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SmartSight: IoT-Based Smart Blind Stick with Weather Detection and Anti-Lost Function

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Abstract

People with vision impairment face challenges in detecting objects while walking. Although many blind sticks are available, none offer weather detection to help users be aware of weather conditions. The SmartSight project aims to build a smart blind stick that not only detects surrounding objects to prevent collisions but also includes additional features such as water detection, anti-lost functionality, and emergency management. Additionally, a mobile application allows guardians to monitor users. SmartSight is designed specifically for the safety of people with vision impairments. The project follows the prototype model methodology, involving phases which is requirement, quick design, build prototype, user evaluation, refining prototype, and implementation and maintenance. Development of this project involves hardware like Arduino, sensors, buzzers, Global Positioning System (GPS), and Global System for Mobile Communications (GSM) modules, as well as software like Arduino IDE, Android Studio, and Firebase. Testing of is conducted using the Accessibility Assessment Checklist method, with feedback gathered via Google Forms. Findings show that users find both the prototype and mobile application user-friendly, convenient, and recommended to use.

1. Introduction

The Internet of Things (IoT) involves a large network of interconnected devices and the technology that facilitates their communication with each other and the cloud [1]. IoT is a network of actuators, sensors, machines, and gadgets that are all connected via IP. In order to perceive, gather, and interact with one another, these devices are incorporated into the network and are under the control of controlling devices [1]. The rapid expansion of IoT is fueled by the widespread adoption of communication technologies, the proliferation of devices, and advancements in computational systems [2]. Organizations across industries are adopting IoT to improve efficiency, enhance customer service, support better decision-making, and create more business value. These industries include the corporate sector, education, households, and healthcare [1]. In healthcare, IoT offers significant potential, particularly in developing assistive technologies for individuals with vision impairments [3]. For example, in healthcare, IoT-based Smart Blind Sticks have been widely used to assist individuals with vision impairment.

Visual Impairment (VI) is a term used to refer to any sort of vision loss, including partial and total blindness. According to the World Health Organization (WHO), there are 285 million people worldwide with visual impairments, including 39 million who are blind and 246 million with low vision [4]. Individuals who are visually impaired are unable to discern fine details and have difficulty distinguishing objects from a distance of six feet.

However, visual capabilities differ from person to person; some may only be able to perceive light, while others may discern blurry shapes, figures, or colors [5]. Navigating their surroundings can be hazardous for people with VI due to difficulties in detecting obstacles in their path. Therefore, individuals who are blind or visually impaired require assistive technology, such as the Smart Blind Stick [6]. Many researchers have focused on designing and developing the Smart Blind Stick, incorporating various features and advancements to enhance mobility for individuals with visual impairments [7].

While there are numerous Smart Blind Sticks available, a review of existing journals indicates that none have been developed to detect weather conditions. This vulnerability puts people with VI at serious risk, as they may encounter hazardous weather situations, such as sudden rain or extreme temperatures, without any warning or preparation. Furthermore, hazardous weather can significantly impact long-term health complications. For instance, sudden rain can make surfaces slippery and obscure tactile cues, increasing the risk of falls and potential health consequences such as fractures and severe traumatic brain injuries (TBIs). Extreme temperatures also pose health risks, such as heat stroke and hypothermia, particularly when individuals are unable to find shelter promptly. Moreover, these incidents might cause psychological distress for people with VI, including anxiety and a loss of confidence in navigating independently. Therefore, there is a need for a Smart Blind Stick with weather detection capabilities.

To address these challenges, this project aims to develop a model prototype of a Smart Blind Stick, called SmartSight, equipped with weather detection and an anti-lost function. Additionally, a mobile application will be specially developed for SmartSight stick's guardians for them to monitor the whereabouts of stick users through real-time location. The effectiveness of SmartSight will be evaluated through user testing. The project utilizes four sensors and two modules: an ultrasonic sensor for obstacle detection, a water sensor to identify puddles, a sound sensor to assist in locating the stick if lost, a temperature and humidity sensor for weather monitoring, GPS for tracking the user's location, and a GSM module for contacting emergency contacts.

