Applying The Internet Of Things, Speech Recognition And Apriori Algorithm For Improving The Walking Stick To Help Navigate For The Blind Person

Sumitra Nuanmeesri, Lap Poomhiran

Abstract: The objective of the article is to propose a prototype of the development of the walking stick to be used as a navigation tool for the blind based on the internet of things devices that work in concert with the speech-to-text technology and Google Maps API. By using the Apriori algorithm to recommend the walking routes that are suitable for the user persona. The results of testing the efficiency of the route recommendation for each trip from the behavior of using the walking stick of thirty-three people over thirty days showed that the accuracy of walking route recommendation was 98.81%. Moreover, the walking stick for the blind persons was evaluated with the black box testing by nine experts and thirty-three volunteers who are blind people. The findings revealed that the users acknowledged the walking stick for blind navigation with the average mean value at 4.53 and standard deviation at 0.51 by experts, and the average mean value at 4.62 with standard deviation at 0.49 by the volunteers. Furthermore, the acceptance of the walking stick system has a high consensus. Therefore, it can be concluded that the development of the walking stick to help navigate for blind people is acceptable and can be used in daily life at the highest level; with the new technology and innovations, it is possible to improve and facilitate daily life more effectively.

Index Terms: Apriori algorithm, Blind person, Internet of Things, Navigation, Speech recognition, Walking stick

1. INTRODUCTION

Based on the survey of the disabled population in Thailand conducted on December 31, 2019, there were 192,502 visually impaired individuals. There were 101,365 females and 91,137 males who are blind people in total [1]. Apparently, the number of blind people in Thailand is not small, and it is crucial for them to use a walking stick for navigation. Presently, several new technologies and innovations have facilitated and supported human beings' daily life. Notably, the internet of things (IoT) has played a significant role in modern society. Since the internet of things is electronic devices that can be combined and innovated to be able to connect to the internet on the global network. Nonetheless, there are very few innovations available for people with disabilities, particularly the visually impaired or blind people who need to use a walking stick for navigation daily. In most stances, there are only walking sticks for the elders or the application of IoT to develop walking sticks for older people. However, the walking stick for visually impaired people which can effectively guide them are incredibly costly or up to 500 USD on average, including WeWALK [2], a smart walking stick for blind people, as illustrated in Figure 1 [3]. Most of the research attempts have been made to focus on just designing protection devices [4][5][6][7][8][9][10] or detect obstacles [11][12][13][14] or avoiding residues for installing smart stick.

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Thus, this study proposes to develop a prototype of the walking stick which requires low production costs for blind people. The features of the developed walking stick include the navigation of general walking directions and the navigation to a destination on Google Maps by specifying destinations with voice commands and recommend the walking routes that are suitable for a blind person's life by Apriori algorithm.

***Fig. 1**. The WeWALK smart cane for the blind [2].*

The overall method for design and develop the walking stick are presented in Section 2. In Section 3, there are the results of testing the accuracy and effectiveness of the route guidance by using the walking stick for blind. Last, a conclusion is provided in Section 4.

2. MATERIAL AND METHODOLOGY

This research proposes that the developed walking stick for visually impaired individuals consists of three major stages: 1) system design, 2) system development and 3) system evaluation, as explained below.

2.1 System Design for Walking Stick Process

The developed walking stick was designed using electronic devices and sensors about the IoT. Each walking stick composes of the following features: detection of objects or blockages on pathways, alarms when encountering hindrances, vibrating alerts, voice prompts for navigation, location coordination, and connection with Google Maps. Hence, the researcher studied and collected the devices that consisted of these features and was cheap enough for providing the features mentioned above to be used for the system development. IoT and sensor devices applied in this research were ESP32 microcontrollers, GSM/GPS module, a gyroscope, accelerator module, waterproof ultrasonic module, voice module, MP3 player module, a speaker, a DC micro coreless vibrator, real-time clock module, light-emitting diode, lithium-ion charger module, and batteries. Details of each IoT and sensor device are provided below.

1) ESP32 Microcontroller: The ESP32-WROOM-32U is one of the ESP32 series. It is the smallest electronic control unit (ECU) for ESP32 microcontroller. There are thirty-eight pins for input and output, adequate for connecting several sensors and devices. Hence, the ESP32-WROOM-32U was operated to regulate the system of the walking stick in this research.

