse environments contrary to those previously proposed, specifically improving small object detection to assist visually impaired people in navigation. Additionally, the Smart Fire Safety Management System (SFSMS) [21], utilizing *AI*, enabled the prediction and coordination of preventive actions with 93% effectiveness in fire incidents. Considering the literature, [22] reviewed trustworthy *AI* models, highlighting the importance of applicability (XAI) and traceability for decision-making in emergencies such as earthquakes, fires, or accidents. Finally, inclusive evacuations were simulated using *AI*, evidencing improvements in exit times of up to 15% compared to conventional models validated through a controlled experiment with 60 participants to analyze the dynamics of wheelchair users and pedestrians on crutches [12].

III. MATERIALS AND METHODS

A. Material Definition

- Temperature sensor
- Proximity/Ultrasonic sensor
- Bracelet construction material
- Microcontroller

B. Selection of IoT Devices

To evaluate the microcontroller, five criteria were defined. The first criterion is Accuracy (C1), which determines the device's efficacy in detecting obstacles, a key factor for reliability in emergencies. The second criterion, Operating Range (C2), considers the effective distance at which the sensor functions. The third criterion is Energy Consumption (C3), a critical aspect for portable devices that must operate for long periods without frequent recharging. The fourth criterion, Ease of Integration (C4), evaluates how simple it is to couple the component with the rest of the system. Finally, the fifth criterion is Resistance (C5), which measures the device's ability to function under exposure to dust, humidity, or impact.

Consequently, Table I presents the decision matrix corresponding to the criteria importance, where "1" signifies that the criterion is of equal or greater importance than the others, and "0" indicates less importance. The results show that criteria C3 and C4 are the most significant.

TABLE I. BENCHMARKING CRITERIA AND PARAMETERS

	C1	C2	C3	C4	C5	Total	Weighted average
C1		1	0	0	1	2	20%
C2	0		0	0	1	1	10%
C3	1	1		1	1	4	40%
C4	1	1	0		1	3	30%
C5	0	0	0	0		0	0%
Total						10	100%

The three microcontroller models considered are: ESP32 (M1), Raspberry Pi Zero 2W (M2), and Raspberry Pi 4 (M3). Table II lists the microcontrollers and their descriptions.

TABLE II. SENSOR AND MICROCONTROLLER MODELS

ID	Model	Description
M1	ESP32	A combination of low cost and low energy consumption, ideal for short-range proximity detection with high ease of integration [23].
M2	Raspberry Pi Zero 2W	Compact board with moderate processing capacity, suitable for projects requiring wireless connectivity and an operating system [24].
M3	Raspberry Pi 4	High-performance board with great processing capacity and connectivity, but with elevated energy consumption [24].

Each device is assigned a score (S) of 1 (low), 3 (medium), or 5 (high) for each criterion. The average (A) is calculated by multiplying the score by the weight obtained in Table I. Finally, Table III summarizes the benchmarking of the three microcontroller models along with their respective scores (S) and averages (A). It is evident that model M1 (ESP32) obtained the highest score (4.20). Therefore, this microcontroller model will be utilized for the present research.

TABLE III. MICROCONTROLLER BENCHMARKS

Aspect	Weighted Average	M1		M2		M3	
		S	A	S	A	S	A
C1	20%	3	0.60	5	1.00	5	1.00
C2	10%	1	0.10	3	0.30	5	0.50
C3	40%	5	2.00	3	1.20	1	0.40
C4	30%	5	1.50	5	1.50	3	0.90
C5	0%	1	0.00	1	0.00	1	0.00
Total	100%		4.20		4.00		2.80

C. *IoT Device construction*

The logical structure of the *IoT* device centers on an ESP32 microcontroller acting as the central unit. Two sensors are connected to it: a *DHT11* to capture temperature and humidity data, and an ultrasonic *HC-SR04* to measure object proximity. The ESP32 processes information from both sensors and transmits it to the end-user using its *Wi-Fi* connectivity (see Figure 1).

