Virtual Walking Stick: Mobile Application to Assist Visually Impaired People to Walking Safely

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Abstract. People affected by temporary visual limitations or early permanent limitations have the challenge of adapting the way to perform their daily tasks. In particular, the activity of walking without support of others not only requires extensive adaptation but also can expose individuals to the risk. For instance, if an object is not identified during the walk, serious accidents may happen. Therefore, assist blind people to walk independently and safely is an important challenge for computational area. With the popularity of smartphones, cameras and new sensors are available at affordable prices and can be used to develop software to help visually impaired people to walk more independently and safely. This paper presents the development of a mobile application to help visually impaired people to walk independently, using the smartphone's camera to alert them about obstacles on the way.

Keywords: impaired vision, walking stick, indoor navigation, safe walk.

1 Introduction

Reports of the WHO (World Health Organization) in 2010 show that about 285 billion people in the world have some type of visual problem. The visual limitations can range from simple cases that can be solved with the use of glasses, by going through cases where the field of vision is reduced, until the more severe cases that include complete blindness. Besides the variation in severity, the visual limitations can be permanent or temporary. People affected by temporary visual limitations or early permanent limitations have the challenge of adapting the way to perform their daily tasks. A special challenge is to avoid object or obstacles during the walking.

In particular, the activity of walking without support of others not only requires extensive adaptation but also can expose individuals to the risk. For instance, if an object is not identified during the walk, serious accidents may happen. Therefore, assist people with visual limitations to walk independently and safely is an important challenge for computational area. The HCI (Human-Computer Interaction) research area has made several contributions to assist people with visual limitations, such as: Interfaces with varying colors and contrasts, text readers, audio messages, voice command

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systems and so on. However, the popularity of smartphones has brought new challenges to establishing appropriate functionality for users with visual limitations, such as the touch screens and the increasing number of apps. In recent years, smartphones have tended design where physical buttons are replaced by virtual icons that increase the amount of features on smartphones. However, the lack or reduction of physical buttons on smartphones limit the use of touch to identify shortcuts to specific applications. Some applications still use the few buttons or labels available references such as the edges of the screen to activate a limited set of applications. The second challenge is the increasing number of applications installed on a smartphone and the need to navigate through screens to locate the desired application. On the other hand, smartphones provide a set of sensors that can be used to create smart shortcuts. This scenario shows the need for creating applications that not only assist in daily activities such as walking independently but also be user-friendly applications for visually impaired.

This paper presents the development of a mobile app to assist visually impaired to identify and avoid obstacles along the way.

2 Related Work

Several works have been developed to create devices and software to assist visually impaired people to walk independently and safely. These works can be classified into indoor and outdoor solutions walking. In general, the solutions to outdoor walks [1] use GPS to guide the user. However, the use of GPS limits the use of these solutions to outdoor locations. This limitation has motivated the search for solutions that guide the user in locations without GPS signal. Typically, solutions for indoor walking are based on some kind of infrastructure to guide the walk. As the use of RFID [2-5] tags, Wifi [6,7] or visual paths based on maps [8] or marked [9,10] paths. These solutions produce specific solutions, such as assisting users to find a way out of a building. However, the generalization of these solutions is not a trivial task. Even its reproduction on a large scale is limited by the cost of deployment of the infrastructure needed, such as installing landmarks or sensors [11].

3 Methodology

The application was developed for Android platform using the SDK API 19. In order to offer an affordable solution, this app was created to only use smartphone built in sensors/device such as autofocus camera and accelerometer. The interface was designed to follow recommendations of NCAM – National Center for Accessible Media. In special, the VWS do not depend of visual interface. All functions are available using gesture command or tactile buttons. Also, there are features to save energy.

The tests were performed using the Samsung Galaxy S4 phones with Android 4.4 and LG Nexus 4 with 4.4.2 android smartphone.

4 The Virtual Walking Stick App

In our work, we develop a mobile app called VWS - Virtual Walking Stick. In order to achieve the proposed objective, the VWS app uses the smartphone's camera to identify objects and people ahead of the camera. In such cases, audible or vibrating alerts are emitted to indicate the object approaching or peoples in front of the user. The distance of the object or the amount of people in front of the user is indicated by the variation of intensity of alerts.