2. Literature Review

IoT describes a collection of physical technologies, such as appliances, cars, and other objects, that are integrated with network connectivity, software, and sensors to collect and share data [8]. The concept of IoT, first introduced by Kevin Ashton in 1999, refers to the idea of uniquely identifiable connected objects that use technologies like radio-frequency identification (RFID) to communicate and exchange information [8].

There are a variety of IoT interactive projects that have been developed, mainly using the Arduino or ESP8266 microcontrollers to control the projects' operations. For instance, one of the most popular IoT projects is the Smart Lighting System, which allows users to control their lighting using devices like smartphones or remotes. There is also the Smart Security System, where users can control their home security remotely. In addition to these projects, the Smart Blind Stick, designed for people with visual impairments, is another example of an existing IoT project [9],[10],[11]. While many IoT projects do incorporate mobile applications, the level of integration and functionality can vary significantly. The Smart Blind Stick project distinguishes itself by offering a novel approach to integrating mobile app functionality, enhancing its usability and providing a unique solution for users with visual impairments. The blind stick has evolved over the years from a conventional tool into an advanced device incorporating modern technology, now referred to as the Smart Blind Stick. The implementation of technology in the blind stick has significantly aided people with vision impairments, allowing them to navigate more easily. **Table 1** shows the comparison between blind stick, highlighting its features and functionalities over time.

Table 1 *Comparison of blind stick*

Product Name	Features
White Stick	• Basic wooden stick without any significant design features • Common and accessible [12]
Smart Blind Stick with Water Sensor [10]	• Introduced water sensor for effective water detection • Implemented infrared sensor for detecting nearby objects • Utilized ultrasonic sensor for object detection.
SmartSight	• Ultrasonic sensor designed to detect obstacles • Water sensor designed to detect water • Anti-lost function that utilized sound sensor Weather detection using temperature and humidity sensor

- Emergency management function includes the use of GPS and GSM

3. Methodology

The Prototyping Model methodology has been selected for this project due to its suitability for systems requiring the development of a functional prototype. This approach was chosen because it facilitates ongoing feedback and iterative improvements throughout the development process. The method begins by constructing an initial version of the system based on fundamental requirements, which is then presented to users or stakeholders for review. **Figure 1** illustrate the phases for Prototyping Model methodology.

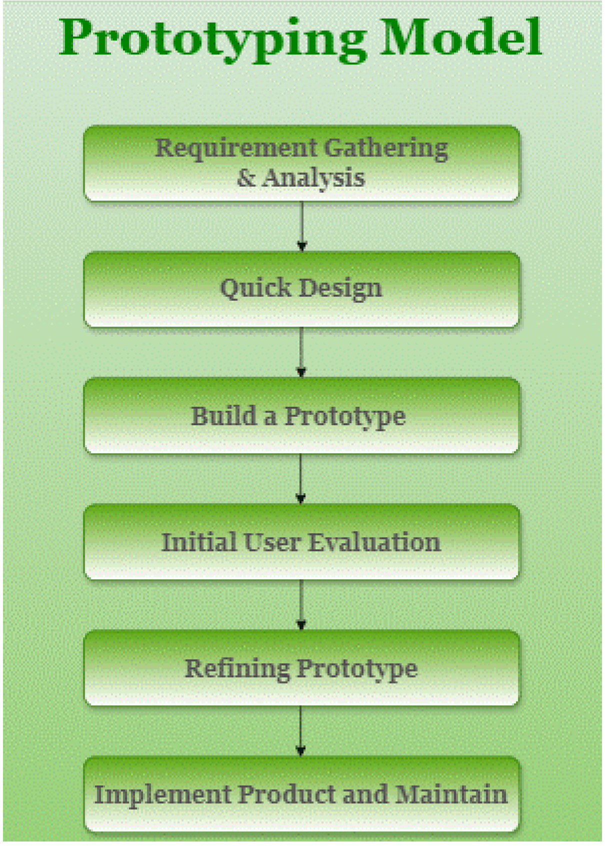


Figure 1 Prototype Model Methodology [13]

