Voice Controlled Navigational Aid With RFID-based Indoor Positioning System for the Visually Impaired

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Voice Controlled Navigational Aid With RFID-based Indoor Positioning System for the Visually Impaired

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***Abstract* — This paper presents the development of a voice-controlled navigational system that could assist the visually impaired people in travelling indoors independently. The system provides audible directions to the users in navigating from a specific location going to the desired destination. This system uses passive radio frequency identification (RFID) tags strategically located along the hallways of the facilities. These tags contain audible directions and they are detected by an RFID reader attached at the tip of a customized cane. The reader is connected to the Raspberry Pi 3 that serves as the brain of the system. It processes the data from the reader, validates the voice input of the user and provides the audio response. The adjustable customized cane measures from 88 cm to 130 cm with an approximate weight of 165 grams, which is lighter than commercially available canes that weigh around 300 grams. The speech recognition feature of the system is evaluated and an accuracy rate of 75.76% is obtained. Its response time in reading the tags is 1.38 seconds for a maximum distance of 1 inch. Overall, the system runs autonomously which helps the visually impaired people in navigating independently inside a specific establishment.**

***Index Terms* — Visual Impairment, RFID, Speech Recognition**

I. INTRODUCTION

Visual impairment is a condition that affects many people around the world. As vision is one of the most vital parts of the body in sensing the environment, its loss causes a big challenge for people to travel from one place to another. Based on the report of World Health Organization (WHO) in 2010, there are 285 million visually impaired people globally; 39 million of them are blind while the remaining 246 million have low vision [1]. The blind and visually impaired people experience challenges in independent living due to their limited perception of the surroundings especially in unfamiliar indoor facilities. Although they can be aided by a cane or guide dog, it is still a challenge for them to navigate without the assistance of sighted persons. The presented number and observations are ample proofs to shed light on the importance and value of developing devices and systems that will greatly help the visually impaired and blind people.

There are various research studies that utilize technologies in helping the blind and visually impaired navigate indoors. One of the studies used sensors as a guide [2]. Another study maximized the availability of modern smart phones for navigation [3]. One more study took advantage of handheld mobile devices in developing a navigational system [4]. While all these systems offer effective functionalities, the end devices may cause some inconvenience in everyday usage since first, they are costly to develop, and second, the user must have an established internet connection to utilize the system. Another study in [5] utilized RFID technology for blind and visually-impaired way finding indoors. Data Matrix 2-D bar codes were adopted for the RFID tags and mounted them with 1.5 and 2 meters from the floor to the wall. They positioned the tags at intersections, doors and long stretches of walls. For operation, the user has the RFID reader during navigation. Once the tags are illuminated by the infrared beam from the reader, the user will receive instructions, directions and information about nearby landmarks. Meanwhile, iBeacons were used in [6] for visually impaired in shopping malls to create a smart environment. Using the BlindSquare App and iBeacon's connectivity, the location of the user can be determined through the iBeacons plotted in landmarks known by the user. Lastly, the study in [7] focused on determining static obstacles and determining the shortest alternate route towards the destination. Their design includes a cane that holds all the devices needed for the navigation and a headset for the audio output. Zigbee modules were used as transceivers and a laptop to act as the server that holds the program for determining the shortest route.

This paper presents a smart navigational system that delivers a brand-new way of indoor environment perception using low-cost passive radio frequency identification (RFID) tags that are strategically located on selected areas, a detachable voice-controlled portable unit that serves as the brain of the whole system, a conversational voice output that tells the user the correct directions and an adjustable customized light-weight cane that detects the tags deployed on the area. The system runs autonomously which empowers the blind and visually impaired people in navigating independently inside the facilities.

II. METHODOLOGY

A conceptual paradigm shown in Figure 1 illustrates how the whole project study was conducted. It shows the overall flow of the navigational system.

In this study, the system used audio as input. It has a microphone for detecting verbal commands from the user. For the RFID tags, these contain the direction data that will be utilized by the RFID reader once activated.

For the process, once the speech of the user is recognized by the device, RFID reader will be able to identify the current location of the user as well as provide specific directions on how to proceed to the desired location. The specific directions and instructions will be provided to the user as a voice output.