Considering the amount of applications installed on a smartphone, its mobility and its limitations of battery and interface, the application needs to go beyond the main goal, to alert the user to obstacles and people, and offer other usability features for people with limitations visual. In this sense, the VWS app addresses three important usability issues. The first is how to run the application without the use of visual icons. For this case, the VWS app can be activated by shaking the smartphone until an alert be emitted. The second issue is how to find the phone if it falls during use. Using the accelerometer, VWS identifies the fall and smartphone beeps to help locate it. The last point is to allow extended use of the application, without quickly draining the phone battery. Since much of the energy consumption of mobile phones is related to the operation of the screen, the application turns off the display to save power.

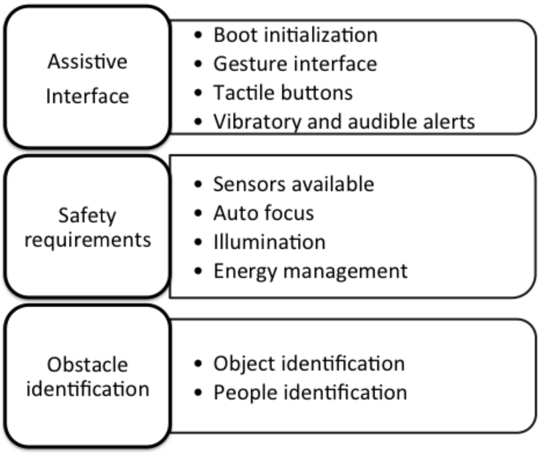

Fig. 1. VWS modules

As shown in Figure 1, the VWS is composed of 3 modules designed to provide the core functionality of the application, as described below.

4.1 Assistive Interface

Since the VWS was developed to assist visually impaired, their functionality and interface are designed to meet the needs of these users. Therefore, the VWS propose a non-visual interface, where gestures or tactile buttons can activate features. The application provides both vibration or sound/voice alerts.

Figure 2 shows the six approaches used by VWS to provide a non-visual interface. The first approach is to *Boot initialization*. It prevents the user from having to find a specific icon to launch the application. Once in memory, the selection between active apps is not an easy task. To simplify this task, we developed the *Shack Activation* function that allows the activation of VWS just shaking the smartphone. When activated, the VWS emits a voice message warning of its activation. The same happens when the application is minimized or closed. The third approach is related to the Vibratoty Alerts, they are used as discrete alerts that are not suppressed by surrounding sounds. The fourth approach is the *Audible alerts*. They allow the transmission of a larger amount of information to the user. The VWS always offers vibration or audible alerts. The selection of the type of alert to be emitted is made using Tactile Buttons. The VWS redefines the function of the volume adjustment buttons. Case these buttons remain pressed for more than 2 seconds; the audible messages are enabled or disabled according to your current status.

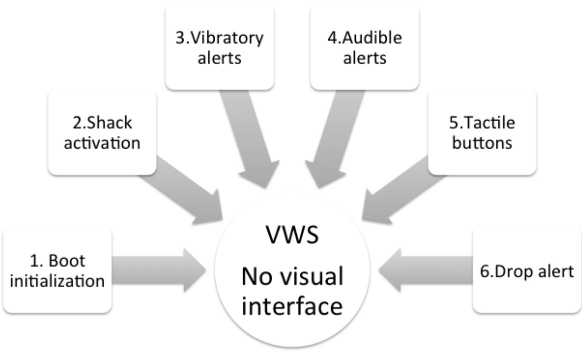

Fig. 2. VWS - No visual interface components

The sixth approach aims to alert the user if the smartphone falls. The drop alert uses the accelerometer to identify movements that might mean that the smartphone fell. In this case, an audible alert is sounded until the screen or any button is touched.

4.2 Safety Requirements

To ensure user safety, the VWS checks if the sensors are available and working properly on your smartphone. For example, although the vast majority of smartphones have built in cameras, not all make it possible to use the autofocus function of Android. In such cases, the application will not function properly and the user needs to be warned. Another limitation related to the smartphone camera is its ability to focus on objects. Figure 2 shows two examples where it is not possible to focus on objects. In figure presents two screenshots of the evaluation of the application interface, since the application does not require a GUI and as a way to save energy.

The screenshot to the left was captured in a situation of absence of light, so the screen is dark and shows the message - Unable to focus. The example on the right, a bright light prevents the focus. In this case, the display appears white and displays the same message - Unable to focus. These limitations have been reduced with the quality evolution of smartphone cameras. More and more cameras feature great capacity light compensation and tend to offer even night vision.