3.1 Requirements

The first phase in the Prototype Model methodology is the requirements phase. This phase aims to identify and research the necessary features and functions for the prototype and the mobile app. For this project, the requirements investigated focused on the prototype's weather detection, obstacle detection, water detection, GPS, GSM, and emergency button functions, as well as the mobile app's emergency contact functionality and location tracking. This phase underscores the importance of meeting the specific needs of individuals with visual impairments to improve their safety, independence, and overall well-being.

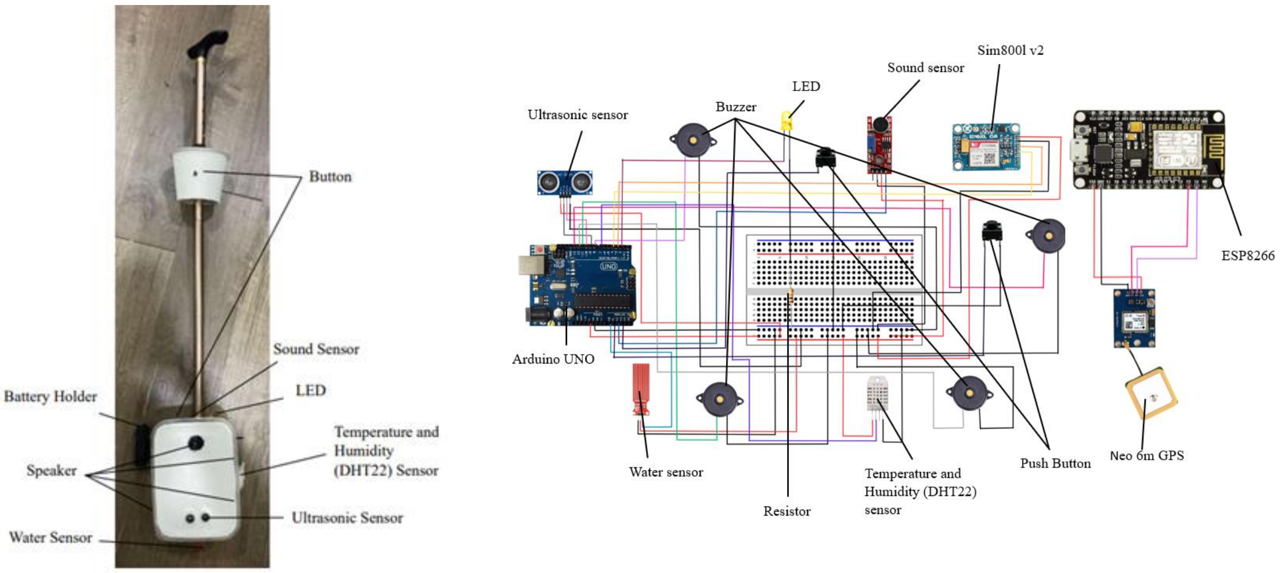
3.2 Quick Design

For this project, the two quick designs involved a prototype design and a mobile app design, focusing on creating the architecture and layout based on the identified requirements.

3.2.1Prototype Design

Figure 2(a) depicts the design of the blind stick, incorporating hardware components such as an ultrasonic sensor, temperature and humidity sensor, water sensor, sound sensor, GPS, GSM module, button, speaker, and buzzer. The Arduino Uno serves as the main power supply for these components.

Figure 2(b) illustrates the circuit board design, featuring the integration of these sensors and components. The Neo6m GPS module uses the ESP8266 to transmit detected locations to Firebase, and each sensor is connected with a dedicated buzzer for alert mechanisms.

