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Braille-based Text Input for Multi-touch Screen Mobile Phones

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ABSTRACT

"*The real problem of blindness is not the loss of eyesight. The real problem is the misunderstanding and lack of information that exist. If a blind person has proper training and opportunity, blindness can be reduced to a physical nuisance."*- **National Federation of the Blind (NFB)**

Multi-touch screen is a relatively new and revolutionary technology in mobile phone industry. Being mostly software driven makes these phones highly customizable for all sorts of users including blind and visually impaired people. In this research, we present new interface layouts for multi-touch screen mobile phones that enable visionless people to enter text in the form of Braille cells. Braille is the only way for these people to directly read and write without getting help from any extra assistive instruments. It will be more convenient and interesting for them to be provided with facilities to interact with new technologies using their language, Braille.

We started with a literature review on existing eyes-free text entry methods and also text input devices, to find out their strengths and weaknesses. At this stage we were aiming at identifying the difficulties that unsighted people faced when working with current text entry methods. Then we conducted questionnaire surveys as the quantitative method and interviews as the qualitative method of our user study to get familiar with users' needs and expectations. At the same time we studied the Braille language in detail and examined currently available multi-touch mobile phone feedbacks.

At the designing stage, we first investigated different possible ways of entering a Braille "cell" on a multi-touch screen, regarding available input techniques and also considering the Braille structure. Then, we developed six different alternatives of entering the Braille cells on the device; we laid out a mockup for each and documented them using Gestural Modules Document and Swim Lanes techniques. Next, we prototyped our designs and evaluated them utilizing Pluralistic Walkthrough method and real users. Next step, we refined our models and selected the two bests, as main results of this project based on good gestural interface principles and users' feedbacks. Finally, we discussed the usability of our elected methods in comparison with the current method visually impaired use to enter texts on the most popular multi-touch screen mobile phone, iPhone. Our selected designs reveal possibilities to improve the efficiency and accuracy of the existing text entry methods in multi-touch screen mobile phones for Braille literate people. They also can be used as guidelines for creating other multi-touch input devices for entering Braille in an apparatus like computer.

Keywords: Text entry, Multi-touch screen mobile phone, Braille

CONTENTS

1 INTRODUCTION

During recent years using multi-touch screen mobile phones has become increasingly common and its popularity keeps growing. Ease of use, optimum use of the device space to have bigger screen and less maintenance cost are among top reasons. Although the first touch-screen mobile phone was introduced in 1992 (IBM Simon), the mobile phone industry changed dramatically in June 2007 when the first iPhone was launched as a multi-touch cellular phone. Following iPhone from Apple, other mobile phone producers introduced their multi-touch screen mobile phones: HTC Touch, Samsung Omnia, the Android phones from Google and several other manufacturers, Blackberry Storm, Nokia 5800 and Nokia N97.

In spite of all advantages of a multi-touch screen mobile phone, the smooth surface of these devices brought up serious accessibility challenges for sightless people. In phones with physical buttons, users feel the buttons and over time they will learn buttons' locations and will be able to interact with the devices without looking. In multi-touch screen mobile phones the feedback provided by the buttons does not exist. This fact tremendously increases the demand of vision in order to operate this sort of mobile phones. Sighted users get in trouble when they are involved with secondary tasks like walking or driving and visionless users are completely unable to operate multi-touch screen mobile phones without the help of any assistive application. Unlike button-based mobile phones that all interactions are constrained with pre-configured hardware, multi-touch screen phones have a software interface which makes them highly customizable. Therefore proper software solution is necessary to make these flat surfaces accessible for vision-disabled people.

This thesis project explores suitable approaches for blind people to use multi touch screen mobile phones. We particularly focus on how an unsighted person is able to enter a text in the form of Braille on these sorts of phones. The fact that Braille is utilized by many visionless people to read and write, makes it a proper candidate for creating a text entry technique for them. After investigating the current practice we propose methodological frameworks to support Braille text entry for blind or visually impaired people.

During this research, we established close contact with Synskadades Riksförbund (SRF), a nonprofit association for blind and visually impaired people in Sweden.

1.1 Thesis Outline

In the first chapter (Introduction) the context of the project is described and SRF is introduced as the practical advisor of the project. In chapter 2 (Purpose) the problem domain, research questions, aims and objectives and the research methods are defined. In the next chapter (Background) basic concepts such as text entry, multi-touch screen and feedback are explained. In the fourth chapter (Research Methodologies) we described methodologies employed in this research to perform the study in different steps. In Chapter 5 (Related Works) a comprehensive review of related works is carried out and strengths and weaknesses of each work are discussed and categorized. This step helps with the designing of the project's prototype. We demonstrated the results of the user study in chapter 6 (User Study Results). These results are analyzed here to be used in the designing process. The potential Braille-based text entry methods are designed, prototyped, evaluated and refined in Chapter 7 (Designing Braille-Based Text Entry Methods). Also, we presented the elected methods as the results of this project here. In the eighth chapter (Discussion) the selected text entry methods are compared with an existing standard method. Also, Future works to make possible improvements are defined. In the last chapter (Conclusion) the outcomes of the discussion are summarized and research questions are answered.

2 PURPOSE

2.1 Problem Statement

Digital and computing devices are now present everywhere in our daily life and they cause many changes in our way of living. Along with all of these changes, huge challenges and possibilities exist for human computer interaction designers to make these devices accessible and useful for everyone.

In this project, we study text entry in multi-touch screen mobile phones for blind and visually impaired people. The glassy screen of these sorts of mobile phones causes serious accessibility challenges for vision-disabled people; and thus it is necessary to facilitate them with proper, usable applications. A few studies have been conducted to make multi-touch screen mobile phones accessible for unsighted people [3, 15], however, since this technology is quite young, there is a long way for designers and developers to make these phones as accessible for sightless users as sighted ones.

According to our knowledge, none of the previous studies on multi-touch screen text entry methods, paid attention to knowledge of Braille. Although all of the blind and visually impaired people do not know Braille, for those who know, it will be easier and faster to communicate with their language rather than learning an extra strategy. Furthermore, almost all blind people have some basic knowledge about the Braille alphabet, which is enough to enable a blind person to use a text entry application based on Braille. None of the available text entry methods in multi-touch screen mobile phones supports blind and visually impaired people to input text in the Braille format; and this is the gap we want to fill during this project.