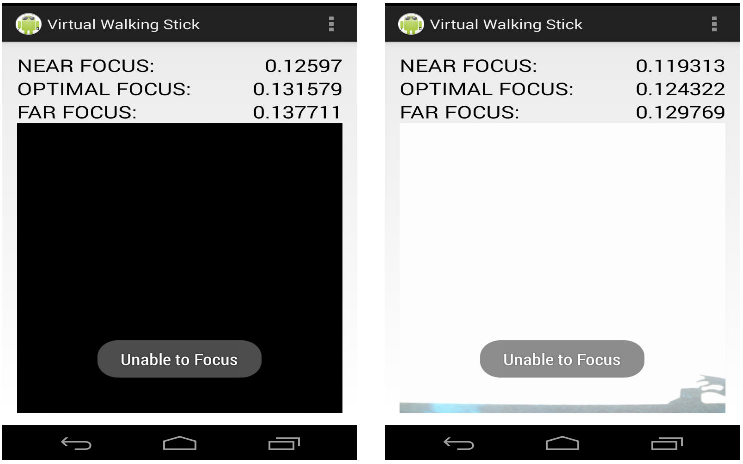

Fig. 3. Example of situation that the camera can not focus on object

Another safety issue is the power management of your smartphone. Despite the VWS reduce energy consumption by simulating the turning off the smartphone screen, the user needs to be alerted about the amount of energy available for your smartphone. Thus, situations where the battery runs out can be avoided.

4.3 Obstatacle Identification

The module of identification of obstacles is responsible for the identification of objects and people in front of camera. The distance between an object and the user is inferred using the focal distance of the object. This value is obtained by using the android method - `getFocusDistance`. This function provides values of 3 variables: Near Focus, Optimal Focus and Far Focus.

To reduce the amount of information to be transmitted to the user, we define three distance values: Near, Medium and Far. These values are based on values of Optimal Focus variable, as follow.

- Near - Optimal Focus ≤ 0.225194
- Medium - 0.225194 < Optimal Focus ≤ 0.304033
- Far - 0.304033 < Optimal Focus

Thus, an object is considered Near, when the value of the variable Optimal Focus is less than or equal to 0.225194. The object is considered Far, when Optimal Focus is greater than 0.304033. Values between 0.225194 and 0.304033 indicate that the object is at a Medium distance.

The vibrational frequency of alerts depends on the distance of the object. The more closely the object, the more intense is the vibrating alert. In turn, voice messages inform one of three distances for the object.

The Figure 4 shows a sequence of 3 screenshots captured during indoor walking toward a wall. The image on the left presents Optimal Focus value = 0.538894 and displays at the center of the screen the message - Far. At that moment a voice message informs the user that the object is far and vibrating alert has low frequency. The central screenshot shows that the user is closer to the wall with Optimal Focus = 0.251161 and displays the message - Medium. The screenshot at right shows the wall right near, Optimal Focus value = 0.225194 and the message - Near. In situations like this, the vibrating alert is issued at high frequency. Continuously, alerts are emitted when the distance is changed. The same behavior occurs when the user moves toward a closed door or any object.

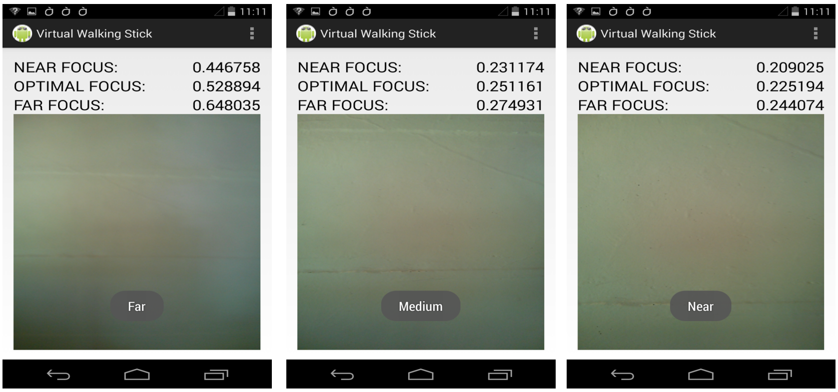

Fig. 4. Indoor walking – Sequence of screenshots of wall approaching

Figure 5 also shows a sequence of 3 screenshots. This time were obtained in a outdoor walk toward a tree. Similarly, as the value of the variable Focus Optimal increases, the messages and the vibrating frequency change.

