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Research paper

Design and Implementation of Blind Runner Guide Android Mobile Application for the Visual Impairment User Experience

Rosa Andrie Asmara[1]*, Fais Al Huda[2], Anik Nur Handayani[3]

[1]State Polytechnic of Malang, Indonesia
[2]Brawijaya University Malang, Indonesia
[3]Universitas Negeri Malang, Indonesia
**Corresponding author E-mail: rosa.andrie@polinema.ac.id*

Abstract

Visual Impairment persons have the disadvantage when they try to walk straight without any active or passive guidance. They usually tend to walk with circle path how hard they try, this is called veering behavior and it is nature in human instinct. For walking, most visual impairment persons will use at least a support cane for their walking guidance. In Running Athletics para-competition, visual impairment athletes did not use a support cane, they will use human assistant and run together beside them. The athletes will hold tether where the other end were held by the assistant, whose called sighted guide. Some visual impairment school in Indonesia have some difficulties to train their runner athletes, one of them is the limitation of human running assistant provide by them. Blind Runner Guide Android Mobile Application offering one great feature for the visual impairment persons. This application will assist users to stay straight during their walk or run. This application still however can only be used for straight run competition, not circle athletic path which is usually used in international standard competition. This paper review the Visual Impairment user experiences using the application. From the experiment results shows that the application could reduce more than 50% percent of veering behavior. Experiment results from the short version UEQ shows 1.625 mean pragmatic quality score (good benchmark), 0.625 hedonic quality score (bad benchmark), and 1.17 overall quality score (above average benchmark).

Keywords: *Visual Impairment persons, Veering Behavior, Blind Runner Guide android application, User Experience Questionnaire.*

1. Introduction

1.1. Background Study

Visual Impairment is the the decreasing ability to see the actual environment and usually could not be fixed by ordinary means, such as glasses or contact lenses. Some references also defined as the best corrected visual acuity of worse than either 20/40 or 20/60 [1]. Complete loss of see from Visual Impairment is called Blind. As of 2015, almost 1/7 people on earth having a variant type of visual impairment [2]. 250 Million people are on low vision and almost 40 million are totally blind. Most of people with low vision capabilities are living in the developing country and over 50 years old age. The percentage of people having visual impairment are decreasing since 1990s [3]. World Health Organization (WHO) also estimates that most of visual impairment persons is preventable with some treatment and medication. Many people can cured their visual impairment from visual rehabilitation, changes in their environment, and using some assistive devices [3].

Most common causes of visual impairment happen from the internal eye factor such as refractive error (43%), cataracts (33%), and glaucoma (2%). Other caused by external factor such as age related macular degeneration, diabetic retinopathy, corneal clouding, childhood blindness, and some other infections. This cases are called cortical visual impairment [3].

Many people with visual impairment can go for travel by themselves, using some means. Mobility specialists are professional specifically trained to teach visual impairment persons to travel alone safely and independently at home or outside. Mobility specialist could also train visual impairment to practice travelling on routes used often by them, such as a route from house to the train station. One important requirement for visual impairment to travel alone is to memorize their route by themselves. They also usually used some tools to assist their walking, such as white cane and long cane. A long cane is usually used to extending range of the users. Cane is used by swinging in low sweeping motion to detect front obstacles. Some people using active assistive guider to helps their mobility, such as other persons or dogs. The dogs already trained to avoiding obstacles, and to assist whether it necessary to go up or down in stairs or escalator. The dog having a limited to guide on complex directions. Some mobile application also developed to assist visual impairment people, such as Corsair GPS, Cydallion, Lazarillo, ANGEO, etc. these application can assist with some navigation, since they are using MAPS API provided for public such as Google Maps API or OSM API. However, this application is very dependable with GPS sensors and will have limitation when it is used inside the building or closed area.

Visually impaired running athletes using sighted guide in the event, to whom attached by a tether. The sighted guide is compul-

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sory since the human nature while running or even walking were affected by the Veering behavior. Veering behavior is an inability to maintain a straight path and will caused disadvantages consequences for visual impaired persons. The path usually will make circles route how hard the blind person try to walk straight [4].