2) GSM/GPS Module: This module is employed for the location coordination tracking process, together with the application of the global positioning system (GPS) embedded in the global navigation satellite system (GNSS). By using GPS tracking, the walking stick could navigate the visually impaired people effectively. In terms of the global system for mobile communications (GSM), it was applied for communicating with the central server, which was later developed in this research. This server acts as a service for obtaining and delivering the data between Google Maps and the walking stick. The Quectel UC20E was chosen and applied for the GSM/GPS module. The Quectel UC20E was capable of running uploads and downloads at 5.76 megabits per second and 14.4 megabits per second, respectively.

3) Gyroscope and Acceleration Module: This module consists of the gyroscope sensor and gravity acceleration sensor. Regarding the gyroscope sensor, it is employed for identifying the walking stick rotation. Suppose the angle or degree of the sensor is tilted or not straight forward. This sensor can detect and alarm the user to rotate the walking stick to tilt its angle. In terms of the gravity acceleration sensor, it is applied for estimating the height of each blockage in accordance with the ground floor. This sensor, in other words, can identify how high an object or hindrance is according to the differences in distance between the laying of the hand and the walking stick of each individual. This results in the calculation of distances or positions of blockages that may hang or rise above the ground. The GY-GMI160 was operated and employed in this research.

4) Waterproof Ultrasonic Module: When it rains, or the weather makes a change to the environment, the performance of the sensor is also affected, especially when detecting objects or blockages. Many ultrasonic sensors had been applied, including HC-SR04, RCW-00001, and RCWL-1201, but they lacked waterproof property. The SN-SR04T ultrasonic sensor module features the capacity of waterproof, a mix of transceiver and receiver in the single examination. In this study, two sets of waterproof ultrasonic modules were employed for detecting objects or blockages above and below.

5) Voice Module: This voice module is the primary voice input for voice commands in the navigation process. Voice commands were basically formulated as analog signals. Then, this module was converted into a digital signal for processing of voice commands later on.

6) MP3 Player Module: The MP3 player module accompanies with a microSD card slot, which keeps all voices responding to the users, including notifications, remaining distance alerts, and turn-left or turn-right alerts.

7) Speaker: A 8-ohm speaker with at least 0.25 watt was utilized to notify and alert to the users.

8) DC Micro Coreless Vibrator: In certain noisy locations, each user of a walking stick may not be able to hear clearly enough. Hence, the vibrating alert will help him or her to hear more effectively. The pattern of vibrating alert would sound different following the environment or hindrances detected. To illustrate, if an object or a hindrance is identified 4 meters away, the vibrator will shake only once to alert. When approaching the object or hindrance, the frequency and duration of the vibration will be increased, too. There are also a variety of extra patterns of vibrating alerts as well. For instance, two consecutive vibrations refer to an object is detected high above the ground but still far away from the user.

9) The Light-emitting Diode: At night, lights will appear on the walking stick to let people see or recognize that a blind person (the user) is walking nearby.

10) Lithium-ion Rechargeable Module and Batteries: The 18650 series of batteries is the lithium-ion battery, which is utilized as the primary power source for each walking stick. Because it is rechargeable, the lithium-ion rechargeable module was chosen to be applied in this study.

The IoT and sensor devices applied in this research are illustrated in Figure 2 and the walking stick design for the blind, which includes all IoT and sensor devices shown in Figure 3.