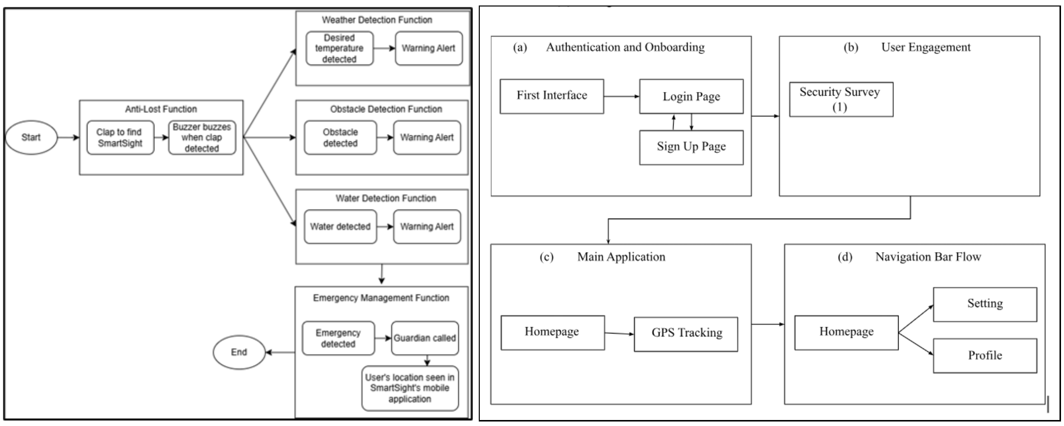


(a) **(b)**

Figure 2 *(a) Blind Stick design; (b) Circuit Board Design*

3.2.2Mobile Application Design

Figure 3(a) demonstrates the functionality of the mobile application integrated with the blind stick prototype, allowing guardians to configure emergency contacts and track the user. **Figure 3(b)** illustrates the overall flow of the mobile application, showing how it interacts with Firebase to store user credential information and facilitate communication with the blind stick.



(a) **(b)**

Figure 3 *(a) Prototype flowchart; (b) Mobile application flowchart*

3.3 Build Prototype

This phase focuses on the development of both software and hardware components to complete the SmartSight prototype. The hardware components are interconnected on a single breadboard to ensure proper functionality. In terms of software development, several tools are utilized, including the Arduino Integrated Development Environment (IDE), Android Studio, and Firebase.

The Arduino IDE is a platform utilized for writing and uploading code to Arduino-compatible microcontrollers. In this project, it manages the operations of various components including sensors, buzzers, the Neo 6m GPS, and the Sim800l Version 2 module. The Arduino IDE is employed for compiling and debugging the code to verify that these components function correctly.

After careful consideration of various factors, The development environment selected for the SmartSight application is Android Studio. As the primary IDE for Android app development, Android Studio offers a wide range of features and integrates smoothly with Firebase. It also provides excellent support for IoT connections, making it the ideal choice for this project.

Firebase was chosen as the cloud storage solution to store emergency contact information and the current location of the prototype user. The integration between Firebase and Android Studio is seamless, which facilitated its selection for this project.

The user interface (UI) of the application was designed to be simple and straightforward, featuring clear icons and large, readable text to enhance legibility for users of all ages. In terms of user experience (UX), functionality and ease of use were prioritized. The process of setting up emergency contacts is straightforward and intuitive, with clear instructions provided at each step. Guardians can easily monitor the whereabouts of the visually impaired person and track their movements, providing peace of mind and enhancing safety.

3.4 User Evaluation

During this phase, unit testing is conducted for each sensor to verify proper functionality of all components. Testing of the SmartSight mobile application is also performed to ensure its functionality, reliability, and user-friendliness. Prototype testing ensures that all sensors operate as intended, while mobile application testing evaluates the application's functionality and flow. Testing is aligned with user needs to facilitate ongoing improvements to the prototype.

3.5 Refining Prototype

During this phase, the prototype for both the blind stick and mobile application is iteratively improved based on user feedback gathered during the evaluation phase. The Refining Prototype phase advances concurrently with the preceding phase, iterating continuously until the enhanced prototype model meets the user's requirements and expectations for this project The project extensively utilizes user feedback to refine and optimize the prototype, as detailed in Section 4.