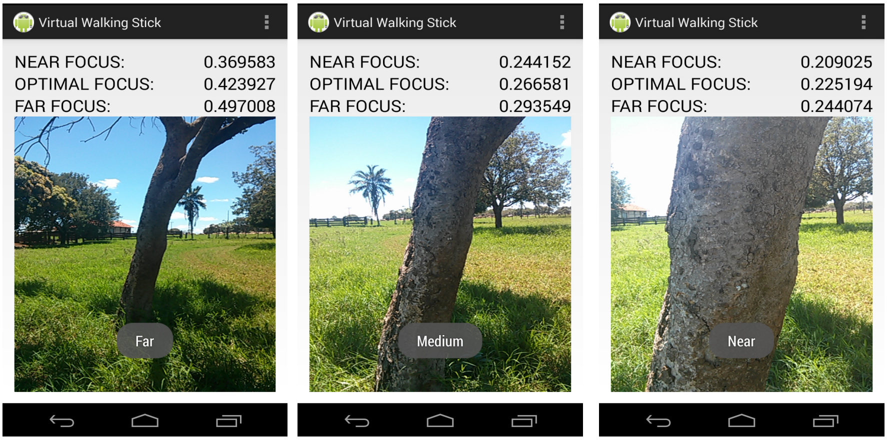

Fig. 5. Outdoor walking – Sequence of Screenshot of tree approaching

5 User Evaluation

For initial evaluation of VWS a qualitative study was conducted to analyse the opinion of individuals with normal vision when performing a walk on a circuit with obstacles and blindfolded to simulate a recent or temporary visual impairment. Therefore, such individuals have no training to use other sensory references as guidance for walking.

The experiment consisted of two walks in circuit with obstacles, always blindfolded and 5-minutes break between them. The circuit was formed by obstacles, walls, people, open and closed doors. The obstacles were chosen to simulate everyday situations. Soft and light barriers were used to prevent risk of injury to participants or fall. In addition, participants were closely monitored throughout the walk. The circuit remained the same for all individuals and walking. Each participant was instructed to walk at a comfortable pace, as if he/she were inside a home or office. It was also recommended to avoid collisions with obstacles. The first walk was performed without the aid of a cane or application. For the second walk, participant received a smartphone with VWS installed. Then he/she was asked to shake the smartphone and start the walk after to hear the message that the app was activated. At the end of the second walk, the participant was guided to an area with padded floor, where he was asked to leave smartphone fall to the ground and then try to locate it. All participants used the same smartphone. We selected 10 participants, 6 men and 4 women, aged between 25 and 35 years old, height ranging from 1.57 m to 1.78 m.

Table 1 shows the obtained results. For each walking, we recorded the time spent to complete the circuit and the amount of touches an obstacle, doors or walls.

Table 1. Description of participants and data collected during the experiment

				1st Walk without App		2nd Walk with App		Difference	
User	Age	Sex	Height (m)	Time (s)	Touches	Time (s)	Touches	Time (s)	Touches
1	27	F	1,63	52	8	119	9	67	1
2	32	M	1,73	82	7	134	9	52	2
3	33	M	1,78	77	13	108	8	31	-5
4	35	M	1,67	74	14	148	13	74	-1
5	35	M	1,66	80	14	165	10	85	-4
6	31	F	1,62	95	13	162	11	67	-2
7	31	M	1,71	102	18	178	12	76	-6
8	29	F	1,60	179	17	235	11	56	-6
9	28	M	1,69	86	13	235	10	149	-3
10	27	F	1,57	66	13	138	10	72	-3

Table 1 shows the Id of the participant, in sequential order of participation, age, sex, height, time taken to complete the task and number of touches on walls, doors and objects, on the both walks without and with the use of the VWS App, respectively. The column with difference of time between walks was calculated using the formula: 2nd Walk Time – 1st Walk Time. Therefore, positive values represent an increase in walking time using the VWS. The difference between obstacle touches was calculated with the formula: 2nd Walk Touches – 1st Walk Touches. Thus, positive values represent an increase in the number of obstacle touches when using VWS app.