1.2. Research Purpose

This research proposed is the design and development of Blind Runner Guide mobile application to reduce the veering behavior on visual impaired persons.

2. Background Study

This sections discuss other blind guidance mobile application and other related previous study.

2.1. Previous Research

Previous research related with waypoint navigation tools are done by some scholar[5][6][7][8]. Many studies cited in [8] shows the GPS sensors feasibility usage. The GPS will locate visual impaired users in outdoor environments. This will guide them through the routes, and providing some information about closed points of interest. Many GPS navigations application are available now, including the world most popular Google Maps free mobile navigation application.

Some wearable embedded systems are developed specially for visually impaired persons. One of the developed systems using some components, which are microcontroller board, various sensors, cellular communication and GPS modules, and solar panel worn on the wrist [9]. The systems employ some sensors to track the path and alert the user of obstacles in front of them. The user is then warned by buzzers sound and some vibrations. The system also has capabilities to alert surrounding people when the user requires assistance, and give alert along with the location to the family or caregivers registered phone number. Smart walking cane for the visually impaired persons also have developed by Murali et al [10]. The conventional cane is then completed by Mobile application developed to avoid Veering behavior are done by Paneel et al.[11]. This research build for Iphone IOS Mobile System. This system used Gyroscope as the sensors to guide the straight direction. They claimed that the previous system is using compass as the sensors and have very limited capabilities due to easily influenced by magnetic inference from environment, e.g. cars, power transmission lines, or even human heart signals. However, this application tends to assist visual impaired user on their walks, which is often distracted by many magnetic field in the pedestrians' path. Some limitation also occurs after some trial of the application, causing gyro drift and affecting gyroscope sensors measuring accuracy. The position also limited to holding in a flat position, and will affect to the accuracy if the device is not held in the flat position.

Some research are focusing on sensor platform mounted on the white cane used by the visually impaired [12] [13]. The sensor platform developed consist of an Ultrasonic sensor and an IMU (Inertia Measurement Unit). The ultrasonic sensor used to measure distance between sensor and the front object while the IMU provides yaw angle of the sensor with respect to an initially calibrated reference frame. IMU is used to detect the orientation of the white cane. The model is demonstrated to have an overall accuracy of 84%, with accuracy as high as 90% for obstacles within 50cm in front of the user [12].

2.2. Microelectromechanical systems (MEMS)

MEMS is a nano technology that provides micro fabrication to create a micro-mechanical or micro-electronic component. MEMS today characteristics are made up device in 1- 100 micrometers in size. MEMS circuit range from 0.02 to 1.0 mm in size. This system consists of central processing unit and I/O unit such as microsensors [14]. Some of material used in major MEMS devices are Silicon for most Integrated Circuit and metal closed superconductor like such as gold. Accelerometers and magnetometer in smartphone are one of commercial application of MEMS device. In the near future, the scale of MEMS will also be decreasing due to the user demands for micro devices.

2.3. Motion sensors

Smartphone device especially Android OS based smartphone provides some sensors which can be used to monitor smartphone motion. Some motions either hardware-based or software-based are gravity, linear acceleration, rotation, significant motion, calculate the steps, and sensor for detecting step. As for accelerometer and gyroscope sensor are hardware-based. Most android based smartphone are equipped with accelerometer and gyroscope sensor [15]. The software based sensors is usually rely on one or more hardware sensors to derive the data.

Sensors used in smartphones, especially those using android operating system is divided into two kinds of hardware-based sensors or commonly referred to as raw sensors, and software-based sensors are commonly referred to as synthetic sensors [14]. Software-based sensors are sensors that do not have a physical form directly, but this sensor is the result of data manipulation of one or more hardware sensors [14].