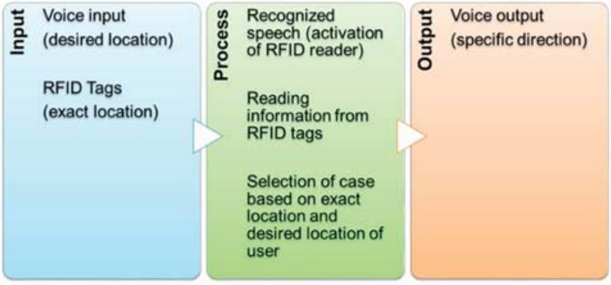

Fig. 1. Input – Process – Output

Figure 2 shows that once the user is within the vicinity of the indoor navigational system, the user would need to state the desired location on the mic of the device. Raspberry Pi will then recognize the voice input and analyze the route to the said location based on the program. The user then would need to hover the RFID reader over the hallways where the RFID tags that contain directions are strategically located. By doing this, the user would receive audible directions through the headset to be able to travel from the place of origin to the desired location once carefully followed.

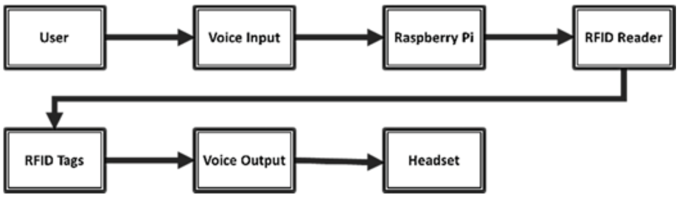

Fig. 2. System Block Diagram for voice controlled navigational aid

For the development of the study, prototyping technique was employed. Prototyping is a method of making a model to test a concept or process for further development. Prototyping serves to provide specifications for a real, working system rather than the theoretical one.

Figure 3 presents the major steps in building the prototype. The process starts with the hardware and software identification to determine the required components in completing the system. This takes place after identifying the specific locations where the system will be installed and after finalizing the peripheral components. After which is the integration or the assembly of the components to develop the portable device as well as to strategically position the RFID tags on the selected hallways of the establishment. For the software development, the process would be conceptualizing the system flowchart then developing the code using Python. The construction of the device was completed upon performing a pilot test to evaluate the system's functionality.

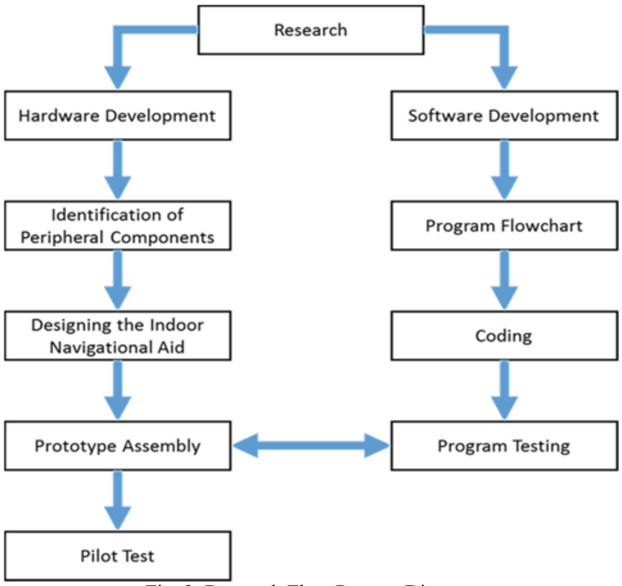

Fig. 3. Research Flow Process Diagram

III. System Design

The proposed system consists of hardware and software part. The hardware part is composed of passive RFID tags, a customized cane, a portable device and a headset with mic. Passive RFID tags contain the specific location and set of instructions that will guide the user whenever it is detected. Since passive RFID tags are used, there is no need for power supply in activating them since the tags are stand-alone and are not dependent to electricity. For presentation and with the consideration of aesthetics, the tags are strategically attached at the back of a carpet that mantle over the selected hallways of the establishment. These tags are detected by the RFID reader that is attached at the tip of an adjustable light-weight customized cane. The cane was thoroughly designed and developed with the consideration of weight and length that adapts to any user. Regarding the RFID reader, whatever data it receives from the tags, it will be sent directly to the portable device that contains the Raspberry Pi. A headset with microphone serves as the input and output medium of the user. After turning on the device, the user will be asked to state clearly the desired destination. It will be processed by the Raspberry Pi and as a response, an audible confirmation will be sent back to the user. The user will only need to follow the audible directions to arrive to the desired destination. The portable device contains the Raspberry Pi 3 that serves as the brain of the entire navigational system. It processes the information being sent by the RFID reader, validates the voice input from the user and provides an accurate voice response that directs the user in heading on to the stated location.