3.6 Implement and Maintain

During the Implement and Maintain phase, the project ensures functionality and meets user needs by conducting routine bug checks, promptly resolving issues, and implementing updates based on feedback. This phase utilizes testing and monitoring tools to support ongoing maintenance, enhancing operational efficacy and efficiency over time to sustain long-term project robustness and value.

4. Result and Discussion

This section describes the functionality of both the SmartSight prototype and the mobile application, including the functionality of every component used in the prototype and user testing feedback. Both products were tested by 15 users to ensure their effectiveness and usability.

4.1 Project Accomplishmet

The SmartSight prototype integrates various sensors and modules to assist users with VI. **Figure 4(a)** presents the ultrasonic sensor, which can detect obstacles up to 30 cm away, emitting increasingly frequent beeps as the user approaches obstacles. **Figure 4(b)** shows the water sensor that identifies water, emitting three high-level beeps (351-400 Hz**). Figure 4(c)** illustrates the temperature and humidity sensor, which alerts the user with a long beep for 3 seconds when the temperature exceeds 33 degrees Celsius, indicating potentially hazardous weather conditions. **Figure 4(d)** shows a sound sensor that aids users in locating their lost SmartSight stick by emitting a tone melody when activated through clapping. **Figure 4(e)** illustrates the GPS and GSM systems, which are crucial for emergency response: pressing the emergency button triggers these systems to send the user's live location via the GPS tracking feature in the SmartSight mobile application and initiate a call to the designated emergency contact.

Finally, to ensure the effectiveness of the SmartSight prototype, a test was conducted with individuals who were blindfolded to simulate the experience of users with visual impairments as shown in **Figure 4(f)**. This testing approach enabled us to gather realistic feedback on the prototype's performance and usability, ensuring it fulfills the needs of its target users.