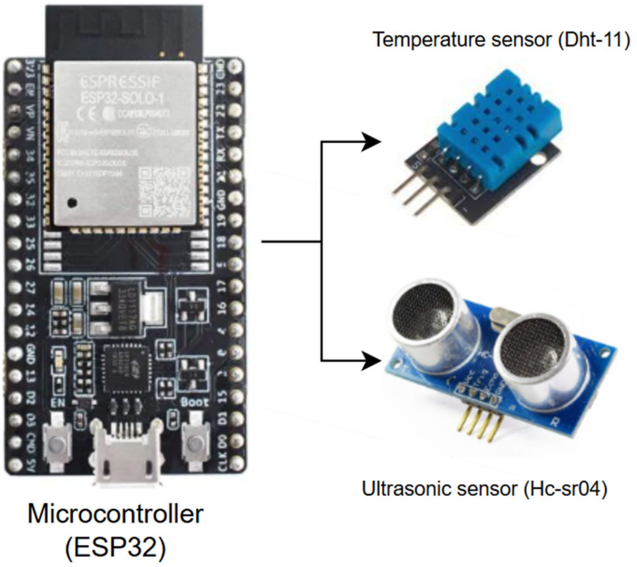
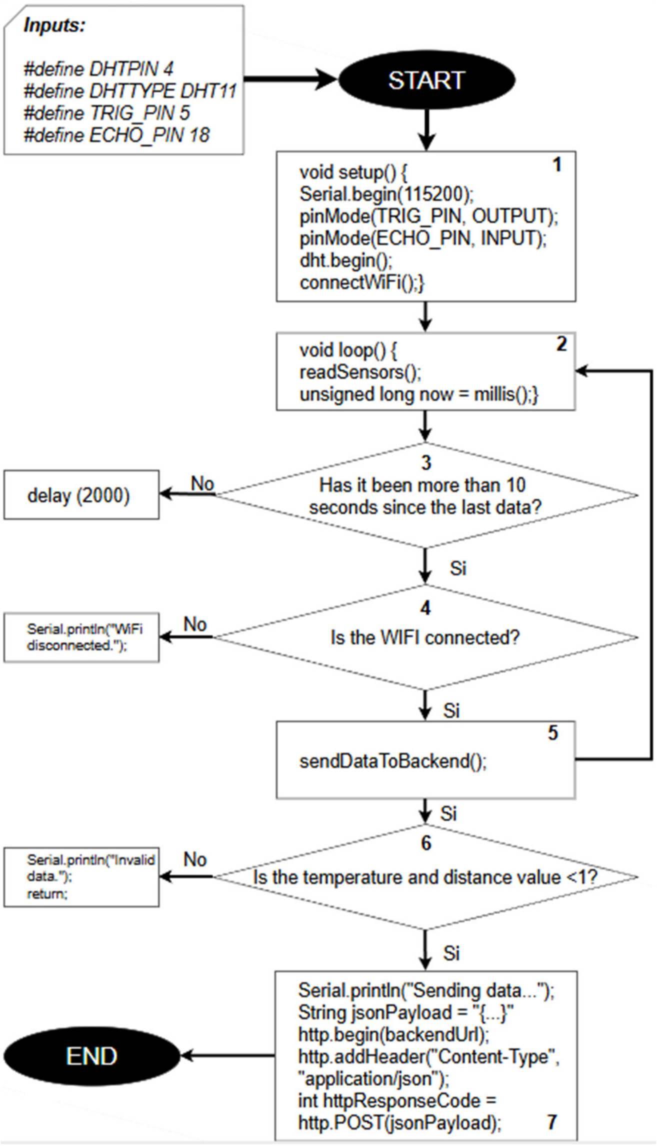


Fig. 1. IoT components diagram

1) *Microcontroller Programming*

The source code for the operation of the ESP32 microcontroller and its sensors was developed in C++ using the Arduino Integrated Development Environment (IDE). For correct data interpretation, libraries specific to each sensor were imported; these handle the conversion of information received in byte format into user-understandable values.

The flow chart in Fig. 2 details the sequence of functionalities implemented by the microcontroller. The first stage initializes serial communication for monitoring by executing *setup()*, configures the input/output pins for the sensors, and invokes the connection routine to the specified *WiFi* network (Step 1).



```
Inputs:
#define DHTPIN 4
#define DHTTYPE DHT11
#define TRIG_PIN 5
#define ECHO_PIN 18
```

```
void setup() {
Serial.begin(115200);
pinMode(TRIG_PIN, OUTPUT);
pinMode(ECHO_PIN, INPUT);
dht.begin();
connectWiFi();}
```

```
void loop() {
readSensors();
unsigned long now = millis();}
```

```
delay (2000)
```

```
Serial.println("WiFi disconnected.");
```

```
sendDataToBackend();
```

```
Serial.println("Invalid data.");
return;
```

```
Serial.println("Sending data...");
String jsonPayload = "{...}"
http.begin(backendUrl);
http.addHeader("Content-Type", "application/json");
int httpResponseCode =
http.POST(jsonPayload);
```

Fig. 2. Microcontroller code flowchart

Following initialization, it enters a main work cycle or loop, which repeats indefinitely to take current temperature and distance readings (step 2). The system uses an internal timer to manage the data transmission interval, set at ten seconds. If the time elapsed since the last transmission is less than the interval, the device introduces a two-second delay before initiating a new reading. If the interval has been met, it proceeds with the transmission (step 3). Before any transmission, the connection status is checked. If the device is not connected, the transmission attempt for that iteration is aborted, and the system returns to the start of the loop in step 2 (step 4). Once the time interval and active connectivity are confirmed, the function responsible for packaging and transmitting data to the *API* service is called (step 5). As a verification of the transmission routine, if sensor values are not greater than one, it indicates a reading failure (step 6). Finally, if the data is valid, a structure containing distance and temperature values is generated to be sent via a *POST* method to the backend (step 7).