The software part includes the keyword detection engine and Python language. An online software named Snowboy was used as the keyword detection engine since it offers an offline detection. Meaning, it operates without the use of the internet. Keyword detection was done by repeatedly recording specific keywords that are part of the program. The software will evaluate the recorded words and after the calibration, it will save the word as a single Python compatible file. Python language was used in developing the whole program of the system. It is used for Raspberry Pi through the Raspbian OS. The program contains the keyword detection engine, the information of each RFID tag and the voice output.

The completed customized cane is shown in Figure 4. Figure 5 presents the actual chassis of the device that is placed inside a belt bag. Figure 6 shows the installed system at the lobby of Fernandina 88 Suites Hotel. The RFID tags are positioned underneath the carpet to make it presentable.

Fig. 4. Customized cane with RFID reader at the end

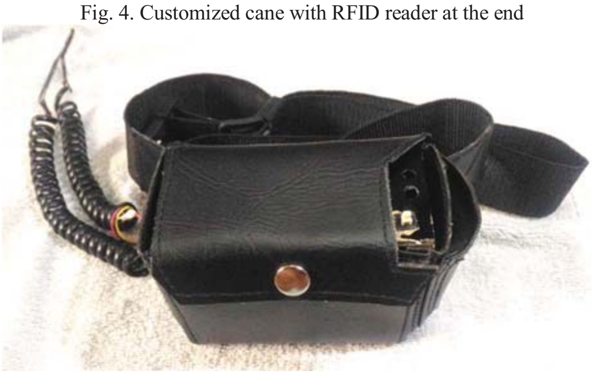

Fig. 5. Chassis of the device

Fig. 6. Chassis of the device RFID tags deployed at the hotel lobby

IV. Results and Discussion

Table I shows the received correct response of the device after uttering the key words. A total of 30 trials per key word was recorded in order to ensure credibility of the gathered data. Figure 7 displays the graphical representation of Table I.

TABLE I. Speech Recognition Test

Keywords	*Trials*	*Received Response*	*Percentage*
Reception	30	21	70.00%
401	30	20	66.67%
Vigan	30	27	90.00%
	Average		75.56%

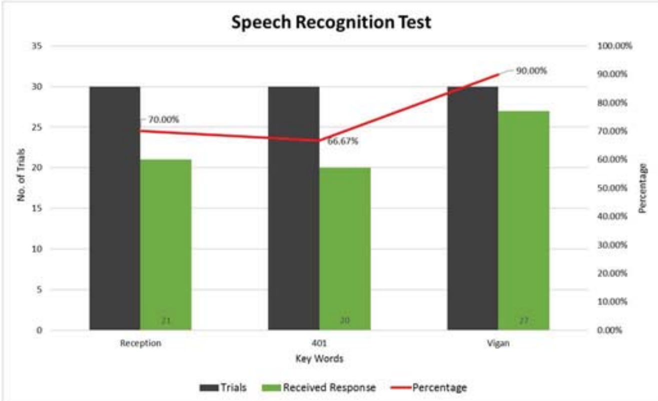

Fig. 7. Speech Recognition Test Graph

The result displayed in Figure 7 indicates that the speech recognition feature of the project is at 75.56% response rate. It means that in every 10 trials of uttering the desired location, there will be approximately 2 instances that the users have to repeat uttering their desired location until the system recognizes it.

Table II shows the details of average independent travel time of the users compared to their travel time with the assistance of a sighted person. It also displays the percentage difference of these parameters. Figure 8 displays the graphical representation of Table II. It depicts the accuracy of the system during the travel time of the user. The establishment has elevators that are used by all clients and visitors of the hotel; hence, the time consumed while waiting for the availability of elevator and while inside it during the travel time were omitted.

TABLE II. Comparison of Travel Time with the Device and with Assistance

Destinations	*Average travel time with device (sec)*	*Average travel time with assistance of a sighted person (sec)*	*Percentage Difference*
Reception to Room 401	33.87	28.00	20.95%
Room 401 to Reception	31.80	28.00	13.57%
Reception to Vigan Hall	28.93	25.00	15.73%
Vigan Hall to Reception	29.27	25.00	17.07%
Room 401 to Vigan Hall	42.07	35.00	20.19%
Vigan Hall to Room 401	41.93	35.00	19.81%