2.2 Aim and Objectives

The main aim of this thesis project is to enable blind and visually impaired people to enter a text in multi-touch screen mobile phones using the Braille language. This aim is fulfilled by reaching the following objectives:

- Identifying the difficulties with multi-touch screen mobile phones text entry for blind and visually impaired people
- Designing some interface layouts to input Braille cells in a multi-touch screen phone
- Discussing whether the proposed methods can actually help improve usability of text entry on multi-touch screen mobile phones for blind people

2.3 Research Questions

This thesis project intends to answer the following research questions (RQs):

RQ1. What are the disadvantages of using the current text entry methods for blind people?
RQ2. In what ways does a blind person employ the Braille to write words?
RQ3. Do our interfaces enhance the usability of mobile phones in terms of text entry for visually disabled users?

3 BACKGROUND

About 314 million of people are visually impaired worldwide and 45 million of them are blind [13]. Since devices which are produced for sighted people do not meet visually impaired needs, they have to buy some other expensive apparatuses, produced specially for them. For example, a “normal sighted person can buy a phone for under £20 which will have the ability to send text messages, whereas blind people have to have something added on or buy a specially made phone for over £300” [14]. Providing these people with suitable software on the same hardware of any device including *mobile phones* could reduce the costs immensely.

One of the main communication channels in a mobile phone is text messaging, which requires the users to be able to enter alphanumeric data. Many applications have been designed to fulfill this aim and the strategy they use, is commonly referred to as a "text entry method". These methods range from pressing a combination of different buttons in button-based mobile phones to some hand/finger gestures in touch-based ones. In designing a text entry method, several factors should be considered. That includes the language in which the text is composed, the device hardware capabilities (e.g. buttons, scroll wheel, touch-screen, and multi-touch screen) and the abilities of the final users of the device. Like any other application, text entry applications should also satisfy usability requirements such as efficiency, accuracy, being easy and fun to use and being easy to learn.

In order to insert a text on a mobile phone, sighted users look at the device and easily find the item which refers to intended character, considering the text entry method is used. Unsighted users, on the other hand, are not able to do that. The situation gets worse for them, when the device is a touch-based mobile phone with a flat screen and no button. The reason is that, in mobile phones with physical buttons, a visually impaired person can feel the buttons and after a while will be able to estimate the target location, which is impossible in devices with smooth screen. Therefore they should be provided whit a proper *eyes-free* text entry method.

Some studies presented their eyes-free text entry methods for touch-based mobile phone [2, 3, 7, 15]. However, they just made possible to input a text for visionless people, and there is a long way to create an eyes-free text entry method in multi-touch screen devices with acceptable amount of speed and accuracy. In this project, we intend to provide visually impaired people an environment in multi-touch screen mobile phones, to be able to enter the text in the form of Braille. Since Braille is a very simple code and used by many of visually impaired people, a text entry based on Braille could improve usability requirements of the text entry to high extend. At this time, famous manufactures like Nokia and Samsung are also researching to employ Braille in their produced mobile phones [29, 44].

This chapter provides some background information and discusses different aspects of text entry method in multi-touch screen mobile phones including: text entry, device feedback and multi-touch screen.

3.1 Text Entry

Several functions in a mobile phone require users to input texts. Examples are entering URLs, writing emails or using the short message service (SMS). SMS text messaging is the most common used data application in the world; with 2.4 billion active users, or 74% of all mobile phone subscribers [12]. Beside all of the SMS benefits such as permanent recording of messages and smaller phone bills, there are some services accessible only through short message service and not a phone call. For instance, attending in some polls is possible only through SMS. In Sweden, according to a Survey by the Swedish Post and Telecom Agency, “ every tenth person sends on average more than 10 SMS per day; every third person aged 16-20 sends on average more than 20 SMS per day” [10].

3.1.1 Overview of Input Techniques

In this section, we explored various alternatives of available text input techniques on mobile phones [19].

Keyboards and keypads: A keyboard is an input device consisting of a number of keys and each key is designated to one letter or number. The user can press each button with any finger, so it can be very fast for a trained person. Keyboard is also used in different types of mobile phones, either in button-based mobile phones (e.g. BlackBerry Curve 8900 or Sony Ericsson Xperia X1) or as a graphical keyboard in touch-screen (e.g. Qtek S200) and multi-touch screen (iPhone) mobile phones.

The biggest problem with this input technique in mobile phones is the small size of the buttons. Each button is about 0.2 inches, where the size of a normal finger tip is about 0.3-0.4 inches (same as computer keyboard keys). This means that a finger can cover two or three buttons, and this requires higher accuracy and results in lower speed.

Gesture recognition: The term gesture has a very broad definition, in that it can be many kinds of physical movements. A gesture is any movement that a digital device can sense and respond to. Gestures can be either touching a sensing surface using a stylus or a finger, or performing free-form human gestures such as hand shaking to send special meaning to a special device [1].

Using a stylus or a finger on a sensitive screen has been largely employed in touch screen and multi-touch screen mobile phones. Tapping, dragging, flicking, nudging, pinching, spreading and holding are the gesture examples commonly used to interact with a multi-touch screen device. All multi-touch screen mobile phone interface designers have tried to make a combination of these gestures that produces an easy-to-use, understandable and memorable pattern of interacting with the device.

Speech Recognition: Input devices that rely on speech, employ voice recognition software programs that transform spoken language to an application command. Similar to when a user clicks on a mouse or presses keyboard buttons and the application recognizes it should perform a particular task, in a same way, when it receives a special speech signal it recognizes to perform the related task to that signal.

Simplicity and intuitiveness are the privileged specifications of the speech-based input devices. Using speech as an input technique can be fast to perform the tasks as well. Many manufacturers have released their voice recognition products such as *Simply Speaking Gold* by IBM which is a speech recognition and speech synthesis system, or *Naturally Speaking* by Nuance which is a continuous speech recognition system, or *QPointer VoiceMouse* by Commodio which lets voice commands manage the mouse functions. Speech has been used as an input method for mobile phones as well. Nexus S is a multi-touch screen mobile phone, co-developed by Google and Samsung that is able to transform what users say to text.

Text recognition: Text recognition means recognizing characters -that have been used by people over years- by computers. In this technique, the picture of the desired character is used to identify what the character is. Nowadays computers are capable of recognizing different kinds of characters with adequate accuracy through the help of Optical Character Recognition (OCR) [20]. Text recognition by computer has a couple of branches: human readable characters and machine readable characters.

