Braille-Coded Gesture Patterns for Touch- Screens: A Character Input Method for Differently Enabled Persons using Mobile Devices

M. Shabnam
Department Of Computer Applications
SRM University

S. Govindarajan
Department of Computer Applications
SRM University

ABSTRACT
Mobile phones play an important role not only in a normal person's life but also in the lives of visually impaired and differently enabled people. This research emerges and grows gradually in the field of interaction systems between mobile phones and visually impaired persons. This paper describes the new Braille-coded gesture interaction method of communicating with a mobile device through touch screens by differently enabled people based on the concept of gesture computing and Braille Write. Using Braille codes to perform gestures on touch screen makes the visually challenged person(s) comfortable because Braille is the basis for communication. The prototype for the gesture input method was initially developed with the Android OS because Android has an open source operating system. Hence, the method is named the Eyedroid interaction technique. Essentially, Eyedroid is designed as a 'screen-layout-less system' to help the visually impaired without experiencing spatial problems. Eyedroid was developed and used by many visually challenged persons. Data were tested with a few post-hoc methods, and the random character input time was two seconds when using our Eyedroid method. The Kirkpatrick comprehensive gesture input method training evaluation models obtain a cent percent easiness from 50% of subjects, cent percent adaptability from 60% of subjects, cent percent accuracy from 65% of subjects.

General Terms
Human Computing Interaction, Artificial Intelligence, Neural Networks, Interface Design, Android application

Keywords
Interface for blind, Text input method in mobile touch, Touch interaction system for visually impaired, Braille gesture input method

1. INTRODUCTION
The literature survey reveals the mobile interaction methods are numerous and adaptive at different environment. The Braille market world is not much more supporting for blind people in the economic aspect, and the Braille Touch [1] becomes the solution for that problem with adequate software performance. The methods for presenting Braille characters on a Mobile device[2] introduce three novel interaction methods scan, sweep, and rhythm which are considered to be the basic gesture based interaction methods for touch screen interactions; This method increase the single character input speed as the influence of Braille base. 'No-Look-Notes' [3] was the notable interaction method that increase much more the text input time. This method uses the 'Eight Wedge Screen layout' which has been adapted in the current mobile interface design solutions gaining Positive feedback from the users as ease of use. It has been derived from the research done by Shaun K Kane, Jacob O Wobbrock [4]. Their research mainly dealing with the matters about the visually impaired people expectations with the regard of gestures on touch screen and the solution they recommend is blind people like edge oriented gestures. Another interesting interaction method is Perkinput[12] developed by Shaun and Wobborock shows improved input speed by blind people with touch screen mobile phone; but the users find the drawback of this system is screen navigational system. Our Braille based interaction system has been developed with considering the screen navigational [12] limitation and gesture preference by blind people. Our 'layout-less-Braille-based mobile interaction method' greatly avoids the screen navigational problem

2. INTERACTION METHOD
The mobile text entry method mainly focuses on the input of a character/number using Braille code on a mobile touch screen. The primary situation in which a blind person can interact with the system is through gestures. All gestures are planned per universally known standards of Braille-based typing. Braille gestures mean swiping with the finger on any part of the screen or tapping with one or multiple fingers. This is the key point through which all other features of this system are undertaken for development. A Braille-coded gesture pattern primarily aims at providing seamless support to the input mechanism through voice feedback to help the input methods. The system guides at every doable moment the visually impaired and allows them to apprehend what is happening at this moment. Distinctive patterns are designed for every specific purpose such as alphabets, special characters, alternative functionalities, and numbers. The sound feedback system keenly concentrates on giving a provision to pay attention to this action being performed. Brian Frey, Caleb Southern, and Mario Romero introduce Braille code on mobile touch screen to open a way for reading text from a mobile touch screen. Jussi Rantala, Roope Raisamo, Jani Ylykangas, Veikko Surakka, Jukka Raisamo, Katri Salminen, Toni Pakkanen, and Arto Hippula introduce different interaction methods in the paper -Methods for Presenting Braille Characters on a Mobile Device with a Touchscreen and Tactile Feedback - which enables the visually impaired to read through haptic feedback and only the text from a mobile phone. They have designed the touch screen as a Braille device through which the visually impaired can only read the text by voice feedback.

2.1. Design of Character Input Method
The Braille system has two columns and three rows for which the system has been developed with several gestures or finger movements. The gestures are used to interact with the mobile touch screen, that is, the Android phone and with the gestures, one can enter alphabets and numbers. There are

five gestures considered as basic gestures to create multiple gesture patterns. The basic gesture patterns are given in the figure 1.