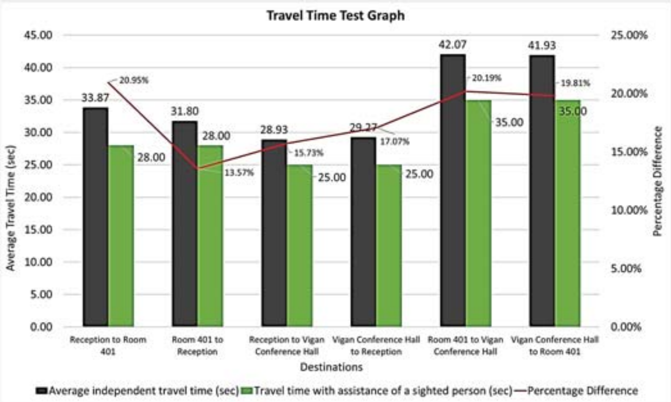

Fig. 8. Travel Time Test Graph

The results at Figure 8 implies that the individual travel time of the visually impaired using the device is approximately 13% to 21% slower compared to the travel time with the assistance of a sighted person. After consolidating the data, the researchers conducted a root cause analysis by asking the users about their experience and indicated the following factors behind the results. First, the users were new to the environment. Since they were unfamiliar to the hotel, despite of being assisted by the device, they said that they still had to adjust to the place in order for them to feel comfortable moving around. Second, the navigational system was new to them. Aside from the fact that they were used to conventional canes, users admitted that it was the first time that they were introduced to the device. They already had tested previous projects for blind assistance; however, majority of them removed the use of cane. According to them, this is the first time that they used a device using a cane that weighs almost the same as their commercial canes. Lastly, blind and visually impaired people are used to be assisted by a sighted person in new environment. This reason explains why it took them longer time traveling independently with the device because normally for new environment, they expect that someone from the establishment would assist them. Although they were not confident to travel alone at first, they were able to get the hang of it after performing additional trials.

The graph also shows that the highest percentage difference in travel time is from Room 401 to Vigan Conference Hall and vice versa. It has a variance of approximately 21%. The reason behind it is their locations. These two rooms are located at two other ends of different floors that has more turns compared to other rooms. This means that the navigation of the users traveling alone on these areas were a bit complicated.

TABLE III. RESPONSE TIME TEST

Distance	*No. of Trials*	*Average Response Time (sec)*
0.25 inch	30	1.37
0.50 inch	30	1.38
0.75 inch	30	1.39
1.00 inch	30	1.38
1.25 inches	30	0

Fig. 9. Response Time Test Graph

Table III demonstrates the average response time of the RFID reader as it detects the passive RFID tags. Different distances were considered in gathering the data. Figure 6 shows the graphical representation of Table III.

The graph in Figure 9 indicates that the RFID reader takes an approximate time of 1.4 seconds to detect and read the passive RFID tags with a distance of up to 1 inch. If the distance is greater than 1 inch, the RFID reader will not be able to read the tags, thus the downward trend at 1.25 inches distance. This confirms the information stated on the data sheet of RFID reader that it can only read tags up to 1 inch of distance regardless of obstructions in between.

After the results from each test have been tabulated, the researchers identified some factors that may affect the functionality of the project. Prior to utilizing the system, possible users must be fully informed on the operation of the device as well as the positions of the RFID tags so that they would be able to focus their cane on those areas to receive audible instructions. Also, while navigating, the cane should not exceed the 1-inch distance limit from the floor so that the RFID reader will be able to detect the tags. Lastly, in utilizing the speech recognition of the device, users may need to repeat themselves in providing desired locations until the device responds with confirmation. This is due to the fact that the speech recognition of the device is at 75.56% response rate.

V. CONCLUSION

Based on the data and results, the proposed voice controlled navigational aid using Raspberry Pi with RFID-based indoor positioning system is successfully implemented. An input and output speech recognition program were developed with 75.56% response rate. A total of 320 passive RFID tags were deployed in the lobby, 4th floor and 6th floor hallways of Fernandina 88 Suites Hotel. The response time of the RFID reader in detecting the tags is 1.38 seconds for a maximum distance of 1 inch. An adjustable customized lightweight cane was fabricated using an aluminum. Its length ranges from 88 cm to 130 cm with an approximate weight of 165 grams. The RFID reader is properly mounted at the tip of the cane. Overall, the operation of the system is excellent.

VI. Future Work

Future work includes enhancement of speech recognition system that will be sensitive to low volume of voice input. Also, it includes improvement of the project which will be suitable for noisy environments since the project is designed for indoor use with minimal noise.

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