2) Bracelet construction

The initial assembly of the *IoT* bracelet prototype was conducted on a breadboard. As shown in Figure 3, the steps followed to complete said configuration are explained below.

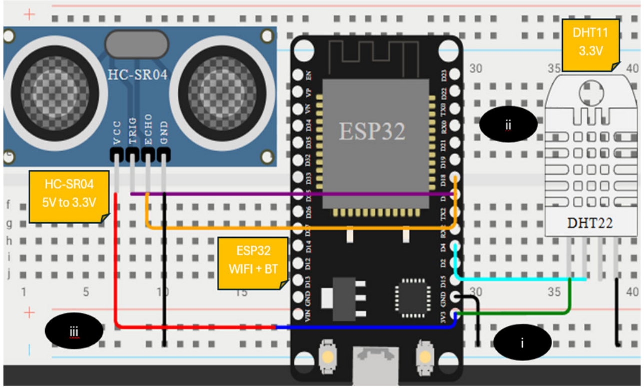
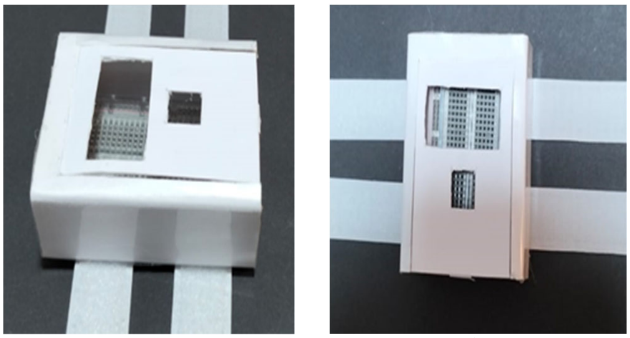


Fig. 3. IoT assembly prototype

First, the circuit power supply is established. The ESP32 uses its 3V3 pin to send 3.3V to the positive rail of the breadboard (marked as ii) and its GND pin to connect to the negative rail (marked as i). This creates common voltage and ground lines used by the sensors.

Next, the HC-SR04 ultrasonic sensor is connected. This module is powered by connecting its VCC pin to a 5V source (iii) and its GND pin to the common negative rail (i). For data communication, the TRIG pin is linked to pin D27 of the ESP32, while the ECHO pin is connected to pin D26. Finally, the DHT11 temperature and humidity sensor is integrated. This sensor is powered by connecting its voltage pin to the 3.3V positive rail (ii) and its GND pin to the common negative rail (i). Data transmission from the sensor to the microcontroller is performed through a single cable connecting the DHT11 Data pin to pin D15 of the ESP32. Additionally, the bracelet casing was fabricated considering the protection of electronic components with moisture-repellent materials and user comfort.


(a) (b)

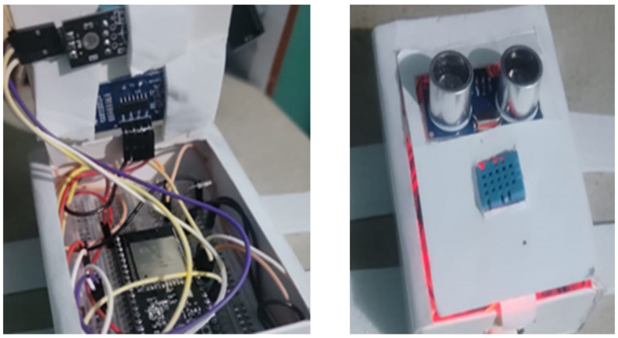

(c) (d)

Fig. 4. IoT bracelet prototype design: Horizontal bracelet design (a), vertical bracelet design (b), internal bracelet assembly (c), and front assembly (d)

The design of the bracelet can be observed in Figure 4, showing bottom and top views highlighting the access openings for sensors (Figs. 4a-b), the internal assembly (Fig. 4c), and the front mounting of the sensors (Fig. 4d), exposing the ultrasonic sensor and the temperature sensor, which are oriented outwards for correct operation.

D. Construction of the Technological Solution

The mobile application is built upon the architecture shown in Fig. 5, which is organized into five layers: Capture, Communication, Presentation, Business Logic, and Storage. Figure 6 displays the context diagram, illustrating the solution's boundaries and its interactions with the users and external systems. In turn, Fig. 7 details the container diagram, decomposing the system's monolithic architecture into its main logical components: (i) Embedded IoT Application, (ii) Edge API, (iii) Mobile Application, and (iv) Mobile Application API. Finally, the system integrates with *Azure AI Computer Vision*, an external artificial intelligence service, to provide object recognition functionalities.

1) Capture Tier

The "Capture Tier" includes the smart bracelet composed of the microcontroller (ESP32) with a temperature sensor (DHT11) and an ultrasonic sensor (HC-SR04), as well as a smartphone with *OS* Android 14+. This reflects the use of wearable devices to identify objects and temperature conditions in real-time. This aligns with designs such as smart gloves equipped with ultrasonic and PIR sensors [5] for transmitting auditory or vibratory alerts.