The human readable characters can be recognized either off-line or on-line. Off-line text recognition is when a written text is recognized by the computer. On the other hand, when the act of recognizing happens real-time while the user is writing the text, it is on-line text recognition. On-line text recognition is basically performed on the touch-based devices, in that the user draws the picture of a character on the screen and the device recognizes what character is drown.

Human readable text recognizers can transform a clear image of a typewritten text into a form that the computer can manipulate (e.g. into ASCII codes) by almost 99% accuracy [21]. However, recognizing different handwritings by a machine is a much more problematic issue. Since different people have different handwritings, determining the accuracy of handwritten text recognition depends on how a user writes and how the machine is taught to read the user's writing. The second text recognition system - machine readable characters – on the other hand is completely recognizable by machines. The most famous kind of these characters, which cannot be read by human, are bar codes.

Text recognition has been implemented as mobile phone applications too. ABBYY Company manufactures a product called *Screenshot* that can create snapshots of images and texts from documents [22]. This application can be very useful for situations where a written text is available, however when the user wants to enter a new text into the mobile phone it is not a suitable way.

To summarize, four input techniques were introduced above including gesture recognition, speech recognition and text recognition are inspired from different senses of human body, touch, hearing and vision respectively; and the direct input devices such as keyboard or keypad. As each of human senses is good for a special perception, each of the above techniques can be best for performing some functions and not so good for some other functions. For example, to translate a non-English restaurant menu in a foreign country, the best way is to get a picture from the menu and let our text recognition application translate it for us in a few seconds, or in driving situations, perhaps the best choice to call someone is just say his or her name and let the speech recognition application find the phone number from a long contact list. The trick is achieving the optimal combination of these techniques to perform a particular task considering the users abilities.

3.2 Device Feedback

In our everyday life, we are guided to interact with the world by the modalities of sensory information that we obtain from our environment and process through our sensory system. This system primarily consists of the visual, auditory, and tactile modalities [32]. In the case of text entry, the device feedbacks tell the users if their action was sensed, and also whether their entered text was accurate. Sighted people simply look at the device and get the feedback, but blind and visually impaired people can only get sensory feedback through their hearing and tactile sense. In the following sections we will explore auditory and tactile feedbacks.

3.2.1 Auditory Feedback

Auditory is something related to the process of hearing. Auditory displays are most often used to attract and direct a user's attention like smoke detector or bus and train announcement. Auditory feedbacks can be either speech or non-speech sounds. Speech sounds, as it comes from its name, are the sounds of reading the words or letters. The words can be whether meaningful in any language or not. Several software are available to provide this speech sound feedback for blind users, like TALKS™ offered by Nuance, which runs on Symbian-based mobile phones or Mobile Speak developed by Code Factory. On the other hand non-speech sounds are any voice that is not speech but can still be meaningful. Non-speech sounds include *earcons, hearcons or auditory icons and spearcons* [33]. Each of these sounds has the specific definition and is useful for special purpose. Here we study these types of sounds in more detail:

- **Earcons:**
  Earcons are non-speech musical sounds used in computing systems to express some information about different computer objects, operations or interactions [34]. They are used to represent the actions and objects that form the interface. Moreover, the earcons of these actions and objects can be combined to express a special interaction in the interface (Figure 3.1).

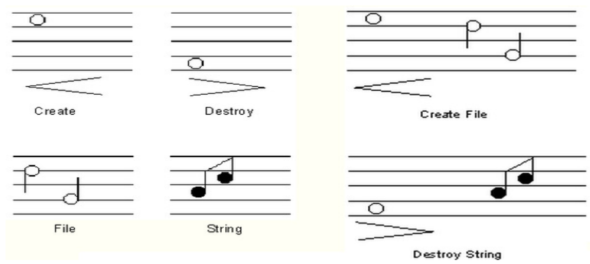


Figure 3.1: Four earcocns and combining them for special meaning [34]

- **Hearcons or auditory icons:**
  Auditory icons are designed to convey information by analogy to everyday sounds. They are sounds from our everyday environment that help us understand what kind of information they are dealing with. They add valuable functionality to computer interfaces, particularly when they are parameterized to convey dimensional information [35].

- **Spearcons:**
  A spearcon is a non-speech sound that is produced by expediting the Text-To-Speech phase in particular ways. Using spearcons instead of speech sounds for the feedback leads to have faster, more accurate and more enjoyable navigation [36].

3.2.2 Tactile Feedback

Tactile feedback is a form of response in some electronic devices that operate on touch sensations. Applying forces, vibrations, and motions are examples of tactile feedbacks that are familiar to most of us via its ubiquitous use in mobile phones such as iPhone. Tactile feedback mechanism should not be mistaken with simple usual vibration motors inside the ordinary mobile phones. When the user taps the screen, it provides a feeling very similar to pressing a button on the keyboard under the user's finger. Even someone new to this technology and the devices that use this technology, can perceive the difference between a tactile feedback and a simple vibration.

When a button is pressed on a keyboard, basically two movements are felt, button in and button out. These movements and the associated audio on a touch-screen should be entirely attuned to the responsiveness of a button on a real keyboard. Today, most of the multi-touch screen mobile phones, like iPhone or Nokia S60, use this capability. Each tap on a button returns a tactile snap on the screen which makes typing very responsive and operable on a smooth surface. In a study from Jussi Rantala and his colleagues presents a tactile feedback technique, based on Braille [17]. In their method, users swipe their fingers across a screen that presents a sequence of cell dots and they feel vibrations of different intensities. An intense pulse means that the dot is raised in that position and a weaker pulse indicates absence of the dot.

3.3 Multi-touch Screen Mobile Phones

"Multi-touch-sensing was designed to allow nontechies to do masterful things while allowing power users to be even more virtuosic." **- Jefferson Y. Han**

Multi-touch is a novel human computer interaction technique. A multi-touch screen device has touchable screen that is able to register two or more touch point inputs of distinct locations simultaneously. These devices are very sensitive and it is quite easy for the users to control their graphical user interfaces. Visually impaired people usually need extra assistance to operate different devices, and it will be cheaper and more convenient if the extra assistance is a software program instead of a hardware device. Multi-touch screen mobile phone design easily allows new functionalities to be added as new software applications.

One of the most common multi-touch screen devices in the world is the mobile phone lunched by Apple, iPhone (figure 3.2). In addition to the default applications that come with an iPhone, there are over 300,000 more applications available in the Apple store [11]. These applications can be designed and developed by any registered Apple developer with the help of iPhone Software Development Kit (SDK).