A magnetometer is a sensor that can detect and measure the effects of the Earth's magnetic field [16]. It will measures the magnetic flux density at the point where the sensors placed. The magnetic field will drops its intensity with cube of the distance from the object. Maximum distance that the sensor could detect the object is proportional with the cube root of magnetometer's sensitivity. This sensitivity is measured in Tesla unit. The magnetometer sensor in smartphone or tablet is utilizing solid state technology creating a Hal-effect sensor that could detects the Earth's magnetic field in three perpendicular axis X, Y, and Z. The voltage produce by hall-effect sensor is proportional with the polarity and strength of magnetic field along the axis sensor. This voltage is then converted to digital signal and represents the magnetic field intensity. The magnetometer in embedded in nano electronic circuit and incorporate another sensor (usually accelerometer) which improve the raw magnetic measurements accuracy by tilt information in auxiliary sensor. In a general term, magnetometer can be used to detect the relative orientation of the device with the Earth's north magnetic [17].

2.4. Signal Filtering

The magnetic field intensity from magnetometer need to be filtered due to noise produce by any other frequency inference. some noise that is need to be removed is the measurements of any metal surrounding the device, such as vehicle, indoor and outdoor position, ambient and temperature noise, etc.

The proposed research will use Low pass filters to filter signals. The signals passed through a low-pass filter to remove high frequency of noise components. The filter works by passing the signals with a frequency lower than a selected cutoff frequency and attenuating signals with frequency higher than the cutoff. The formula for low-pass filter is shown in Equation 1.

$$y_i = \alpha x_i + (1 - \alpha)\, y_{i-1} \quad (1)$$

Where the α value is the cutoff value of the frequency that one want to pass. The cutoff need to be verified on different smartphone brand and different hardware specification. This step can be occupied by calibrating the sensors before the application start to used. The signal passed from low pass filter are then smoothed using FIR (Finite Impulse Response) Moving Average Filter. The fiter takes W samples of input at any time and takes the

average of W-samples and producing a one output value. This is very simple and low computation cost method to filter noisy component of the intended data. As the length increase, the smoothness also increases, where the sharp transitions are increasingly less sharp. The filter performing three function:

1. Takes W input value, calculating the average of those W-points and will produce one output value.
2. Some delay time will also happen due to the calculations
3. This filter acts as low pass filter.

The moving average filter is added in discrete form as shown in Equation 2. The equation for moving average filter input of W-point discrete-time represented by the vector m and the output vector m_w, is

$$m_w(x) = \frac{1}{w} \sum_{i=0}^{W-1} m(x-i) \quad (2)$$

2.5. Speech synthesis

Speech synthesis is the system tends to produce human speech from computer system. This system is called a speech computer or speech synthesizer. One of the speech synthesis application is a text-to-speech system which convert normal text into speech [18]. A text-to-speech (TTS) engine is divided in two parts: frontend and backend part. Two tasks in frontend are converts text contain numbers and symbols into its equivalent words. This preprocess part is called text normalization or tokenization [19]. The frontend is then assign transcriptions to word, and dividing the text into phrases and sentences. This process are often called text-to-phoneme conversion. Output of the frontend part is symbolic linguistic representation. The backend part usually called the synthesizer converting the symbolic linguistic into speech. the text to speech stages are shown in detail on Fig 1.

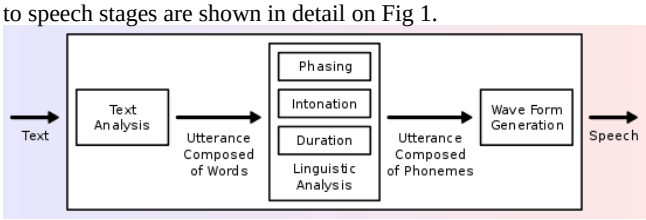


Fig. 1: Text to speech system overview

The proposes research is using Google Text-to-Speech API as the speech synthesis technologies which is developed by Google Inc. this application is specifically developed for Google Android operating system. It can read aloud the text and support many language including Bahasa Indonesia. Cloud Text-to-Speech also developed progressively by Google Inc. and will be our consideration to be used in the next upgrade development system. The TTS system is suited for visual impaired persons which have difficulty to read character. This system also performed well on fast output information for walking or even running stage notifications.

2.6. User Experience Questionaire

User experience questionnaire (UEQ) was first developed in German version on 2005. To ensure a relevance of the practical scale, a data analytical approach was used. Each scales determines a distinct aspect of a product. The UEQ use seven stage to reduce a central tendency bias for every question. This items are scaled from -3 to +3 whereas -3 represents worst case, 0 for neutral, and +3 for the best answer [20].