- ESP32 Microcontroller: Versatile and widely used in *Internet of Things (IoT)* systems, especially in assistive devices. It stands out for its processing capacity and connectivity. This board demonstrates the ESP32's ability to support 2.4GHz *WiFi* connectivity with 40nm technology, allowing interaction with peripherals such as cameras and microphones [17].
- DHT11 Temperature Sensor: This sensor operates in a range of 0 to 50°C, measuring relative humidity from 20% to 90% with an accuracy of ±5% RH, and temperature with an accuracy of ±2°C. Both readings are delivered with 8-bit resolution [25].
- HC-SR04 Ultrasonic Sensor: Functions as a transmitter-receiver system to measure distances without contact in a

range of 2 cm to 400 cm; its operation is based on sending a burst of 8 ultrasonic pulses and measuring the return echo time to calculate the distance [26].

2) *Communication Layer*

In this layer, *WiFi/4G* and *Bluetooth* are used to link the bracelet to the mobile device. Furthermore, data obtained by the microcontroller is sent to the *Edge API* service for processing. Studies validate this connectivity in *IoT* infrastructures using *LoRa radio* on Raspberry Pi for real-time interaction between wearable devices and servers [6].

3) *Presentation Layer*

The Assisted Intelligent Vision (VIA) solution is a software system developed in Spanish under the *Flutter* framework for Android, integrated with the external *Azure AI Computer Vision* service for real-time object recognition. Figure 8 shows the activity diagram regarding the eleven functionalities of the technological solution and its actors (BLV persons, the mobile application, and the IoT device). Through programming logic that establishes permissible limits for each parameter of the data captured by sensors, an evaluation is performed to determine whether the route or individual location is safe. Additionally, using the *Azure AI Computer Vision* service, obstacles extracted from photos of the chosen route are recognized, and the system visually determines whether it is safe. All these functionalities are displayed to the user with an inclusive and pertinent design aimed at both BVI persons and their companions.

4) *Storage Layer*

A *SQLServer* relational database is used to capture parameters obtained by the sensors and the AI service. This data corresponds to the main content of the reports for related functionalities. The database is composed of four tables: *Users*, *Devices*, *Reports*, and *DetectedObjects*. The *Users* table stores information for each person. The *Devices* table saves information on data obtained by the IoT bracelet. The *Reports* table stores the route registry and the objects detected in their analysis. Finally, the *DetectedObjects* table stores detailed data for each found object, which are nested within the *Reports* table.