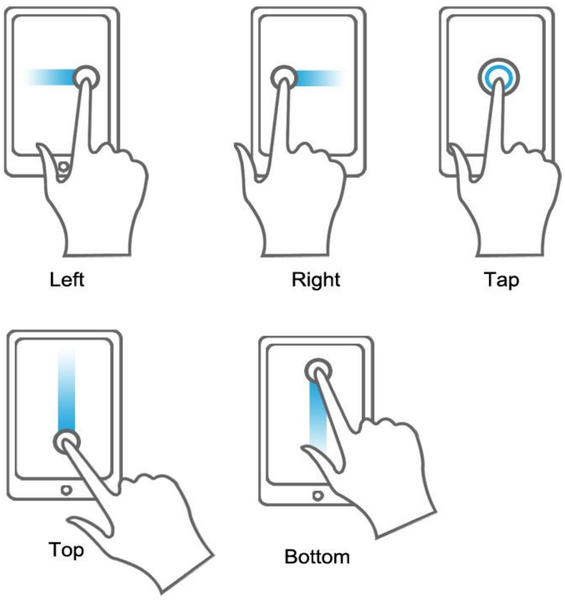

Figure 1.Basic gestures

Before we begin with the gestures, we will explain how our system is related to the braille alphabet. The reading braille system has two columns[8]. The first column has dots 1, 2, and 3, and the second column has dots 4, 5, and 6. We have arranged the system layout per the reading Braille system.

2.1.1. Reading Braille dots arrangements:

The first row has dots 1 and 4 from left-to-right.

The second row has dots 2 and 5 from left-to-right.

The third row has dots 3 and 6 from left-to-right

Table 1. Braille- Gesture Mapping

Dots in a row	Gesture to perform
Left-dot is active, right-dot is inactive	Swing Left-to-right
Right-dot is active, left-dot is inactive	Swing right-to-left
Both dots are inactive	Tap the screen with one finger
Both dots are active	Swing from bottom to top

When the Braille row is like - a dot on the left-side/first-column is activated, and the dot in the same row on the right-column is deactivated, then the finger has to swipe from left-to-right. For each character the Braille code consists of three rows, in the ratio of one gesture for on row, totally three gestures are given for three rows to input one character. We will provide an example of the alphabet A. The Braille dots are represented in figure 2. Table 1 shows the respective gestures for row dot representations; Table 2 shows gestures to write character A.

Table 2. Braille-Gesture of Character A

Gesture 1	Swing from left-to-right	For row 1
Gesture 2	Single Tap the screen with one finger	For row 2
Gesture 3	Single Tap the screen with one finger	For row 3

To enter the character A, the gestures, such as swing from left-to-right and single tap, single tap, are to be given on the touch screen of the mobile device. Each character needs three gestures. Namely, the user has to give three gestures to input a character. This is because the gesture patterns are developed based on 3*2 matrix Braille code rows. Each row needs one finger gesture on the touch screen, respectively.

2.1.2. Prototype Design-Eyedroid Implementation

The architectural design of the Eyedroid system is described in the paper "The Eyedroid frameworks" [11]. The user interaction module for the Eyedroid design is extracted in this research work. The interaction module Eyedroid consists of an interaction screen layout and audio feedback. The Eyedroid system enables the finger swing anywhere on the screen regardless of the screen corners. Namely, the user does not need to navigate the screen to select a particular object from the screen. For example, to select a character 'A' on the screen, the use can make the finger gesture anywhere on the touch screen. The screen layout is not explicitly designed, but it is designed implicitly. The external screen layout is blank, and the interior screen layout is considered as a collection of pixels.

The input parameters are:

1. 'Number of pixels covered in one gesture' is considered as Np,

2. 'Speed of gesture action' is considered as Sg,

3. 'Time Duration of one gesture' is considered as Tg.

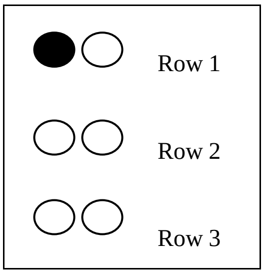

Figure 2 Braille for A [7]

The given gesture is understood based on the three parameters above by the system. The character input method utilizes the gesture pattern, i.e., a fling from left-to-right, a fling from right-to-left or anything from the set of five gestures mentioned in Table-1. The parameter values such as the Np threshold value is set as 100 pixels, the Sg value is set as 2000 pixels, and the Tg value is set as 1000 ms. Therefore, a gesture performed by an informant is recognized by the system as the finger gesture travels a minimum of 100 pixels in a minimum of 1000 ms with a minimum speed of 2000 pixels per second.

Threshold values of Np, Sg, and Tg:

Np minimum =100 pixels.

Sg minimum = 2000 pixels.

Tg minimum = 1000 ms.