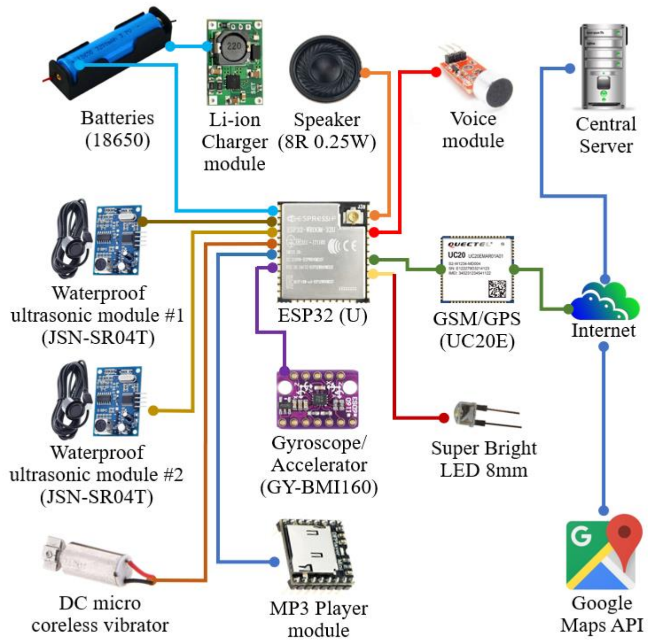

***Fig. 2**. The IoT and sensor devices for developing the walking stick for blind people.*

***Fig. 3**. The walking stick with IoT and sensor devices for blind people.*

2.2 System Development of The Walking Stick

To develop this walking stick for visually impaired people, the researcher divided the system development process into three main parts: 1) the processing part in the walking stick, and 2) the service part in the central server.

1) The processing part in the walking stick: This section was formulated in the Arduino platform towards the application of the Arduino IDE version 1.8.10. The operating system used was Windows 10 professional edition with 64bits. C++ was the primary language utilized for developing this section. All processing sensors were developed as described in the previous section about devices and sensors. A sound recording was also used for warning the user as part of the microSD card, as explained above. In terms of voice commands conveyed by users through the voice module, they were digitized and then transmitted to the central server for interpreting the voice commands into the requested destination setting. As soon as the central server has processed the request, it will convert the destination coordinate information as well as the turning point information into coordinates and distances back to the application in the walking stick to calculate the alert range and walking directions.

2) The service part in the central server: This central server consists of the services developed in the PHP language version 5.6.22 combined with Java language and run by Apache version 2.2 on Windows Server 2008 with a 64bits structure. There were three primary services on this server, including speech-to-text service, map direction service, and route recommendation service. Concerning the speech-to-text service, the Web Speech API was run and utilized to transform the voice commands to text commands in the Thai language. The text commands were associated with the location names (the destinations where the visually impaired people would like to go). In terms of the map direction service, the researcher established the service for working with the Google Maps API in JavaScript language, particularly for the Directions Service. All data from the Directions Service in Google Maps API was reformatted, and then returned to the walking stick to navigate its user. For the route recommendation service, this service applied the Apriori algorithm to predict and recommend the route for a blind person in a daily trip. Apriori algorithm is a technique in data mining processing for machine learning. It can create predictive rules by recognizing the use of pattern recognition based on the association rules [15]. It helps in reducing the number of alternatives or unnecessary walking routes which are the candidate of itemsets that higher than the minimum support value. The Apriori algorithm has the following main work processes: First, building the k-itemsets which are candidature from 1 to n itemsets where k is {1,2,3,…,n} and n is the total number of candidates. Then the large itemsets were found at k-1 levels, such as itemset {AB} and {AC} were found on itemset {ABC}. Second, loading the item from database or dataset for counting the support value of itemset candidature of the large itemset at k level. Next, find the itemsets which the support value equal to or higher than the minimum support value at k level. Next, building the candidate itemsets to search the large itemsets at the next k+1 level. Then repeat these processes until the candidate itemsets do not generate. The Apriori algorithm processes can be illustrated in Figure 4.

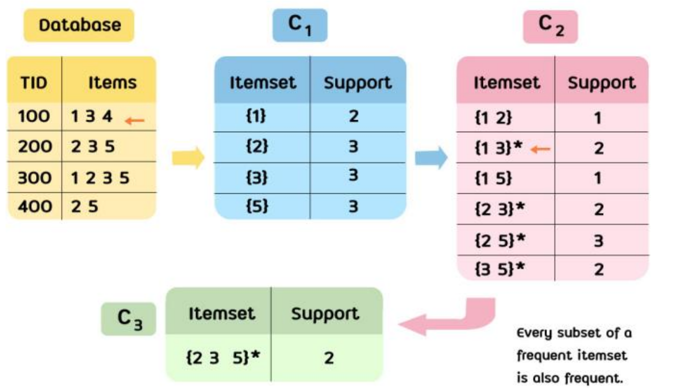

Fig. 4*. The Example of the Apriori algorithm processing.*

2.3 The Model Development

The model of this work was developed by using the Apriori algorithm especially the route recommendation service has mentioned above, the data was collected and computed based on the daily walking of the thirty-three blind persons or people with unclear vision such as lottery dealers, chiropractors who are volunteers, and using a walking stick for thirty days. In this study, the documents describing the protocols and ethical research conduct were sent to the participants to sign. There are 2,350 records in a total of the data collection. These data were split into a training dataset and test dataset. All data were processing with Java in Weka version 3.8.4, which is a favorite free tool for data mining. The result of this process are the association rules for route recommendation. The efficiency of the developed model was measured. At this process, the 10-fold cross-validation technique was conducted to evaluate the model's effectiveness in terms of accuracy. These efficiency values are famous and used in [16][17], which can be calculated in (1).