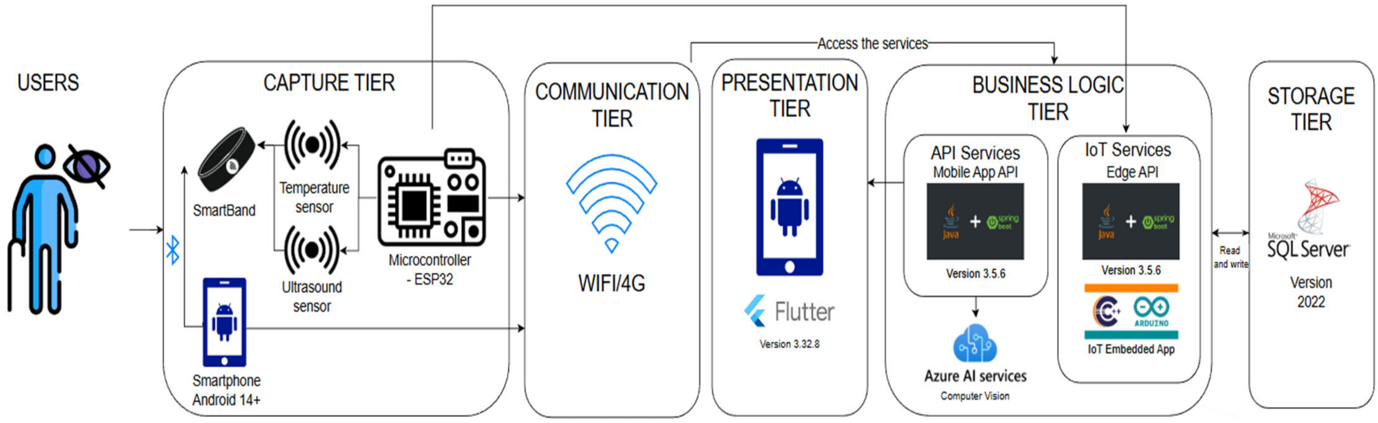


Fig. 5. Physical architecture diagram

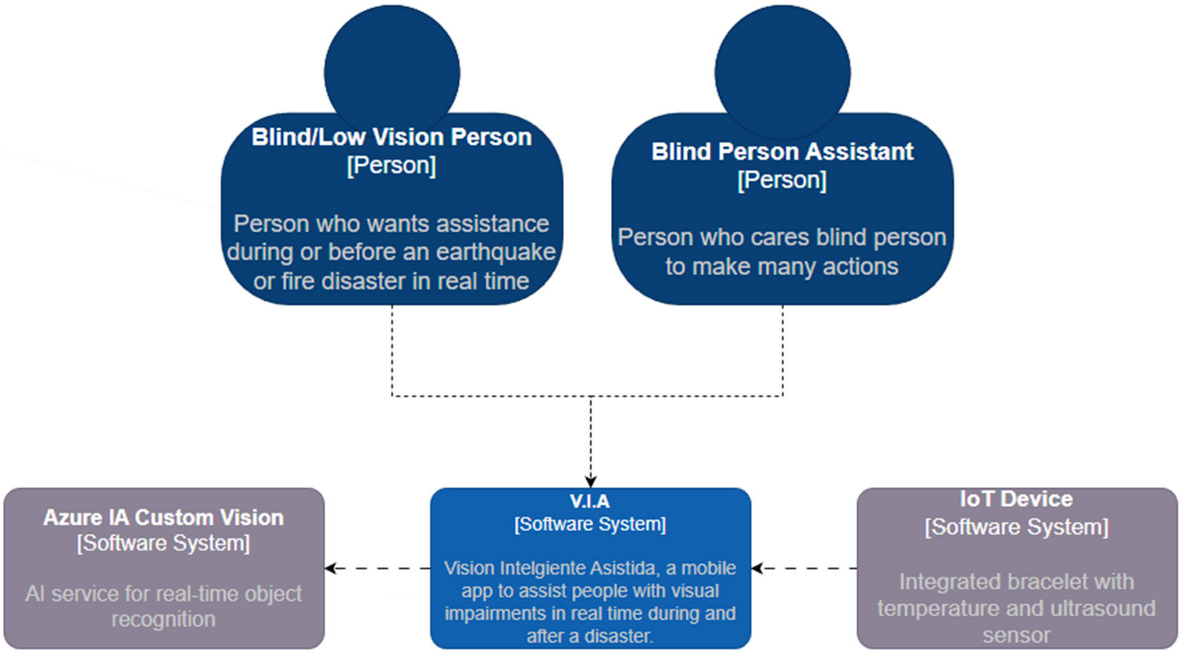


Fig. 6. C4 context diagram

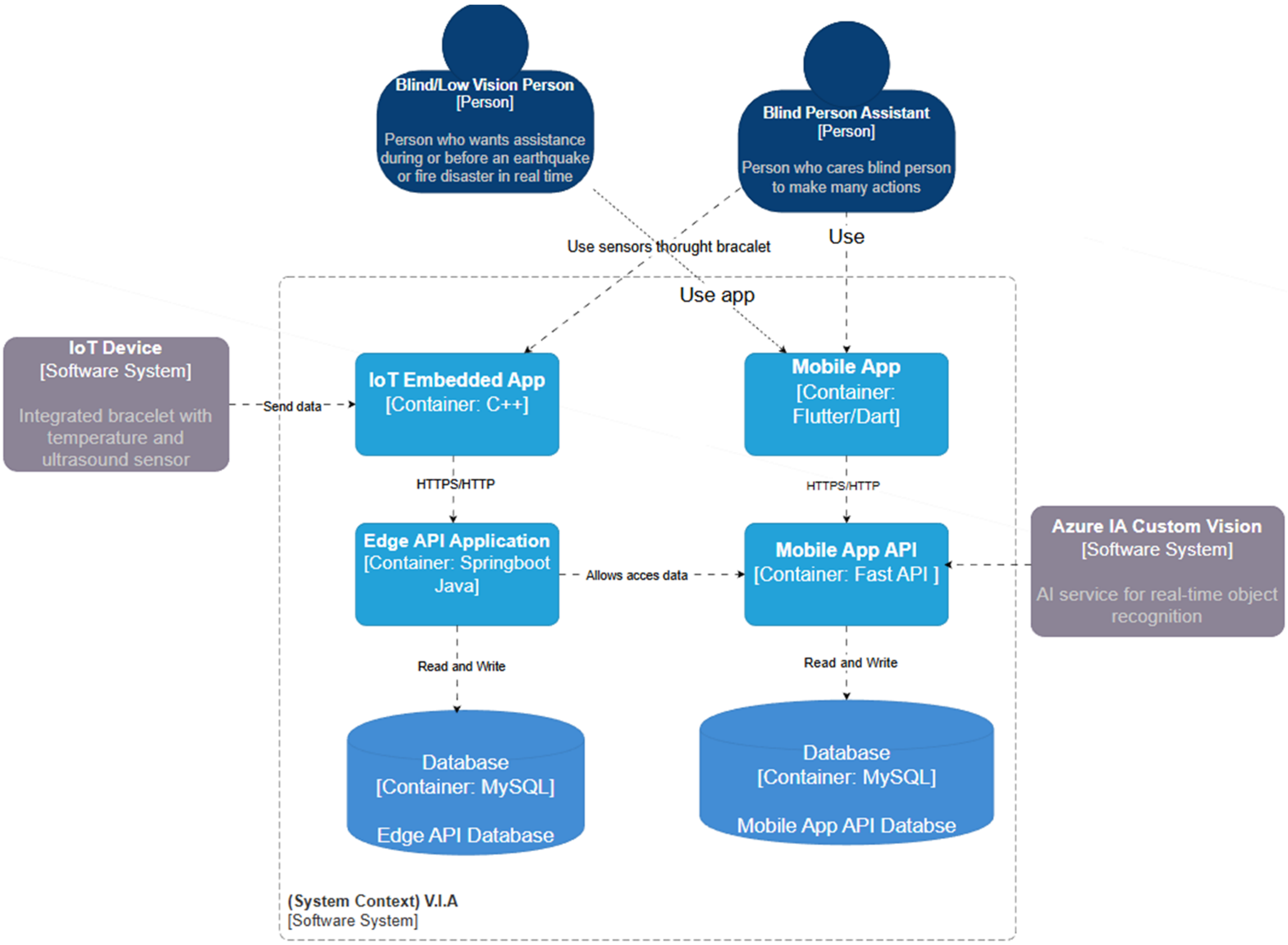


Fig. 7. C4 containers diagram

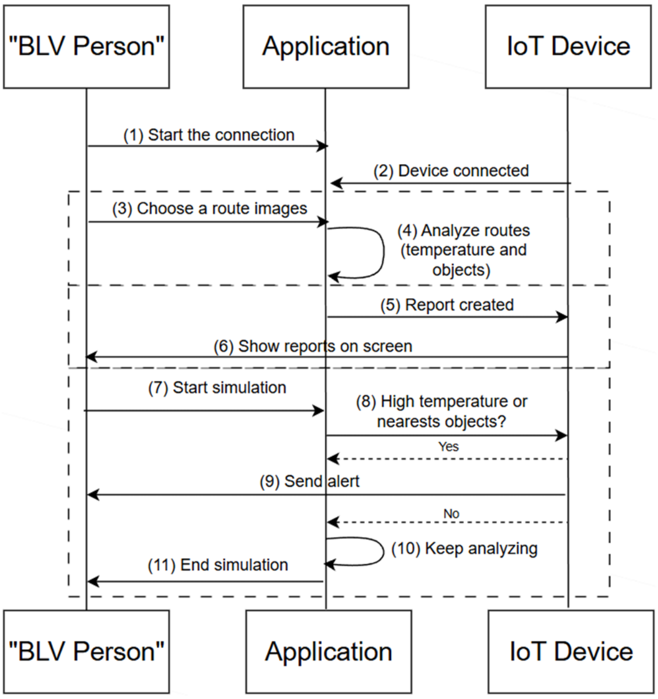


Fig. 8. Technical solution activity diagram

IV. VALIDATION

System validation was conducted using an experimental design within a controlled and safe environment, aimed at assessing the efficacy of the technological solution without exposing participants to actual risks. The participant group consisted of two distinct profiles: companion users and visually impaired individuals (or blindfolded users for testing purposes). The experiment was structured into three testing scenarios: Scenario 1 (Preventive Route Analysis), scenario 2 (Obstacle Detection), and scenario 3 (Fire Detection). Figure 10 illustrates scenarios 2 and 3 using a 3D simulation.