Figure 3.2: Apple multi-touch iPhone [45]

4 RESEARCH METHODOLOGIES

This research studies text entry methods in multi-touch screen mobile phones for visually impaired and blind users. It aims at exploring proper methods to enable unsighted people to input Braille. To obtain this goal, and in order to answer our first research question, we chose survey and interview as two suitable methodologies commonly used for user studies. Survey and interview helped us to get familiar with the challenges users already have with current text entry methods and what they expect from a well-designed text entry method on their multi-touch screen mobile phones. Moreover we identified what actions blind people are able to do and what actions are easier for them to perform in the context of using mobile phones. Beside these methodologies, we performed a comprehensive literature review not only on the user study, but also on related text entry strategies, related input techniques and Braille input devices to identify their strengths and weaknesses. We then tried to use the positive points and avoid the negative ones in our designs and development.

After gathering required information, we investigated the options to design a Braille-based text entry method. In this stage we introduced six different strategies to enter a text using Braille alphabet. To make them clear, we documented all designs in detail, utilizing Gestural Modules Document and Swim Lanes techniques. Next we created low-fidelity prototypes of our methods and let our users test them. To evaluate our prototypes we followed an inspection method called Pluralistic Walkthrough, which assisted us in recognizing the weaknesses of our designs and also let the real users to compare our models and express their preferences. We selected our best text entry methods based on users' opinions and principles of a good gestural interface; and finally we used Usability Testing technique to compare them with a text entry method already in-use in the iPhone by visually impaired people. Throughout the following sections we explain how different methodologies assisted us in answering the research questions and achieving the project objectives.

4.1 User Study Methods

As it was mentioned above, we performed two different methodologies to fulfill different aspects of our user study. In this section these two methodologies are explained, and further their results are used as the basis for the prototype.

4.1.1 Survey

Survey is one of the user study methods in this research that is performed to gather quantitative data from the users. Survey is a useful methodology to collect information from a large number of users. Application designers can recognize the costumer's needs and preferences through the help of surveys to a large extent, and therefore the result of the surveys will be useful in designing the product of a project.

We decided to use a questionnaire survey in this research to get more familiar with a very special sort of users of mobile phones, visually impaired and blind users. The results of the questionnaire make the user's knowledge and background more clear. Questionnaires have different advantages and also some risks that should be considered. The advantages include low cost, flexibility and the manageability of the survey result. We can gather a wide range of information from different places rapidly and easily convert the results to a usable form.

On the other hand survey has some risks such as, how to find and motivate qualified users to participate. To overcome this risk, we decided to perform an online survey, so that we do not limit ourselves to a special area and larger numbers of participants can take part in our survey. We distributed the questionnaire in different blind associations in Sweden and the

United States. It has also been translated to Persian and Chinese and has been sent to Iran and China as well. Having responses from different countries gave us a diversified result that is not confined to one high-tech country.

Another challenge specific to our survey was having blind people fill the questionnaire out. In order to simplify this task for participants, we created HTML and PDF formats of our questionnaire, (the HTML format is available at http://questionpro.com/t/AE1MYZItgF) [43]. If the participant feels comfortable with the HTML format, he or she fills it out in a few minutes; otherwise they can use the PDF format and write their answers in an email. All of our participants had someone around to help them. One other undeniable risk of surveys is honesty, and to make sure our questions were answered by qualified users, we only sent our questionnaire to official blind association in private.

4.1.2 Interview

Interview is another user study method we used to expand our understanding of user requirements and complaints. This qualitative approach helped us gather different users' opinions about the current situation of the research topic, and their demands for the future.

During our user study phase, we met with some blind and visually impaired mobile phone users at SRF several times. Since the aim of this project is designing methods and applications, we didn't conduct predefined structured interviews to let interviewees feel free to express their ideas. Semi-structured, open ended interviews bring up new ideas interview, which can be very useful in the design process. Therefore, we propounded the main aims and issues of our project, and let the interviewees talk about their views. In some cases interviewees asked for more time to think about some of the questions and they came back to us after they reached their final opinions.

4.2 Documenting and Prototyping Methods and Techniques

After gathering information from the user study process, investigating strengths and weaknesses of related works, inquiring Braille knowledge and studying Braille input devices, it's time to start the design stage. Users' expectations and capabilities from the user study, and other perceptions from the literature reviews are all considered in the following steps of this stage.

4.2.1 Documenting

Documenting a gestural system helps to understand what is being built and what decisions are made in the system. For documenting the designs we used two individual techniques: Gestural Modules Document and Swim Lanes [8]. These two techniques together clarify what exactly can be done with the system and what consequences every action has.

Gestural modules are the basic gestural vocabulary of the system. Using gestural modules document approach, we can demonstrate an overview of the gestures that apply to the entire system and the commands that apply to them. In addition to the information presentation, this technique works well with our prototyping technique, Wireframes [8].

The second technique we used to document our designs is Swim Lanes. This technique illuminates the detailed gestures and the sequence of gestures. Swim lanes is borrowed from comic books where a sequence of images, accompanied by texts, are used to tell the story. In this research the story is the step by step gestures of entering Braille characters and consequent actions. In this framework different perspectives of a scenario can be displayed on a single page [8].

4.2.2 Prototyping

After documenting the text entry designs, we created some prototypes. The definitions of documenting and prototyping a system are very close together and the difference between these two is marginal. In most system developments, a prototype is an object that users can interact with in some manner, while documentation does not have this capability [9]. As such, prototyping was a necessary step of this project in order to be able to evaluate our designs and get feedbacks from the users.

There are many types of prototypes in terms of shape and size, from a simple paper mockup to a final version of the real product. But, generally all of the prototypes fall into two groups in terms of fidelity: low-fidelity and high-fidelity prototypes. The former are the sketchy simple prototypes that do not have all of the characteristics of the final product, but include main concepts of the designs and are very useful to collect feedbacks. High-fidelity prototypes, on the other hand, have a lot of details and functionalities that are very close to the final products.

Both of low- and high-fidelity prototyping have some benefits and drawbacks. However, the following reasons encouraged us to choose low-fidelity prototyping [9, 18, 39]:

- ✓ **More useful feedbacks from the users:** One of the biggest problems of high-fidelity prototypes is that the users are distracted by the fringe features. They usually focus on details like the colors and fonts of the page instead of the main concepts that we as designers really care about. Low-fidelity prototyping, on the other hand, can provide us with the big picture feedbacks we are actually looking for.