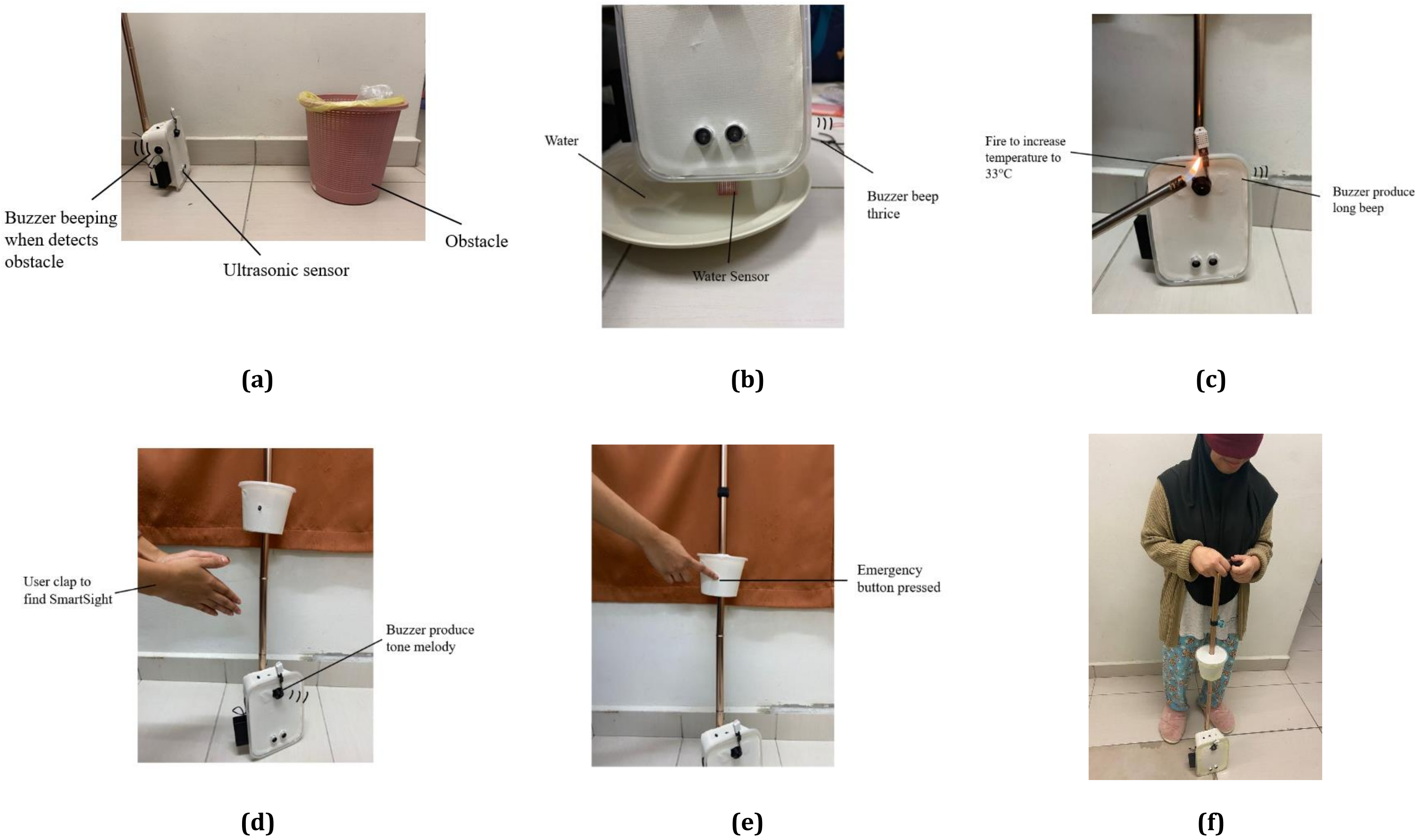


Figure 4 *SmartSight prototype testing (a) Obstacle detection; (b) Water detection; (c) Weather detection; (d) Anti-lost function; (d) Emergency management function*

The SmartSight mobile application complements the hardware by offering user-friendly features. Users begin by logging into their accounts, as shown in **Figure 5(a)**. Those without accounts can sign up using the required details, as depicted in **Figure 5(b)**, and then proceed to log in. Upon successful login, new users are required to answer one survey question about their role in relation to the SmartSight stick user, as shown in **Figure 5(c)**. **Figure 5(d)** shows the homepage, which serves as a central dashboard. From the homepage, users can access the GPS tracking feature by selecting the GPS button. **Figure 5(e)** illustrates the real-time location of the SmartSight stick user, based on the GPS components integrated into the SmartSight prototype. This location data is stored in Firebase and updates every time the stick starts moving. To enhance user mobility in navigating the app, navigation buttons are provided at the bottom of the screen.