When a gesture swung by a user does not meet the above threshold values, it may not be recognized by the system as a gesture. The system reads three gestures and recognizes the respective character. That particular character is given as voice feedback to the informant. So, the total throughput time of 'one character input' is calculated as the:

Gesture time + character recognition time + Voice feedback time;

The character input time formula is a basic example for the human machine interaction process. The major advantage of the gesture input system is avoiding the character tracing/screen spatial problem. At the time of the training on the gesture character input method, several users are not able to do the gesture swipe from bottom-to-top properly. For the gesture through the index finger, they move the finger towards the right at the end of the swipe, which does not cover the 100 pixels exactly from bottom-to-top, and the system understands the gesture pattern as a left-to-right gesture pattern rather than as an actual swing from bottom-to-top. The system is modified to avoid this 'miss-gesturing' problem. For the modified system parameter, threshold values are reduced to make error-free gestures. The parameter's (Np, Sg, Tg) threshold values that modify the system are adjusted to be less to capture the minute slops of the swing gestures made by the users. The first Eyedroid system with high threshold values is named Eyedroid. The second Eyedroid system with a reduced threshold value is named Eyedroid-B for referencing purposes.

Software:

- OS Base – Android Core framework

Hardware:

- Touch Screen with multi-finger touch
- Speaker-enabled phone
- Vibration device
- Minimum resolution of 320x480 pixels
- Five Finger responsive screen

3. TESTS OF INTERACTION METHODS

3.1. Purpose

The blind subjects are introduced and trained with Eyedroid interaction method. This experiment conducted with the blind subjects to understand and analyze the usability features and to measure the text input time.

3.2. Participants

Overall, 12 visually challenged people participated in this experiment. Two females and one male candidate from the age group 20 to 30, one female and four male participants from the age group 31 to 50, three male participants from the age group 51 to 65, and two participants from the age group above 65 were selected from across different geographical regions. The participants were chosen for the line experiment across a different cross section of society, age groups, and socio economic status as well as from the physically challenged population. For example, more than 10% of the participants belong to other religions from Chennai, which is the state capital of Tamil Nadu, India. A very small percentage of the population is represented by physically challenged personalities. Figure 2 demonstrates the structure of the participants (visually challenged) for the live experiment. Within the population of the ten participants, each one understands one of the two existing methods, such as the button-based input method and touch-and-tell input method. To make the participants familiar with the gesture input method, a tutorial was prepared and practiced. The tutorial demonstrates the important keys of the Eyedroid system such as "how to do the finger gesture on the touch screen"," what the basic gestures are", and "how the gestures relate the Braille code with the character". The technical pilot training was conducted, and the training duration was two days for practicing gestures and other unfamiliar interaction methods. The pilot training was comprised of three trainers to train the participants. This experiment was performed with short-term training for the visually impaired participants. This experiment was performed to observe the usability measures of the new interaction method compared with the existing interaction method by different age group members.

3.3. Apparatus Specification

The gesture method is tested with the Samsung mobile phone installed with the gesture interaction system Eyedroid. Every method is tested to input/write a character, and the time taken to write and recognize a character is calculated.

3.4. Kirkpatrick Evaluation: Long-term Technical Training

Two months of training was provided for the same set of participants on the gesture input method, which they are not familiar with. Three trainers train them to input characters using the hard button-based mobile method, touch-and-tell method using the Talks software for the mobile touch screen, and how gestures can input characters using the touch screen. The Kirkpatrick four-level model is used to evaluate the effectiveness and participant's feedback for the long-term technical training.

3.4.1. Training Assessments

Level 1 Reactions: The content of the Smile sheets shows the interest of the visually challenged participants towards understanding the different interaction systems for mobile phones. Participants have a 100% satisfaction on the audio tutorial and an 80% satisfaction with the trainers' training.

Level 2 Evaluation-Learning: The learning occurs laboriously and numerous self-assessments and group assessments were performed for each interaction method. The character input time is gradually reduced for the three methods after easily learning the fundamentals. According to the button-based method and the touch-and-tell method, the participants consider the screen edges as the origin point, and then they trace the characters easily by keeping in mind the positions of each character. Our gesture method poses the logic of recalling the Braille code for each character, and then the participants have to map the Braille code with the gesture pattern. The logics for inputting characters were understood and learned 100% by the participants, which reduces to the number of errors in typing. The character input time is also reduced. The number of errors committed by the ten participants was observed was reducing.

Level 3 Evaluation- Transfer
This level measures the changes in the trainee behavior in accessing the interaction systems of a mobile phone. The same set of participants in experiment 1 attended the training. To evaluate the psychological feelings of the trainees after three months of training, we conducted a test for participants to type their residential address as fast as they could into a mobile phone with the freedom of using any input method. Most of the participants started with the gesture input method, and a few of them started with the touch-and-tell interaction method. Out of the 10 participants, eight participants used the gesture input method and two of them used the touch-and-tell method. Because the gesture method does not use any screen layout references, the participants felt that this method was a very easy one, and they expressed that they started using the gesture method to type the address from their subconscious mind. They really enjoyed writing characters using the gesture method. Because the other two methods use screen layout references to identify the position of the character, they are system dependent. The gesture method is entirely human dependent because the gesture patterns are called from human minds. The finger gesture action occupies just a few milliseconds, and three gestures occupy a maximum of 1 to 1.5 seconds only. Hence, the gesture method is a very easy and handy method for the participants.