The scale structure for UEQ consist of 6 different scale with 26 items [21]. These 6 scale are:

1. Attractiveness, to score the product overall impression.
2. Perspicuity, to score the product easily familiarity.
3. Efficiency, to score the user effort to use the product.
4. Dependability, to score the user interaction with the product.
5. Stimulation, to score the excitement to use the product.
6. Novelty, to score the creative and innovative of the product.

Attractiveness is related with user psychology (valence dimension). Perspicuity, Efficiency, and Dependability are somehow related with aspect of pragmatic-quality (goal directed). Stimulation and Novelty are aspect of hedonic-quality (not goal directed). However, UEQ short version consists of 8 items was used in this research [20]. Table 1 below shows the short version of UEQ used:

Table 1: UEQ English Short Version

obstructive	o o o o o o o	supportive
complicated	o o o o o o o	easy
inefficient	o o o o o o o	efficient
confusing	o o o o o o o	clear
boring	o o o o o o o	exiting
not interesting	o o o o o o o	interesting
conventional	o o o o o o o	inventive
usual	o o o o o o o	leading edge

Benchmark graph will classify blind runner guide application into 5 categories [20]:

1. Excellent: in the area of 10% best results.
2. Good: 10% of benchmark dataset results are better and 75% worse results.
3. Above Average: 25% of benchmark results are better than the evaluated product results, 50% worse result.
4. Below Average: 50% % of benchmark results are better than the evaluated product results, 25% worse result.
5. Bad: in the area of 25% worst result.

2.7. System Overview

The proposed system developed on Android operating system based smartphones. The main purpose of the blind runner guide system is to assist user walking straight to reduce the veering behavior. Blind runner guide system utilizing two sensors on the smartphone which are magnetometer and accelerometer sensors. These sensors are then filtered to reduce and smooth the sensor signal. These sensors also have to be calibrated for the first time usage due to some parameter adjustment on the filter. The notification to the user will be spoken aloud using Google Text-to-Speech API. There are several processes start from acquiring signal data from magnetometer and accelerometer sensors, filtering noise sensor data using low-pass filters and smoothing the signal using Moving average filter, then correcting magnetometer data utilizing information from accelerometer sensor to determining compass direction. The signal processing from sensors is illustrated in fig. 2.

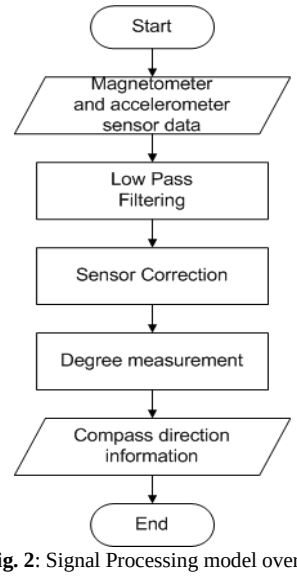


Fig. 2: Signal Processing model overview

3. Implementation

The development of blind runner guide applications performed using the 7.0 Android operating system version (code: nougat). To be noticed that this is not limited to be used in 7.0 version only, rather support for previous versions as well since of the native functions have been supported by android. The smartphone device must have magnetometer and accelerometer sensor to used blind runner application. For the specifications of smartphone hardware used in this study are described in detail in Table 2. Some of the Smartphone brand used for the experience are Xiaomi Mi 5 and Samsung Galaxy J7 Pro smartphone.

Table 2: Recommended Hardware spesification

No	Component	Value
1	CPU	1.4 GHz
2	RAM	4 GB
3	Magnetometer	100 Hz
4	Accelerometer	200 Hz

The Hertz (Hz) unit used in Magnetometer and Accelerometer sensor is the standard frequency unit to define the number of signal cycles per unit time (second). More frequency specification on the sensor will perform more sensitive perceiving its environment. With the more amount of signal cycles it can be used to produce more accurate signal acquisition. Fig 3 below shows the magnetometer data plot from blind runner application. The data already filtered and smoothen using the filter described in the previous sub section.