- ✓ **Our special users:** Our user group is formed from visually impaired and blind people, and the device they were supposed to give feedbacks on, was a mobile phone with a smooth surface. This fact makes a low-fidelity prototype more suitable for presenting the text entry designs than a real application. We created the prototypes in a way that our visionless users could touch, feel and recognize the method's layout.

- ✓ **Easier design modifications:** All throughout the design process, users' feedbacks can affect the design and low-fidelity prototypes are a lot easier to modify.

- ✓ **Saving time and money:** We have six text entry method designs to propose. Having a high-fidelity prototype for all of them required so much time, while creating the low-fidelity prototypes was a rather fast process. Moreover, having high-fidelity prototypes would cost much more (running an application on the iPhone device costs 99$).

All in all, according to our user's capabilities, and also the feedback we are looking for in this research, low-fidelity prototype was the best choice.

To implement our prototypes we employed the Wireframe technique. Wireframing is a paper-based prototyping technique that skips the details and lets the users to focus on main features and functionalities of the product. The way it lays out the structure of a product is very similar to how a blueprint explains the structure of the building.

In touch-screen system prototyping, the object's size on the wireframe screen should be equal to the size of that object in the final product. It is commonly called "pixel-perfect" prototyping, and it prevents designers to design a very crowded screen or a screen with a big empty space. The following aspects of a gestural system are demonstrated in wireframes [8]:

- **Controls:** The place and size of the objects are completely mapped out in wireframes.

They explain what users are able to do throughout the system and how. They specify consequences of touching different points of the screen and state the different possible gesture's resultant.

- **Conditional objects and states:** The states of the objects should be shown in the wireframes just like they are in a real application. The states include, but are not limited to, idle objects, default selections, static and disabled objects, and selected objects. These should all be clearly observable in the wireframes.

- **Constraints:** Wireframes should explain all possible business, legal, technical or physical constraints. If an action or a gesture seems to be logical to perform on the system, but for any of mentioned constraints it is unavailable, it should be stated in the wireframe.

4.3 Evaluating Method

After documenting and prototyping the text entry designs we need to present them to the real users and find out what they think about the designs. By having the users' opinions we can recognize the weaknesses of the designs and try to refine them. Generally there are three kinds of usability evaluation methods [40]: testing, inspection and inquiry.

In the testing method, real users operate the prototype of the system and the evaluator observes how the system responds. In the inspection method, usability experts, software developers or sometimes users examine the prototype for the usability-aspects of the user interface. In the inquiry method, the evaluators gather the information of users' likes, dislikes, requirements and understanding of the system by talking to them while they are operating the prototype.

4.3.1 Pluralistic Walkthrough

The usability evaluation approach we employed in this research was an inspection method called Pluralistic Walkthrough. After the low-fidelity prototypes are completed, a user and the developers meet together to go through the main tasks, and at the same time discuss and evaluate the usability of the system. This discussion between the users and designers leads to an assessment of the potential usability difficulties of the system from different perspectives.

A pluralistic walkthrough method is conducted through a couple of steps. First, the product, with descriptions of all of the interfaces, is presented to the user and user is asked to express the action he or she wants to perform in as much detail as possible. Then, a discussion begins in that the user starts first and designers follow.

4.3.2 Usability Testing

Usability testing is an evaluating technique used to measure ease of use of a product. Products such as foods, consumer products, web applications and computer interfaces can be evaluated through the help of usability testing. This technique generally assesses how well the product covers four aspects of usability: efficiency, accuracy, recall, and emotional response.

To conduct a usability testing, a scenario of several tasks should be defined. The participants perform these tasks using the product being tested, while observers perceive the results. This technique can be performed using either paper or implemented prototypes. We employed this method to evaluate our selected text entry methods and compare them with a method currently in use in iPhones.

5 RELATED WORKS

The belief that new is always better, is most people's tenet. But, to have a well designed application or system it is not necessarily to just innovate something. Designers are responsible to apperceive user expectations from the system and satisfy them in an easy and effective way. In fact, a well-designed system can be a mixture of different related studies based on qualities such as, what it should do, how it should do, what it should look like, and so on. Having deep knowledge of the history of the project and former studies is a big help to know what these qualities are and how to combine them.

In this chapter, we first review some previous researches about mobile phones eyes-free text input. Exploring previous related researches helped us to recognize some possible challenges which existed in our own project. It also demonstrates how different researchers have deal with these difficulties. Then, we classify the gist of these studies to use in our designing.

5.1 Overview of Previous Eyes-free Text Entry Methods on Mobile Phones Studies

Text entry on mobile phones is a well studied subject area. Different methods have been proposed for easy text input both in touch-based and button-based mobile phones. Basically there are three major groups of eyes-free mobile device text entry [2]:

1. **Touch-based strategies:** this group, itself, is divided into a couple of subcategories based on its technology:

1.1. Multi touch-based strategies: text entry on multi-touch screen mobile phones is a very young research topic, and a few studies have recently introduced their techniques to overcome eyes-free text entry issue on such devices.

To succeed in dealing with multi-touch screen usage for visionless users, Apple announced a system called "VoiceOver". VoiceOver is a system that uses text-to-speech technique to make the information on the screen accessible for blind and low-vision people. Although VoiceOver relies on speech, it is not just a simple screen reader. Different kinds of gestural touch-input were defined to enable user to utilize the device in an efficient way. For example, user can tap three fingers on the iPhone screen to hear how many home screens there are and which one he or she is on, or flick three fingers to the left or right to move between the screens. VoiceOver does not just belong to iPhone and text entry application. It works for all other functions on iPhone and also other Apple's products like Mac and iPad. However, what is important for us here is find out how VoiceOver works for entering a text on iPhone.

In order to inter a text using VoiceOver, user should swipe his or her finger over one graphical QWERTY keyboard layout, simulated on iPhone. VoiceOver reads the letters that the user touches. When the user finds the intended character, he or she should tap anywhere on the screen with another finger and the letter is selected (Figure 5.1).

