CHAPTER I
INTRODUCTION

1.1 Background

The development of the Internet of Things (IoT) has grown significantly over the last decade and has become a major foundation for modern intelligent systems. IoT enables physical devices connected to the internet to perform the processes of sensing, processing, transmitting, and visualizing data in real time [1], [2]. The integration of sensors, microcontrollers, internet networks, and cloud services enables IoT to provide responsive and distributed systems. IoT implementation is widely found in smart home, smart city, industrial monitoring systems, and digital health services.

The use of IoT is not limited to industrial and commercial sectors, but also has strong potential in the development of assistive technology for persons with disabilities. One group that requires sensor-based technological support is visually impaired users. World Health Organization reported that approximately 2.2 billion people worldwide experience vision impairment, and approximately 1 billion cases have not been adequately addressed [3]. Visual impairment directly affects mobility, spatial orientation, and safety during movement. Common risks include collisions with static objects, sudden obstacles, and falls caused by holes or changes in ground elevation.

Conventional assistive devices such as the white cane have long been used to support visually impaired navigation. The cane works through direct physical contact between the cane tip and objects around the user. Rusito and Setiyawan [4] shows that the integration of ultrasonic sensors into microcontroller-based devices can improve detection range compared with conventional canes. Purwanto and Wahid [5] also proved that ultrasonic sensors can detect objects to 200 cm with a good success rate. A study by Kazi et al. [6] developed a smart cane with an added GPS module to send the user location to the family.

In addition to cane-based approaches, several studies have begun developing wearable devices in the form of belts. A study by Rima Tamara Aldisa developed an ultrasonic belt design based on Arduino Uno R3 and sensor HC-SR04 that can detect objects at distances to 1.5 meters with output buzzer as audio warning [7]. The system shows that belt-based medium can be used as an alternative navigation aid without requiring the user to hold the device directly. However the developed system still focuses on horizontal obstacle detection and has not been integrated with location tracking systems or real-time cloud services.

Another study by Muhammad Alamsyah et al. developed a safety belt for visually impaired users that integrates ultrasonic sensors and a GPS module with GSM-based communication to send the user location via SMS [8]. The system added a location tracking feature, however the communication mechanism still uses SMS and has not used cloud services for real-time data synchronization and does not form a structured IoT architecture between device, cloud, and mobile application.

Although these studies show positive results, several limitations remain. First, most studies still use canes as the main medium so users still have to hold the device and hand movement remains limited. Second, detection systems generally focus only on horizontal obstacles and have not optimized simultaneous hole detection. Third, data communication integration remains limited. Several location tracking systems still use SMS as the transmission medium [6], which does not support real-time data synchronization and has efficiency limitations.

The development of cloud computing services provides a more efficient solution for data exchange. Firebase Realtime Database enables data synchronization directly between devices using an event-driven mechanism without a manual refresh process [9]. The implementation of an ESP32-based IoT system connected to cloud services has proven to provide stable communication performance with low latency [10]. With this approach, the navigation aid system can work locally, and can also provide remote monitoring features in real time.

Based on these conditions, this study designs a virtual navigation aid system for visually impaired users based on ultrasonic sensors in the form of a wearable smart belt. The selection of a belt as the device medium is based on technical and ergonomic considerations. The belt enables two ultrasonic sensors to be mounted strategically, namely a front sensor to detect horizontal obstacles and a bottom sensor to detect potential holes or ground surface drops. This configuration enables simultaneous two-direction detection without limiting the user's hand movement.

ESP32 was selected as the system control center because it is integrated with a Wi-Fi module and has adequate processing capability to sensor readings and process detection logic, and send data to cloud service [11]. The GPS NEO-6M module is used to obtain the user's location coordinates periodically [12]. The system output is an audio warning through DFPlayer Mini and speaker, and vibration feedback through vibration motor, was designed to provide a rapid response to hazardous conditions.

This system was designed using a Three-Layer Architecture consisting of Device Layer, Cloud Layer, and Application Layer. Device Layer handles sensor reading, detection logic processing, and local warning delivery. The Cloud Layer uses Firebase Realtime Database as a medium for synchronizing location data and detection status in real time. The Application Layer is an Android application that displays the system location and status directly to the user's family.

System development was carried out using the prototype method because the designed system involves the integration of hardware, firmware, cloud services, and mobile applications requiring gradual testing and refinement. Through this approach, the initial design was realized as a smart belt prototype, then tested in terms of detection accuracy, data communication stability, and system response in real conditions. The test results were used as the base for iterative improvements until a system that meets functional requirements is obtained and targeted performance criteria.

Based on previous studies, there has been no system that integrates obstacle and hole detection in one wearable device smart belt, connected with cloud service real time, and is equipped with a mobile monitoring application in one structured end-to-end IoT architecture. This study introduces novelty in comprehensive integration between dual ultrasonic sensors, GPS module, ESP32 microcontroller, Firebase Realtime Database, and Android application in one integrated virtual navigation system.

With this approach, the developed system not only functions as a local assistive detection device, but also as navigation aid system based IoT that support safety, usability flexibility, and real-time location monitoring, and location monitoring in real time. This study is expected to contribute in development assistive technology that more adaptive and integrated for improve mobility and security visually impaired persons in era digital.

1.2 Problem Formulation

The research problems are formulated based on technical challenges found in previous studies, namely:

1. How can an ultrasonic sensor-based navigation aid system be designed to detect front obstacles and potential holes in real time?
2. How can the navigation system be integrated with Firebase Realtime Database to support real-time GPS data transmission through the internet?
3. How can a wearable-based navigation aid system be designed to improve mobility flexibility for visually impaired users without requiring a handheld assistive device?
4. How can an Android application display real-time GPS location information for monitoring by the user's family?

1.3 Research Objectives

The objectives of this study are:

1. To designing the navigation assistive device for visually impaired based on ultrasonic sensor that can detect obstacles in surroundings.
2. To integrate the device with Firebase Realtime Database for real-time data synchronization.
3. To develop a wearable-based navigation aid system that improves mobility flexibility for visually impaired users without requiring a handheld assistive device.
4. To provide a real-time GPS location tracking feature that can be accessed by the user's family through an Android application.

1.4 Research Benefits

This study is expected to provide the following benefits:

1. Academic Benefits

   a. Provides contribution in development literature regarding application of Internet of Things and real-time cloud in assistive technology for visually impaired persons.
   b. To serve as a reference for future studies in development navigation aid system wearable-based, integration IoT with cloud service real time, and development interface mobile supporting.
2. Practical Benefits
   a. For visually impaired persons, this study is expected to improve safety and comfort while walking through mechanism audio warning and vibration generated by the navigation aid system.
   b. For families of visually impaired users, this study provide feature location monitoring user in real time so that can improve sense of safety.

1.5 Research Limitations

To keep this study focused, the scope of this research is as follows:

1. The environmental detection mechanism is limited to HC-SR04 ultrasonic sensors for detecting front obstacles and potential holes.
2. The device medium used in this study is a smart belt, not a cane.
3. The database used in this study is Firebase Realtime Database.
4. The interface was developed only for the Android application and does not include iOS or other platforms.
5. The location tracking feature is limited to GPS data transmission to the Android application through Firebase.
6. Sensor reading accuracy is affected by belt placement, user height, sensor angle, body movement while walking, and floor surface conditions.
7. The GPS module is used only for location tracking and not for automatic route navigation.
8. GPS reading depends on satellite signal availability, so testing is more optimal in open areas.
9. The detection focus is limited to front obstacles and potential holes. It does not include complex navigation features such as road maps, GPS routing, object recognition, or environmental mapping.