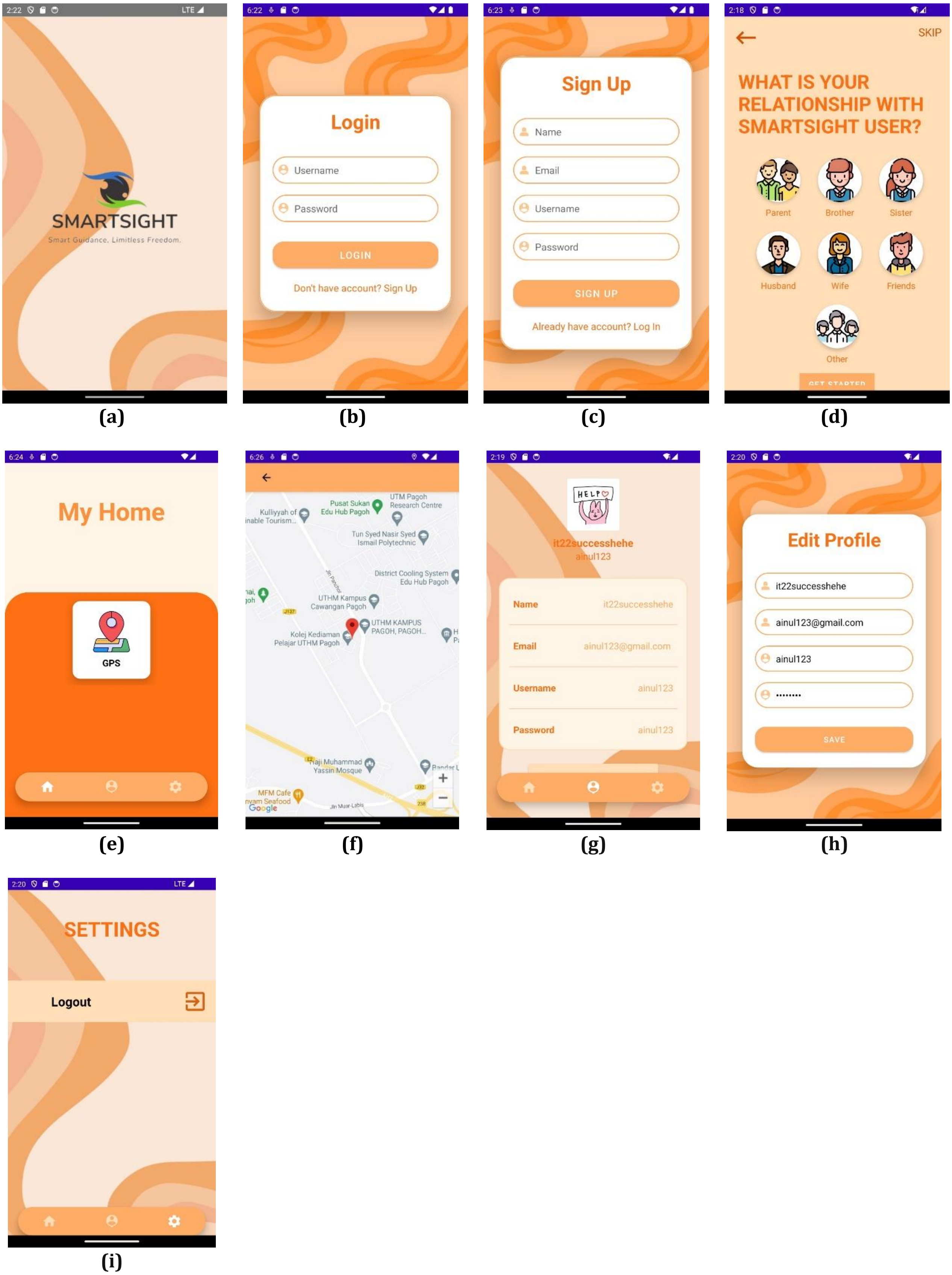


Figure 5 *SmartSight mobile application testing (a) Splash Screen; (b) Login Page; (c) Sign Up Page; (d) Survey page; (e) Homepage; (f) GPS Tracking Page; (g) Profile Page; (h) Edit Profile page; (i) Logout Page*

4.2 User Satisfaction

User testing confirmed the effectiveness of the SmartSight prototype and mobile application. Participants successfully navigated the functionalities of both the SmartSight prototype and the mobile application, providing valuable feedback on the project. Feedback was gathered using Google Forms, utilizing a scale ranging from 1 to 5. Here, 1 indicates a negative response (e.g., very dissatisfied, very difficult), while 5 indicates a positive response (e.g., very satisfied, very easy).

Table 2(a) shows the results of user satisfaction with the SmartSight prototype, while **Table 2(b)** presents the results of user satisfaction with the SmartSight mobile application from user testing. **Table 2(a)** explained that users are generally satisfied with an average score of 4.13, indicating the prototype meets user expectations. Users found the prototype easy to use, with an average score of 4.40, which is crucial for regular usage. The prototype scored 4.60 in reliability, showing it effectively detects obstacles and hazards, ensuring user safety. An average score of 4.27 reflects high satisfaction with safety features, making the user feel secure. The score of 4.47 suggests users would recommend the SmartSight blind stick to others, indicating high overall satisfaction.