Level 4 Evaluation- Results
The following evaluation chart shows the measurement of three factors, such as easiness, adaptability, and accuracy for the three different interaction methods. The participants give marks for each measurement factor from 0 to 10 and from poor to excellent. The subjects are given forms to score the easiness (The intuitive feature of interaction method), adaptability (the point of adapting to Braille base interaction system), Accuracy (the gestures are accurately recognized, the gestures are clear) counter measures for 10 marks. The score sheet showed cent percent easiness from 50% of subjects, cent percent adaptability from 60% of subjects, cent percent accuracy from 65% of subjects.

3.5. Test bed for Eyedroid before and after training

The aim of the live experiment 3 is to test the impact of the long-term training on the gesture input method. After a long-term training gesture interaction method, we conducted a live experiment to observe and analyze the character input time between the two gesture interaction methods.

3.5.1. Procedure

Experiment 2 consists of two sessions. This experiment includes sessions before and after the long-term training. When measuring the character input time, the gesture input method is performed in the first session before long-term training. After the training measurement, the input time is performed after training in the second session. Although the Braille code-based gesture input method seems to be confused at the first time for the visually challenged people, the logical way of doing the figure gestures allows the people to handle the touch screen very effectively without any screen spatial problems. The 'gestures' formulated based on the Braille code, persevere a deep blind-interaction technical concept, leverage the visually challenged to understand and adapt the system flawlessly. Participants use the Eyedroid system and are asked to input a character randomly. The time taken to gesture and to receive the audio feedback is observed from twelve participants before and after the long-term training. Few participants entered the aimed character after only two or three attempts. They did the gesture in two seconds, but the gesture did not occur correctly on the touch screen. Therefore, they had to repeat the gesture for four or five seconds to input the aimed character on the screen.

Figure 3. User gestures to input text

3.5.2. Technical Settings

The Eyedroid system is deployed on the Samsung Galaxy mobile phone. The audio feedback is achieved by using speaker of the phone. The data are observed from each individual at different times. Twelve participants use the Eyedroid system at different times. Session 1 consists of 12 sub sessions; session 2 consists of 12 sub sessions. The total character input time is calculated the same as mentioned in experiment 1. Thus, the time starts from making the three gestures of a character up to the response they receive.

3.5.3. Data Analysis

Data taken from the 12 participants before and after training are tabulated in the post-hoc paired t test performed to test the effectiveness of the training.

Table 3.Character input time after long term training

Persons	Input time in Sec	
	Before Training	After Training
P1	5	2
P2	7	1
P3	6	1
P4	4	.8
P5	3	1
P6	4	3
P7	2	1
P8	8	2
P9	5	3
P10	4	.5
P11	9	1
P12	10	2

3.5.4. Result

The two-tailed paired t test, p value is not equal to zero ($p=0.0001$). Hypothesis $\mu 0$: There is no difference in the performance of the participants between before training and after training; $p=0$, which is false (as $p\neq 0$), and there is a statistically significant difference between before training and after training. Hypothesis $\mu 1$: $p < 0.01$, the performance of the participants is more effective after training than before training; the actual p value is less than 0.01 ($p=0.0001$) and implies that the training is very effective, and the participants' performance was significantly improved. Participants enter characters very fast after training.

4. CONCLUSION AND FUTURE ENHANCEMENT

This research work is started to develop the Braille-coded gesture-based interaction method on a layout-less touch screen, which greatly relaxes the screen spatial problems and succeeds with a character input time of two seconds. Our live test bed experiments proved that our gesture-based interaction method is more efficient than the other mobile interaction methods. However, our solution is exceptional for non-Braille literates. Along with the spatial problem, we added the problem of audio feedback. During the experiment time at different environmental places, it is noticed that the participants are not able to hear the audio outputs properly in crowded places. Hence, it is planned to extend the Eyedroid system with the aim of designing a Braille code-based tactile output feedback model. The system is expected to be successful in the field of human computing interaction. The Eyedroid system is extendable. More features that are the mobile application utilities such as phone, contacts, SMS, calendar, games, and a text scanner from wall papers will be developed with basic gesture patterns. Basic mobile requirements are collected from urban and rural places. The Eyedroid system will satisfy the basic expectations of visually impaired persons from large geographical regions in Tamil Nadu, India.

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