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \quad (1)$$

Where:

TP refers to the path that reaches the destination is true, with a given path that allows reaching the destination true.

TN refers to the path that reaches the destination is false, with a given path that allows reaching the destination false.

FP refers to the path that reaches the destination is true, with a given path that allows reaching the destination false.

FN refers to the path that reaches the destination is false with a given path that allows reaching the destination true.

Moreover, with the use of the black box testing, the walking stick system for navigating the visually impaired people was evaluated by nine experts in information technology and health care, and thirty-three volunteers who are the blind or people with unclear vision, and they have used or are using a walking stick and have it. The black box testing has been widely used for testing a system, which does not require the recognition of internal processing.

The criteria of the evaluation indicators in the black box testing included: 1) functional testing, 2) compatibility testing, 3) usability testing, and 4) performance testing. In terms of scoring, it was based on the Likert-scale [18] principle, as shown in Table 1.

TABLE 1
THE SCORING CRITERIA FOR EVALUATING THE WALKING STICK

Scale	Range of weighted mean	Meaning
5	4.51 – 5.00	The highest
4	3.51 – 4.50	The high
3	2.51 – 3.50	The medium
2	1.51 – 2.50	The little
1	1.00 - 1.50	The least

The evaluated data were analyzed to mean value with the standard deviation (SD) [19][20]. In order to acknowledge that the evaluation results are in the same direction and are acceptable with consensus, these data were analyzed in the quartiles, including quartile 1 (Q1), quartile (Q3), interquartile range (IQR), and the quartile deviation (QD) [21][22] with the median as the based value for comparing the difference of quartiles.

3. RESULTS

The confusion matrix results of the developed model testing by 10-fold cross-validation was shown in Figure 5.

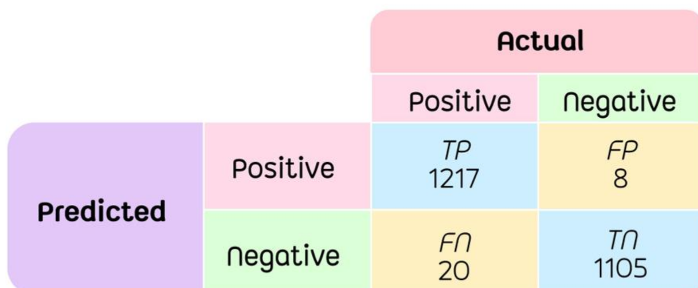

Fig. 5*. The confusion matrix table of route recommendation.*

According to (1) in the previous section, the efficiency of the developed model for the route recommendation of each trip from the behavior of using the walking stick of thirty-three people over thirty days showed that the accuracy of a walking stick with the route recommendation was 98.81%. The results of efficiency evaluation by black box testing of the walking stick for blind navigation are illustrated in Table 2.

TABLE 2
THE EVALUATION RESULTS OF THE WALKING STICK BY EXPERTS AND USERS

Criteria topic of evaluation	Mean	SD	Quartiles			IQR	QD	Meaning Level
			Q1	*Median*	*Q3*			
Experts								
1. Functional testing	4.56	0.53	4	5	5	1	0.5	The highest
2. Compatibility testing	4.56	0.53	4	5	5	1	0.5	The highest
3. Usability testing	4.56	0.53	4	5	5	1	0.5	The highest
4. Performance testing	4.44	0.53	4	5	5	1	0.5	The high
Total	**4.53**	**0.51**	**4**	**5**	**5**	**1**	**0.5**	The highest
Users								
1. Functional testing	4.76	0.44	5	5	5	1	0	The highest
2. Compatibility testing	4.52	0.51	4	5	5	0	0.5	The highest
3. Usability testing	4.76	0.44	5	5	5	1	0	The highest
4. Performance testing	4.45	0.51	4	5	5	0	0.5	The high
Total	**4.62**	**0.49**	**4**	**5**	**5**	**0**	**0.5**	The highest