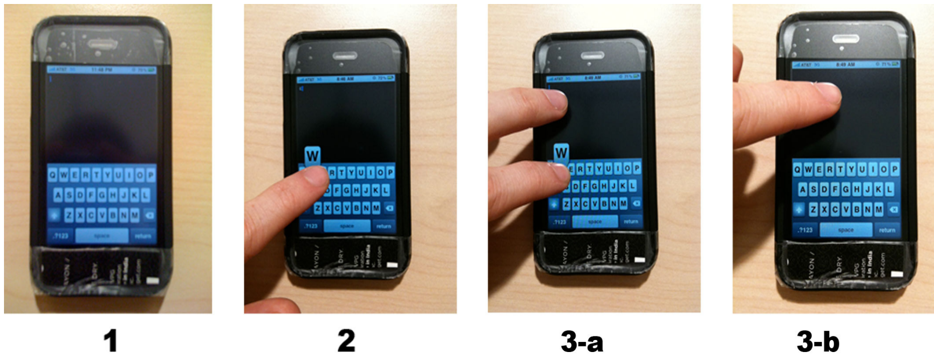


Figure 5.1: VoiceOver text entry [3]

In addition, VoiceOver offers a function to correct an error. By flicking a finger up and down, the user is capable to move the cursor point through a line of text, and VoiceOver read each character it passes.

One other study introduced an eyes-free multi-touch text entry method called No-Look Notes [3]. No-Look Notes has two pie menus, in the first one screen is divided into 8 each part includes 3 or 4 characters and in second one screen is divided into 3 or 4 parts (depending on what part of previous menu were chosen); each part includes one character. By tapping each part of menus, the application reads the character(s) of that part for the user. Users should move their finger over the screen to find the part which includes intended character and then tap the screen with their other fingers to select that part. To choose which character of that part they want to enter, they should do the same with the second menu (Figure 5.2).

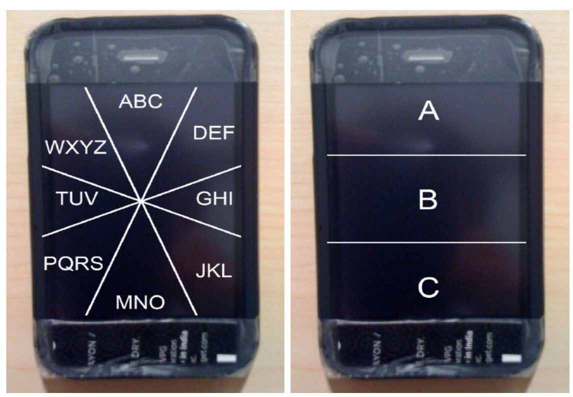


Figure 5.2: No-Look Notes [3]

1.2. Single-touch based strategies: Tinwala and MacKenzie presented an eyes-free text entry method for touch-screen mobile phones uses *Graffiti* strokes [2]. To enter text, user should draw Graffiti alphabet on the screen and at the end of the stroke the application tries to identify the intended character (Figure 5.3).

Figure 5.3: The Graffiti alphabet [2]

They were not the first which used stroke-based alphabet. David Goldberg and Cate Richardson suggested *unistrokes,* for eyes-free text entry former. It was designed as a high speed text entry method. However, it seeks for the expert users to operate it (Figure 5.4).

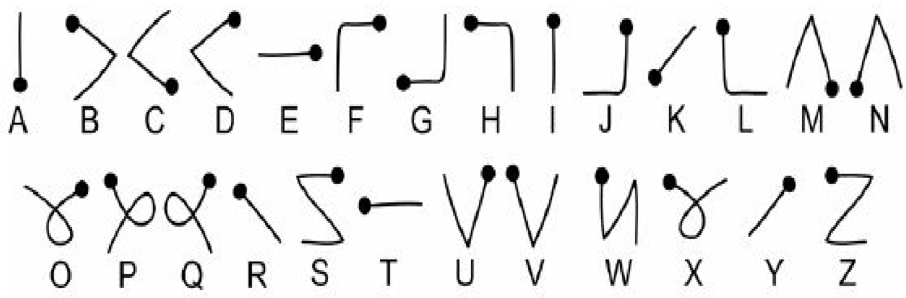


Figure 5.4: Unistrokes alphabet [2]

NavTouch is another technique nominated for eyes-free text entry in touch-screen phones which is a navigational method in that the alphabet was divided into five rows, each starting with a different vowel (Figure 5.5). User can navigate the alphabet by flicking his or her finger in four different directions [6].

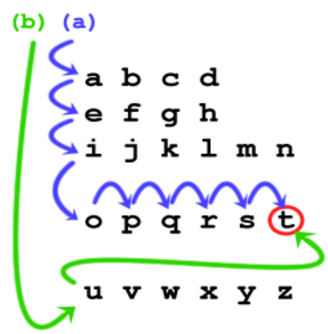


Figure 5.5 Navigating letter't' using NavTouch [6]

By swiping finger up and down, the cursor move vertically over the vowels, and swiping the finger horizontally left and right cause cursor to move through the each line.

Although there are much more touch-based strategies to enter a text on mobile phones like QWERTY keyboard layout and phone pad layout on the screen, they are almost impossible to be operated without the ability of vision. Therefore we avoid explaining such methods here.

2. **Button-based strategies:** Most of the available eyes-free text entry user-interfaces belong to button-based mobile phones. Multi-tap Input, Keyboard Input [4], TiltText [5] and the most recent NavTap and BrailleTap [6, 7], can be named as examples of this group of text input methods.

   Almost all of us have had some experience to enter a text to button-based mobile phones using multi-tap input or keyboard input. Perhaps multi-tap still is the most common existing way to enter a text to mobile phones. Using such technique to input a text is fast with less error, but, since it strongly relies on button feedback, it has nothing to say for touch-based mobile phones.

TiltText relies on the combination of pressing a button from a standard 12-keys keypad and tilting the mobile phone. There are two steps to enter a character using TiltText method. First, pressing and holding the button which includes the intended letter or number. Second, tilting the device in one of four direction (left, forward, right, back), depend on the character that should be entered. For example button '7' includes letters 'P', 'Q', 'R' and 'S', to enter a 'P' user should hold the button '7' and tilt the phone to the left. Tilting forward, right and back input the letters 'Q', 'R' and 'S' respectively (Figure 5.6).

