

## CHAPTER V

### CONCLUSION & RECOMMENDATIONS

#### 5.1 Conclusions

Based on the design, implementation, testing, and analysis of a virtual navigation aid system for visually impaired users based on ultrasonic sensor with integration of Firebase Realtime Database and Android interface, it can be concluded that the main objectives of this study have been achieved. The system was successfully realized in the form prototype smart belt that integrate Device Layer, Cloud Layer, and Application Layer as one integrated unit system Internet of Things.

Objective first, namely designing the navigation assistive device for visually impaired based on ultrasonic sensor that can detect obstacles in surroundings, has achieved. The system uses two ultrasonic sensor HC-SR04 that is placed in section front and bottom device. Sensor front used for detect horizontal obstacle at a distance  $\leq 120$  cm, whereas bottom sensor used for detect potential hole when distance reading exceeds 130 cm. Test results shows that obstacle detection front obtain 8 True Positive, 0 False Positive, 0 False Negative, and 2 True Negative. while that, hole detection obtain 6 True Positive, 0 False Positive, 0 False Negative, and 4 True Negative. Second scenario producing value accuracy, precision, recall, and percentage detection success rate of 100%. With result the, system has able to provides warning for obstacles and hole according to threshold that set.

The second objective, namely integrating the device with Firebase Realtime Database for real-time data synchronization, has also been achieved. ESP32 successfully sends GPS location data to Firebase Realtime Database through connection internet. Data stored in Firebase can be received by the Android application using real-time listener mechanism. Test results end-to-end latency shows average latency of 1 seconds or is below the target  $< 2$  seconds. All location data update enters in category very smooth. In addition, system also able to detect condition offline when the timestamp does not update within the specified time range.

Objective third, namely developed navigation aid system wearable-based for improve mobility flexibility visually impaired persons without a handheld assistive

device, has achieved from side design and implementation physical. Device successfully made in the form of a smart belt so that user not needs hold assistive device such as cane electronic. Output local in the form of sound from DFPlayer Mini and speaker and vibration from vibration motor can remain active when the system detects condition danger. Results User Acceptance Test shows that respondents can feel vibration warning clearly and understand audio warning that given by system. However, because testing is conducted to non-visually impaired respondents with eyes covered cloth, result this still is evaluation initial and has not can generalized fully for experience visually impaired persons actual.

The fourth objective, namely providing a real-time GPS location tracking feature that can be accessed by the family through the Android application, has been achieved. The Android application that was developed using React Native successfully displays user location data based on GPS coordinates transmitted by device to Firebase Realtime Database. Alpha testing functional based black-box shows that function data transmission location to Firebase, map update in the application, detection offline status, login Firebase Authentication, display device list, and application theme changes runs according to scenario test. All test case in Alpha testing functional based black-box obtain status Pass with percentage success 100%.

Overall, prototype system has meet majority target evaluation that set. Metric obstacle detection, hole detection, latency, detection offline, Alpha testing functional based black-box, and User Acceptance Test has meet target. percentage acceptance user in UAT reaches 88,67% from target minimum  $\geq 80\%$ , so that system can declared accepted with category very good by simulated respondents. Nevertheless, aspect system reliability has not fully meet target because test result endurance shows stable session percentage of 85,71%, whereas target that set is  $\geq 95\%$ . This condition shows that system already successfully functional, but still requires increase in stability operational, especially in side power supply, regulator, load Wi-Fi modem, and distribution current between component.

Therefore, this study successfully proved that navigation aid system based on a smart belt can was designed and implemented with integration of ultrasonic sensor, ESP32, GPS NEO-6M, Firebase Realtime Database, and Android

application. The system has able to run function detection local and location monitoring real time end-to-end. However, prototype still needs was developed further so that more stable, safe, and representative for used in testing with visually impaired persons actual.

## **5.2 Recommendations**

Based on result study and limitations that found during the testing process, there are several recommendations that can be used for development system in further study.

First, aspect reliability power supply needs improved. Test results shows that stability system still affected by load several component that works concurrently, especially ESP32, ultrasonic sensor, GPS, DFPlayer Mini, vibration motor, and Wi-Fi modem. Further study recommended using regulator step-down with capacity current that more stable, separates line supply ESP32 and Wi-Fi modem, and using cable power with size that matches to so that decrease voltage not causes reboot device.

Second, firmware initialization process needs optimized. Under specific conditions, ESP32 experience load work high when first turned on because must reads two ultrasonic sensor, run connection Wi-Fi, initialize GPS, prepare DFPlayer Mini, and perform connection to Firebase in time that close together. This condition increasingly weight if Wi-Fi modem has not obtain signal internet. Therefore, development further needs implement mechanism staged initialization, namely initialization gradual between function detection local and function connection internet. Function detection sensor preferably remain prioritized so that device can provide local warning although connection internet has not available.

Third, the firmware needs to implement more structured task scheduling. The use of `millis()` already helps reduce blocking processes, but system can be further developed by separating task priorities, for example high priority for sensor reading and warning output, and low priority for Wi-Fi connection and Firebase data transmission. This approach can reduce the risk of process conflicts when the device is first turned on.

Fourth, system needs tested in variation user height and placement position belt that different. Position bottom sensor very affected by height belt, placement

angle, and body movement user when runs. Testing further needs determine range user height, position ideal belt, and calibration threshold bottom sensor so that reading hole more stable.

Fifth, hole detection needs was developed with method validation additional. Ultrasonic sensor bottom can experience reading not accurate due to reflection wave in floor, surface glossy, surface sloped, or surface uneven. For reduce false alarm, further study can added filter reading, validation several sample consecutive-turut, sensor additional such as IMU, or method sensor fusion.

Sixth, feature GPS needs equipped mechanism handling condition indoor. GPS NEO-6M module difficult obtain coordinates accurate in room covered or area with obstacles building. Therefore, further study can added fallback based Wi-Fi positioning, BLE beacon, or storage location latest so that application remain can provides information when signal GPS not available.

Seventh, UAT needs conducted to visually impaired persons actual. UAT in this study still using non-visually impaired respondents with eyes covered as simulation. Testing further with visually impaired users actual required so that evaluation comfort, trust itself, response for warning, and pattern use device can more represents condition user actual.

Eighth, further study can compare performance Firebase Realtime Database with service communication IoT other such as MQTT broker, WebSocket server, or Firebase Cloud Firestore. This comparison can be used for determine architecture communication that most stable, efficient power, and according to for system wearable based IoT. In addition, Android application also can was developed with feature movement history, notification when device offline, indicator battery, and settings device so that process monitoring by family become more complete.