Scenario 1. This scenario focused on the validation of object recognition and environmental assessment, a task performed by the companion user. During the test, the participant utilized the mobile application's "Route Analysis" feature to capture a predetermined path. The interaction and processing flow for this scenario is detailed in the activity diagram presented in Fig. 9.

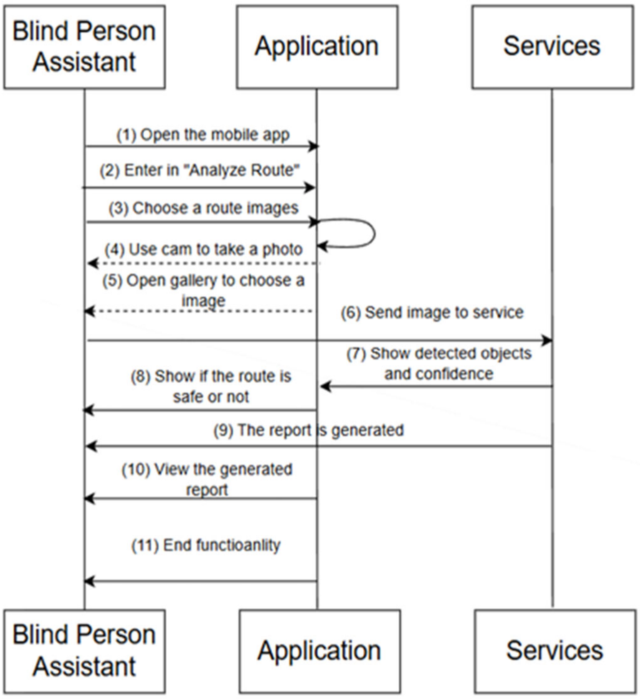


Fig. 9. Activity diagram for scenario 1

Scenario 2. This scenario validated the interaction between the user and the alert system during active navigation. In this test, the visually impaired participant completed a controlled circuit using the "Simulation" feature; the logical flow is detailed in Fig. 11. During the test, the ultrasonic sensor's response was evaluated regarding the activation of auditory and vibration alerts upon detecting the proximity of physical obstacles

Scenario 3. This scenario introduced a fire simulation to verify that thermal sensor could detect a temperature rise and trigger the immediate evacuation alert (Fig. 10b). This process is governed by the logical flow previously described in Scenario 2.