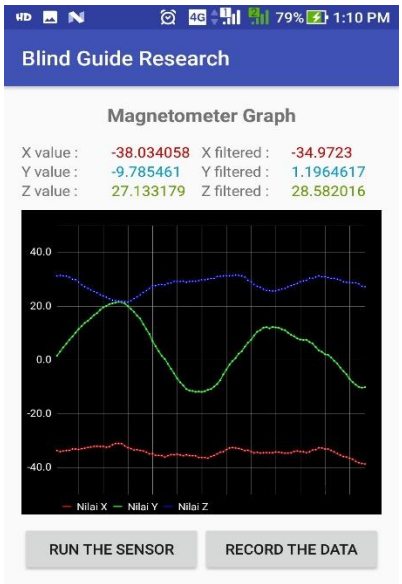


Fig. 3: Magnetometer data visualization from application

3.1. Experiment Setup

Some considerations are performed before the experiments taken. First is the surrounding environment. According to several surrounding environments, the application signal acquisition performed well on wide indoor environment. This could happen because on outdoor environment, some external metal object will cause the significant false signal reading on magnetometer. Wide indoor hall will keep the device have some space with metal object. Flat no slope and ceramic type floor is used, with wide no obstacle object to prevent subject hit and injured during experiment. Second consideration are the distance of the walk performed. In this experiment, we try for 5 and 10 meters and analyze both distance to compare the application performance for visual impaired person walking stage without any assistive device or person. Third consideration is the position of the device. In some trial, it is recommended to have device in perpendicular position, whether it is face-to-face or not. In the next experiment, the development will focus on positioning the device inside the clothes front pocket of the user. Four consideration is the type of users. The experiment will use 4 visual impaired persons which have total blind and almost total blind. These persons perform daily walking using white cane. These 4 persons asked to walk straight in 15 meters with no white cane nor assistive normal person surrounding them. Most of them could not perform walking straight direction properly. The 4 persons used as a subjects are the students of State University of Malang, Indonesia with visual impaired condition.

3.2. Navigation Lock threshold

After the calibration of the sensor, the next step for the application is to determine which direction user will head. They could perform this direction by lock the direction in specific point represents by compass needle graphs. After the determination of the direction point, user can press lock button provided in the bottom of compass graph. the direction point will represent by compass degree of earths pole magnetic field direction. Filtered accelerometer and magnetometer sensor also previewed in the interface window. The user interface window for direction lock stage shows in figure 4. One the user walking straight, the application will read user direction overtime. The declination allowed in the experiments is below 10 degrees. If the user walking direction declination more than 10 degrees right or left, the application will notice the user to direct in opposite left or right direction. The notification performs using Google TTS API.