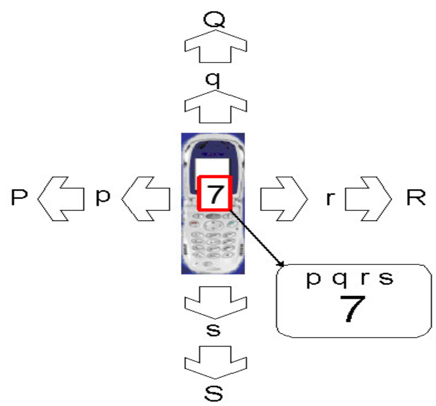


Figure 5.6: Input characters using TiltText method [5]

NavTap has the same strategy as NavTouch (explained above) implemented on button-based mobile phones. In BrailleTap, as it comes from its name, the knowledge of Braille is used. Cells of the Braille alphabet mapped on phone's buttons '2', '3', '5', '6', '8' and '9', and users press related buttons to fill or blank the respective dot for each letter [7]. Evaluations of the only Braille-based text entry method (BrailleTap) have clearly shown that, this method has less errors, less keystrokes and more accuracy in comparison with its peer methods based on other strategies (NavTap and MultiTap). Although BrailleTap is a button-based technique, its evaluation outcome encourages adopting Braille for text entry methods intended for vision-disabled people.

3. **Speech-based strategies:** Some studies have employed speech for mobile text entry. These systems are able to transform spoken language to written text. Although it seems that speech can be an appropriate strategy to use, it is highly prone to error and has privacy issues.

There is one other study on multi-touch screen mobile phones for blind people, which is not about a text entry application, but since it is based on Braille and may give some hints we bring it here. This application called Nokia Braille Reader has been developed together with Nokia, Tampere University and Finnish Federation of Visually Impaired [29]. Nokia Braille Reader allows blind users to read received messages. When the user received a message this application is opened automatically and user read the message letter by letter in Braille. For reading, the user touches the screen and vibration motor inside the phone give a feedback for each dot of the cell. The user feels a sharp pulse for the raised dots and soft pulse for the empty dots (Figure 5.7).

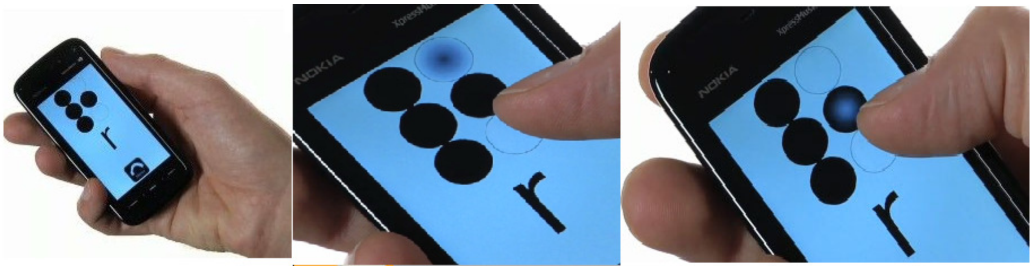


Figure 5.7: Nokia Braille Reader: The user hold a finger on the screen and application read the cells dot by dot [29]

5.2 Summary of Previous Eyes-free Text Entry on Mobile Phones Studies

In the last section different groups of methods for eyes-free text entry have been explained. Although all of them don't work on multi-touch screen mobile phones, since they are designed to be used eyes-free, they may include some hints and points that need to be considered. Thus, in this part we summarize all of them and mention the biggest advantages and disadvantages of each. In addition, in order to have deeper information, we investigate several characteristics of a good gestural interface on each mentioned method. These characteristics consisting of [1]:

- **Being learnable and memorable:** It is the major issue regarding gestural interfaces, specially for a visually impaired user. Before a user start to interact with a gestural interface, it should be clear that where the items are located and how to begin to interact with. Also, it should be easy for visionless users to fix the gestural interface in their mind.

- **Being responsive:** In any gestural interfaces, a user needs to know if the order is heard and understood correctly or not. Thus, a gestural system must provide a feedback for any single action. For visually impaired users, it becomes even more important.

- **Being meaningful:** One of criteria which make an interactive gestural system very popular is that the actions the users perform have a meaning for them.

- **Being clever:** A clever system predicts the user's next action and provides an unexpected proper situation. Such a system can be a big help for visionless user.

- **Being playful:** The playful system is a system that errors are happened rarely. In other word, it is difficult to make an error. Moreover it should allow users to undo their mistakes easily.

- **Being good:** A good gestural system respects to its users abilities and avoid making them appear foolish in public. Such a system does not make the gestures so difficult in that only young and healthy people are able to perform it.

In the following tables all of the characteristics above are investigated for most related eyes-free text entry methods described before, for visually impaired and blind users. In this section we wanted to recognize how different text entry methods treat to satisfy these principles. In addition, the most significant advantages and disadvantages of each method are mentioned: (These information are based on our perception the result of our user study and other related research evaluations)

Table 5.1: Good gestural interface principles on VoiceOver

1-VoiceOver	
Being learnable and memorable:	• Learn period depends on user's knowledge of QWERTY keyboard. Still long period of time for learning (for young person like Jimmy Petterson who uses QWERTY keyboard everyday it took 2 month) • Memorizing highly depends on how often the user work with QWERTY keyboard
Being responsive:	• Highly responsive • Provide speech sounds for each single touch • Visionless user get respective feedback for every single point of the screen
Being meaningful:	• Gestures designed for different actions are the coherent moves (e.g. *flicking* a finger over the graphical keyboard to *look for* the desired character, *tapping* anywhere on the screen with another finger to *select* the character when it is find, *sliding* a finger *to right* to *make a space, sliding* a finger *to left* to *erase* a character, etc.)
Being clever:	• Not so clever • A dictionary of English words is provided, when a user enter the first letter of a special word, it can guess the rest
Being playful:	• Highly playful • It requests a confirmation tap for any selecting tap the user performs • User can move the cursor forward and backward in the text by sliding a finger up and down to correct the mistakes
Being good:	• Finding an intended character among large number of buttons can be difficult enough for some users to find themselves unable to perform
Advantages and disadvantages:	Advantages of the VoiceOver in iphone are the responsiveness of the application and enabling the vision disabled user to enter whatever normal user can. On the other hand, we can mention large number of buttons which are very close together, small size of the buttons and long time of learning period as the big disadvantages of using VoiceOver for visually impaired people. Also, hearing the sounds of each tapping point can be kind of annoying.