(a) (b)

Fig. 10. 3D modeling of scenario 2 (a) and scenario 3 (b)

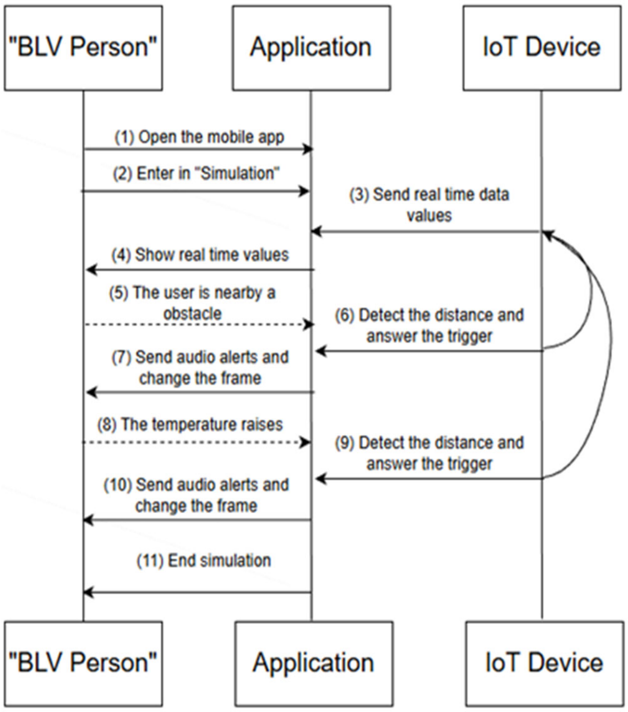
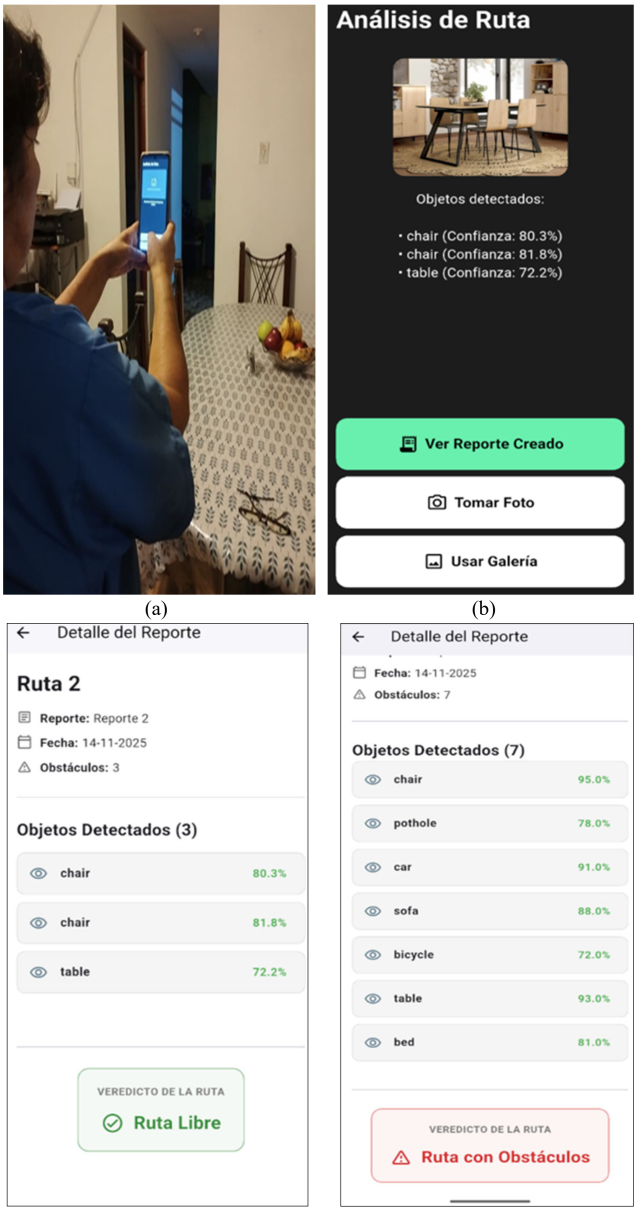


Fig. 11. Activity diagram for scenario 2 and 3

V. RESULTS AND DISCUSSION

1) Scenario 1: Preventive Route Analysis

This scenario consisted of evaluating an evacuation route using images processed by the Azure AI Computer Vision service. Figure 12a illustrates the companion user capturing an image of the route to be evaluated and the results. The AI service detects the objects present within the scene (Figure 12b), and the system analyzes this data to determine the path status on the "Report Detail" screen. Figure 12c presents a scenario with a limited number of obstacles; since the count falls below the predefined risk threshold, it is classified as a "Clear Route". In contrast, Figure 12d shows a case where this threshold is exceeded (7 obstacles), triggering a red visual warning labeled "Obstructed Route" to alert the user.