The difference in time to complete the circuit showed that all participants needed more time used as the VWS. This increase in time can be explained, since participants started the walk more slowly to understand the relationship between the frequency of vibration and distance of objects. In some cases, the participant waited for a change in the frequency of prompts to continue the walk. Furthermore, we observed an increase in the pace of the walk at the end of the circuit. Regarding touches on obstacles, the comparison between the amounts of touches performed during walks, showed that only two participants increased the number of touches when using the VWS. Most of touches was a type of confirmation of the object presence and we could notice that as the participant felt more comfortable with the use of VWS, he tried to walk without touching the walls and obstacles, as initially oriented. Another examples of touches are the collisions caused by small changes in directions that did not avoid the collision with object.

After the completion of two walks, participants answered six questions such with open answers, as shown in Table 2.

Table 2. List of question used to evalute the use of VWS app

Id	Question
Q1	Compare your feelings/sensations during each walk.
Q2	Was the VWS app useful to identify and avoid obstacles?
Q3	Could you identify people during the app-assisted walk?
Q4	It was easy to find the smartphone after dropping it?
Q5	Did you use the audible alert to find your smartphone?
Q6	What are your suggestions for improvements to App?

Table 3 presents a summary of the responses to the 6 questions. As a strategy for the creation of Table 3, we seek to highlight the criticisms or comments that could assist in the development of the application.

Table 3. Resumo das respostas dissertativas

User	Q1	Q2	Q3	Q4	Q5	Q6
1	More safety	Yes	Yes	Yes	Yes	More/faster alerts
2	More safety	Yes	Yes	Yes	Yes	More/faster alerts
3	More safety with better results	Yes	Yes	No	Didn't work	Sharper alerts
4	Helpful	Yes	Yes	No	Didn't work	More/faster alerts
5	More safety	Yes	Yes	Yes	Yes	Continuous alert
6	Felt confused	Yes	Yes	No	Didn't work	Sharper alerts
7	More safety	Yes	Yes	No	Didn't work	Develop a smartphone's support
8	More safety	Yes	Yes	Yes	Yes	Increase vibration intensity
9	More safety	Yes	Yes	Yes	Yes	Sharper alerts
10	More safety	Yes	Yes	Yes	Yes	Allow

Evaluation of responses showed that users felt more secure through the use of VWS. Only the number 6 volunteer reported that she felt confused by the vibrating alerts. Despite this observation, all participants agreed that the application helped during walking. The identification of people addressed by Question 3, it worked in all cases. However, the drop alert, questions 4 and 5, failed 4 times. Users, who experienced this failure of the function, also reported difficulties in finding the smartphone. When the drop alert worked, the volunteers reported that the smartphone has been found easily. The combination of the answers to Questions 4 and 5 can be interpreted as an indication of the importance of the drop alert. Suggestions for improvements obtained with question 6 show that vibrating alerts may initially cause confusion, since we are not accustomed to using vibrations to guide us. However, despite the participants remember the feeling of confusion when suggesting improvements, they evaluated the application as useful and felt safer when using the VWS. This point will be evaluated more broadly with blind users who already have training to use different kinds of information to guide the walk.

6 Discussion

The VWS was developed for use native solutions of smartphones as cameras and accelerometer or face recognition functions. This approach allows the development of cost-effective and accessible apps for the user. Just install and use the application, without requiring externals devices or processes. A disadvantage of VWS is the need for smartphones with cameras sophistic. However, the evolution of smartphones shows that the prices of smartphone are reduced after a few months of its launch. Especially, when new competitors emerge in the market. The current version of VWS depends on the ability to focus of smartphone camera. Which does not occur in dark environments or lack of contrast, cases where the user is alerted. However, these limitations have been reduced with cameras with great capacity for light compensation.

7 Conclusion and Future Work

The VWS App makes use of sensors and processing power of modern smartphones to assist visual impaired people to identify and to avoid obstacles during the walking. Once, VWS only use smartphone camera to identify objects and peoples, it is ready to use, immediately after installation. None extra devises or infrastructure is required. Thus, it can be used to help walking at any place. Moreover, once the smartphone are become popular, this approach offers a low cost solution and easy to be scaled.

Furthermore, this paper contributes with a one of the main challenges of usability for visually impaired people presenting the development of an app with non-visual interface.

Our ongoing work aims to incorporate functionalities to identify known people, to recognition of voice commands, to describe objects and to guide long walks using GPS.

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