Table 2 *(a) User Satisfaction with the SmartSight Prototype Stick; (b) User Satisfaction with the SmartSight Mobile Application*

Statement	1	2	3	4	5	Average
How satisfied are you with the overall functionality of the SmartSight blind stick?	0 (0%)	0 (0%)	4 (26.7%)	5 (33.3%)	6 (40%)	4.13
How easy was it to use the SmartSight blind stick?	0 (0%)	0 (0%)	1 (6.7%)	7 (46.7%)	7 (46.7%)	4.40
How reliable was the SmartSight blind stick in detecting obstacle and hazards?	0 (0%)	0 (0%)	0 (0%)	6 (40%)	9 (60%)	4.60
How satisfied are you with the safety features of the SmartSight blind stick?	0 (0%)	0 (0%)	2 (13.3%)	7 (46.7%)	6 (40%)	4.27
How likely are you to recommend the SmartSight blind stick?	0 (0%)	0 (0%)	0 (0%)	8 (53.3%)	7 (46.7%)	4.47

(a)

Table 2(b) shows that users are very satisfied with an average score of 4.40 for overall functionality of the SmartSight mobile application. The application received an impressive average score of 4.73, showing it is easy to navigate. The reliability score of 4.00 indicates general satisfaction, though there is room for improvement. Users rated the interface and design highly, with an average score of 4.40. The average score of 4.33 suggests users are likely to recommend the app, reflecting a positive overall experience.

Statement	1	2	3	4	5	Average
How satisfied are you with the app's overall functionality?	0 (0%)	0 (0%)	0 (0%)	9 (60%)	6 (40%)	4.40
How easy was it to navigate the app?	0 (0%)	0 (0%)	0 (0%)	4 (46.7)	11 (73.3%)	4.73

How reliable was the app in performing tasks?	0 (0%)	0 (0%)	2 (13.3%)	11 (73.3%)	2 (13.3%)	4.00
How satisfied are you with the app's interface and design?	0 (0%)	0 (0%)	0 (0%)	9 (60%)	6 (40%)	4.40
How likely are you to recommend the app?	0 (0%)	0 (0%)	0 (0%)	10 (66.7%)	5 (33.3%)	4.33

(b)

These findings highlight how SmartSight could improve mobility and safety for individuals with visual impairments. The user satisfaction results highlight the strength of both the SmartSight prototype and the mobile application. High scores in functionality, ease of use, and safety features demonstrate the project's success in meeting user needs. Ongoing testing and refinements will further enhance these features and improve the overall user experience.

5. Conclusion

The SmartSight product is truly an innovative solution that leverages technology to assist individuals with visual impairments. The incorporation of diverse sensors assists users in navigating their environment, while a mobile application ensures their safety. SmartSight can be further enhanced as an IoT-based product by incorporating machine learning to detect upcoming potholes. Additionally, voice-recognition technology could be integrated with Google Maps to facilitate navigation. Lastly, the implementation of Radio Frequency Identification (RFID) could be considered to enhance the security features of SmartSight.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

This journal requires that all authors take public responsibility for the content of the work submitted for review. The contributions of all authors must be described in the following manner:

The authors confirm contribution to the paper as follows: ***study conception and design, data collection, analysis and interpretation of results:*** *Ainul Bahriah Mohd Khir, Nur Farah Aina Ahmad Mazrullah, Nurul Izzah Zahirah Che Kamarudin, Mazniha Berahim;* ***draft manuscript preparation:*** *Ainul Bahriah Mohd Khir, Nur Farah Aina Ahmad Mazrullah, Nurul Izzah Zahirah Che Kamarudin, Mazniha Berahim. All authors reviewed the results and approved the final version of the manuscript.*

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