Regarding Table 2, in terms of the evaluation by the experts, functional testing, compatibility testing, and usability testing had the highest mean of 4.56, with a standard deviation of 0.53. Furthermore, security testing had a mean value of 4.44 and a standard deviation of 0.53. For the results of evaluation by the users, functional testing, and usability testing both had the highest mean of 4.76, with a standard deviation of 0.44. Second, compatibility testing had a mean of 4.52 and a standard deviation of 0.51. Security testing had a mean value of 4.45 and a standard deviation of 0.51. Overall, according to the system evaluation, the developed walking stick evaluated by the users received higher mean values for all criteria than of the evaluation by experts. The developed walking stick evaluated by the users had an average mean of 4.62 and a standard deviation of 0.49. While the developed walking stick evaluated by the experts, it had an average mean of 4.53 with a standard deviation of 0.51. Furthermore, the evaluation results were assessed according to the principle of user acceptance. The IQR and the QD were applied in this evaluation. All IQRs were not higher than 1, which conformed to the QD where no one was higher than 0.5. It can be implied that users accepted the developed walking stick. The system evaluation results regarding user acceptance are illustrated in Figure 6.

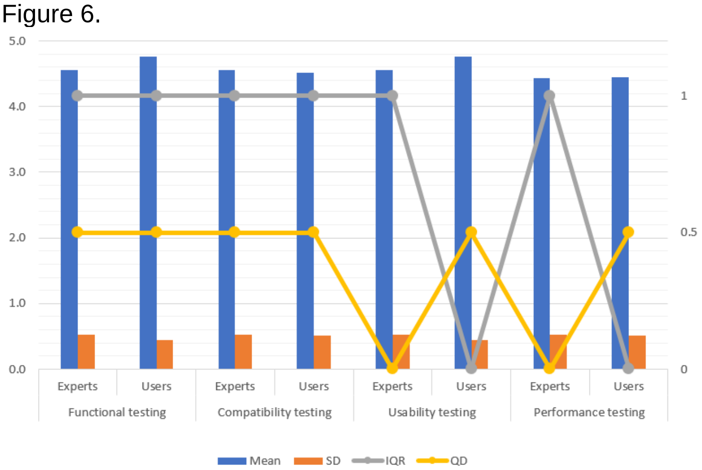

***Fig. 6**. Comparison results of efficiency evaluation by experts and users.*

4. CONCLUSION

This research introduces the development of walking stick for blind navigation towards the application of the IoT devices and sensors, speech recognition, and Apriori algorithm for improving the walking stick to help navigate for the blind person. These walking stick can detect objects and hindrances which are located either above or below. That is to say, whenever the system detects an object or a blockage, it will send an alarming signal in the form of alert sound, including vibrating alerts from a walking stick. Moreover, it can also suggest appropriate daily blind pathways from individual blind behavior. While each user may use the developed walking stick to reach his or her requested destination, he or she can utilize voice commands to set destinations. The walking stick will interpret the voice commands into the destination names, and the audio data will be converted and sent to the central server. The central server then processes the voice commands by converting speech to text in Web Speech API. Voice commands which have been converted to text will be delivered to 'Search' for travel directions via Google Maps API. Lastly, the map direction information will return to the walking stick to navigate the user. Besides, the developed system was evaluated towards the use of black box testing in the areas of functional testing, compatibility testing, usability testing, and performance testing. There were forty-two evaluators, including nine experts and thirty-three end-users who are blind persons. The findings revealed that the total average mean of the system evaluated by the users was higher than by the experts. Regarding the evaluation by users, the total average of mean was 4.62, and the standard deviation was 0.49. In terms of the evaluation by experts, the total average of mean was 4.53, while the standard deviation was 0.51, indicating that the developed walking stick was effective at a high level with high consensus. Because of the values had the interquartile range no more than 1, and the quartile deviation no more than 0.5 concerning the four assessment indicators. It can be concluded that the development of the walking stick for blind navigation towards the application of the IoT can support, enhance, and play a significant role in the daily life of visually impaired people at a high level.

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