Análisis de Ruta

Objetos detectados:

- chair (Confianza: 80.3%)
- chair (Confianza: 81.8%)
- table (Confianza: 72.2%)

(a) (b)

Detalle del Reporte

Ruta 2

Reporte: Reporte 2
Fecha: 14-11-2025
Obstáculos: 3

Objetos Detectados (3)

chair	80.3%
chair	81.8%
table	72.2%

VEREDICTO DE LA RUTA
Ruta Libre

Detalle del Reporte

Fecha: 14-11-2025
Obstáculos: 7

Objetos Detectados (7)

chair	95.0%
pothole	78.0%
car	91.0%
sofa	88.0%
bicycle	72.0%
table	93.0%
bed	81.0%

VEREDICTO DE LA RUTA
Ruta con Obstáculos

(c) (d)

Fig. 12. Results of scenario 1: User companion choose an image to evaluate (a), obstacles detected by IA service (b), report generated classified as "Clear Path" (c) and report generated classified as "Path with Obstacles" (d)

2) Scenario 2: Obstacle Detection

This scenario validated the real-time simulation functionality by capturing data via the IoT bracelet and processing it within the Edge API. Fig. 13 presents the results of this scenario. When the visually impaired user approached an obstacle (Fig. 13a), the sensor registered a distance below the predefined threshold, as evidenced by the console logs (Figure 13b). Consequently, the system logic identified an obstacle and generated a yellow visual warning labeled "Obstruction" (Figure 13c), followed by both vibration and an auditory warning.

3) Scenario 3: Fire Detection

This scenario validated the same functionality as scenario 2 but focused on high-temperature detection. Fig. 14 shows the results obtained in this scenario. When the user was exposed to high temperature (fire), as depicted in Figure 14a, and the sensor registered a value exceeding the established limit (Fig. 14b), the mobile application responded instantly. It triggered a high-priority red visual alert labeled "Fire Danger" (Fig. 14c) to signal immediate evacuation via an auditory alert.

¡OBSTRUCCIÓN!

Objeto Cercano Detectado: 4.9 cm

Sensor: esp32_01

(a) (c)

```
23:24:52.503 -> Temp: 25.80 C, Hum: 55.00 %, Dist: 3.94 cm
23:24:54.504 -> Temp: 25.80 C, Hum: 55.00 %, Dist: 4.92 cm
23:24:56.531 -> Temp: 25.80 C, Hum: 55.00 %, Dist: 4.92 cm
23:24:56.570 -> Enviando datos al backend...
```

(b)

Fig. 13. Results of scenario 2: Visually impaired user near an obstacle(a), console results by IoT device (b) and results in the mobile app (c)

¡PELIGRO DE INCENDIO!

Alta Temperatura Detectada: 27.6 °C

Sensor: esp32_01

(a) (c)

```
23:18:01.690 -> Temp: 27.60 C, Hum: 49.00 %, Dist: 61.11 cm
23:18:03.712 -> Temp: 27.50 C, Hum: 49.00 %, Dist: 42.14 cm
23:18:05.716 -> Temp: 27.50 C, Hum: 49.00 %, Dist: 28.55 cm
23:18:05.716 -> Enviando datos al backend...
```

(b)

Fig. 14. Results of scenario 3: Visually impaired user near fire (a), console results by IoT device (b) and results in the mobile app (c)

VII. CONCLUSION AND FUTURE WORK

In this study, a mobile application was developed to assist in the evacuation of blind and visually impaired individuals by utilizing an *IoT* bracelet and AI services. The process was defined in four stages: (1) material definition, (2) microcontroller benchmarking, (3) IoT bracelet construction, and (4) development of the technological solution.

To validate the prototype's efficacy, three controlled prevention and reaction scenarios were analyzed. Key metrics, such as obstacle classification accuracy (confidence score) and sensor response latency, were identified to determine the tool's reliability in emergency situations.

The results demonstrated that the proposed solution is a valuable tool for inclusive safety. The integration between the processing capacity of *Azure AI Computer Vision* and the immediacy of the *IoT* device enabled a balance between preventive environmental analysis and real-time hazard detection.

For future work, it is recommended to implement a lightweight *Edge AI* (*MediaPipe*) to classify objects in real-time without internet dependency. This initiative seeks to optimize the application's efficiency and enrich navigation assistance, thereby improving user independence and establishing new technological foundations for the civil protection of vulnerable populations. Furthermore, it is suggested to expand the validation scope by including a greater diversity of user profiles.

ACKNOWLEDGMENT

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