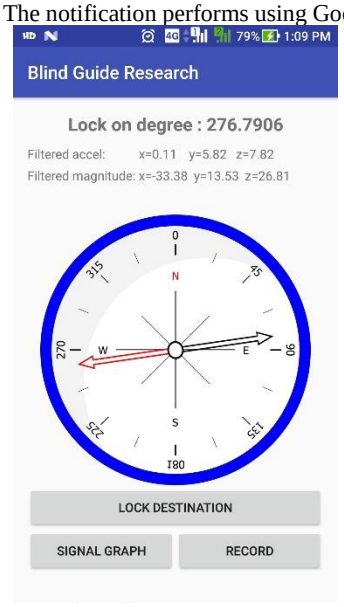


Fig. 4: User Interface of directional lock on the application

4. Result and Discussion

The experiment results of Blind Runner Guide android application evaluate some important information needed for the next improvement development of the application. Some information related with user experience are the notification for turn left or right speech using too long sentences, degrees of declination threshold is too small, and no voice command over lock direction button. Figure 6 below shows the veering behavior experiment data acquisition event in indoor area. Table 4 below shows the User Veering experiment without any assistive device or other person. This table shows 4 different visual impaired persons A, B, C, and D. Minus value mean left declination. Table 5 below shows the Veering behavior experiment with Blind Runner Guide Application. From both Table 4 and Table 5 shows that some significant difference were occurs on visually impaired persons veering behavior. During the experiments, some event has to be eliminated before the data acquisition recorded. Several subject seems to worry for walking straight without using any assistive device or normal person assistant. They used to use those assistive device, and when they are not using it they somehow feel hit some obstacles during their walk. Before the data acquisition process is done, subject need to walking straight training without any assistive device several time. After some training, they have got their confidence to walk without any interrupting nor obstacle in front of them. On start line, there are one person to direct subject to straight point. on finish line, there are one person to stop the subject to walk forward. From the experiment results, we conclude that some subject could not be significantly reduce their veering behavior due to some factors. Those factors are different response time for each user to the audio notification of the system, delay time of the audio notification system, user feedback declination which is different declination degree response for each user, and device position extreme shifting or changing due to walking events. From the overall veering behavior experiment results, we can conclude that Blind runner guide application can significantly reduce visually impaired persons veering behavior.

From the UEQ of 4 visually impaired persons, we can obtain mean score, benchmark comparison results, and interpretation for each Pragmatic Quality, Hedonic Quality, and Overall Quality as shown in Table 3.

Table 3: Mean Score for each quality

Scale	Mean	Comparison to benchmark	Interpretation
Pragmatic Quality	1.625	Good	10% of results better, 75% of results worse
Hedonic Quality	0.625	Bad	50% of results better, 25% of results worse
Overall	1.17	Above Average	25% of results better, 50% of results worse

Benchmark graph for short version UEQ of Blind runner guide application is shown in Figure 5 below.

Table 4: User Veering Experiment without any assistive device or persons

Data Acquisition	Distance	A	B	C	D
1	5 meter	-1.77 m	0.74 m	0.25 m	0.56 m
	10 meter	-0.3 m	0.15 m	0.15 m	0.27 m
2	5 meter	0.45 m	0.25 m	0.15 m	0.34 m
	10 meter	0.75 m	0.25 m	0.25 m	0.25 m

Table 5: User Veering Experiment with Blind Runner Guide Application

Data Acquisition	Distance	A	B	C	D
1	5 meter	-0.15 m	0 m	0 m	0.15 m
	10 meter	0.3 m	-0.2 m	0 m	0.1 m
2	5 meter	0.4 m	0.2 m	0 m	0.15 m
	10 meter	0.4 m	0.2 m	0.3 m	0.2 m

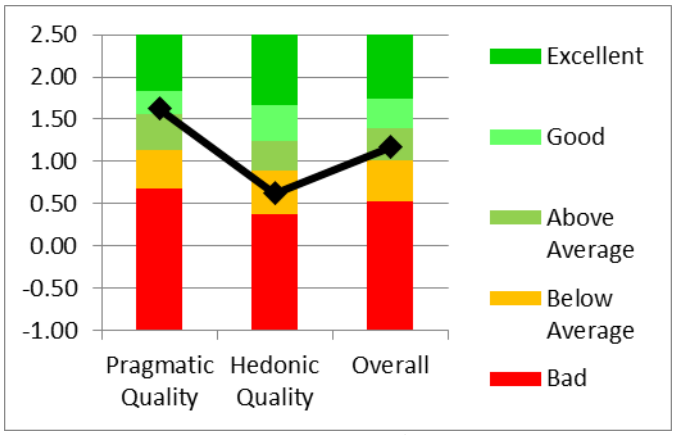


Fig 5. Benchmark graph short version UEQ of Blind Runner Guide Application



Fig. 6: Veering Data acquisition with Visually impaired persons

5. Conclusion

Design and implementation of blind runner guide android mobile application with declination lock audio notification for walking straight have been tested and proofed to significantly reduce veering behavior of visually impaired persons. From the experiment results Table 4 and Table 5 shows that the application could reduce more than 50% percent of veering behavior. Experiment results from the short version UEQ shows 1.625 mean pragmatic quality score (good benchmark), 0.625 hedonic quality score (bad benchmark), and 1.17 overall quality score (above average benchmark).

For the next development, one can focus on solve some problems occurs during the experiments event mentioned and test the results.

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