Table 5.2: Good gestural interface principles on No-Look Notes

2-No-Look Notes	
Being learnable and memorable:	• Not so easy to learn • Users can not memorize the exact location of each group of letters, specially in the first pie menu • Letter groups are adhesive together, therefore user should flick a finger over the groups each time and memorizing the exact location of them is a hard work
Being responsive:	• Highly responsive • Provide speech sounds for each single touch
Being meaningful:	• Highly meaningful • Categorize pie menus based on alphabet order makes it more meaningful
Being clever:	• Not so clever
Being playful:	• The user tap needs to be confirmed with another tap, so an error happens rarely
Being good:	• Good for visionless users • Letter groups cover all the screen, Users do not have any choices than choosing their intended letter
Advantages and Disadvantages:	In No-Look Note the letter groups are designed in a way that users can not miss any group when they are looking for their desired letter. This can be the biggest advantage of No-Look Note method. Also, it uses the corners and sides of the phone screen which are much easier to find for blind users. On the other hand, by using No-Look Note, a user only is able to enter the letters and no function is anticipated to enter the numbers, punctuation marks or the other symbols and characters.

Table 5.3: Good gestural interface principles on NavTouch

4-NavTouch	
Being learnable and memorable:	• Easy learning for whom have the knowledge of English alphabet and their order • Hard to memorize that desired letter is in which row of letters
Being responsive:	• Highly responsive • Provide speech sounds for each single touch
Being meaningful:	• Not very meaningful • This method just designed rather easy way for tracing the alphabet
Being clever:	• Not clever
Being playful:	• Hard to make an error • The user finally will reach to the intended letter
Being good:	• In one way, it is simple method to enter the letters • In another way, looking for letters one by one among all 32 alphabet is an exhausting move
Advantages and Disadvantages:	The most significant property of NavTouch is its simplicity. It is easy to be learned and performed with few errors. However, by using this method a user is just capable to enter the letters and not numbers and other symbols. Also, the large number of screen stroke for letters input can count as the biggest problem of this method. In addition the user has to hear the voice of all letters which are exist in the path of intended letter.

Table 5.4: Good gestural interface principles on BrailleTap

5-BrailleTap	
Being learnable and memorable:	• Based on common knowledge of many blind people • Highly learnable for who has a basic knowledge of Braille alphabet • Highly memorizable for who has a basic knowledge of Braille alphabet
Being responsive:	• Provide non-speech sounds for filling or blanking the dots • Provide speech sounds for each entered characters
Being meaningful:	• Totally meaningful for Braille literate
Being clever:	• Not clever
Being playful:	• Errors may be happened for beginners • The user are able to undo the mistakes
Being good:	• Extremely good for Blind and visually impaired people
Advantages and Disadvantages:	The best thing about the BrailleTap is that, it specifically focuses on its user's knowledge. It offers a method for mobile phone text entry that many of its users already have some experiences of it from other input devices (e.g. Braille writer).

Table 5.5: Good gestural interface principles on Graffiti strokes/ unistrokes

3-Graffiti strokes/ unistrokes	
Being learnable and memorable:	• Learning highly depends on knowledge of English alphabet • For people who aware of English alphabet it is completely learnable, for blind people who haven't had any contact with English alphabet it is hard to learn • Graffiti alphabet are highly memorable due to the similarity between them and English alphabet, on the other hand unistrokes alphabet are not easy to be memorized due to big similarity between different letters
Being responsive:	• Provide speech feedback for the strokes it recognizes, however there may be many strokes which it is disable to recognize due to bad input and therefore it will not provide any feedback
Being meaningful:	• Extremely meaningful • Users totally perceive what they perform
Being clever:	• Clever applications • They guess the desired user's letter by receiving some vague shapes
Being playful:	• Not playful applications • Errors happen frequently specially for beginners • They misunderstand or do not understand at all the not very exact inputs
Being good:	• Not so good for visually impaired and blind users • It is highly prone to error • It does not use the blind people's alphabet
Advantages and Disadvantages:	The correspondence between the writing on a paper and entering text on a mobile phone makes these methods highly meaningful. Perhaps it is the most important advantage of these methods. In addition entering any letter directly into mobile phone without the need of searching the screen, strongly increase the speed and decrease the number of screen stroke .The biggest problem which needs to be improved is large number of errors in these methods.

5.3 Conclusion

Following points are the hints we extracted from related eyes-free text entry researches explained above:

The number of options a user may tap in each stage should be as less as possible: since blind users cannot see the screen it is vital for them to be able to memorize the application structure. Low number of options helps them to memorize it faster and operate the application easier.

The items a user may tap should be as big as possible: considering the size of the screen and the number of the options, the size of the items should be as big as possible. Having big items on the screen is the huge help for vision disabled users to find them.

The items should be placed on the screen in a meaningful and intelligent way: design of the application layout has an essential role on usefulness of the application. The items of the application should be placed on the screen, firstly in a meaningful way that user can understand and memorize it, secondly in an intelligent way that enable user to find them faster. Corners and sides of the phone screen are always easier to find for blind people than center of the screen.

The method needs to be highly responsive: due to our users cannot see the screen they need to be aware from any single action during the entering the text.

Gesture of the application should be meaningful: this helps the users to communicate to the application easier. It can be flicking a finger to the right to enter a space or to the left to deleting an entered character.

It should be hard for users to enter unwanted character: most of the methods request a confirmation tap from the user to make sure the selected character is the right one. Although it works very well, it increases the number of screen stroke and as a result reduces the speed.

A blind user should be able to enter all numbers and symbols beside the letters: except letters there are many numbers and symbols in a text which a person wishes to enter into the mobile phone. The text entry method should enable blind users to do that and be careful not to increase the complexity of the method simultaneously.

The unnecessary sounds should be as less as possible: in most of the mentioned methods the blind users are forced to listen to the sounds of unwanted characters while they are looking for their intended one. This can be annoying for them and the people who are around them.

Users should be able to delete their mistakes: during entering any texts some intentional and unintentional mistakes may happen which should be deleted. The blind user should be able to reach to the wrong letter through the shortest path and delete it.

The text entry application should be clever: there are many small lateral techniques which can be added to the text entry method to perform user's needs unexpectedly and make the method clever. For instance, the text entry method can use automatic word finishing technique or letter prediction system, or it may include message translation system in that it translates the short terms of some words which are common in informal text messaging to the real words (e.g. "How r u?" to "How are you?"), or add the question mark automatically at the end of the sentences start with question words.

6 USER STUDY RESULTS

In this chapter, we show the result of the two user studies we have done at the beginning of the project. We performed several interviews and a survey in the form of questionnaire. Each method clarified different aspects of user's preferences and capabilities and provided us useful hints in design process. In following subsections survey and interview results are shown individually.

6.1 Survey Results

Survey is one of the methods we have employed to get more familiar with our very specific users. At first we required to be up-to-date with current state of the text entry for visually impaired mobile phone users. Also we needed to get informed what our real users think about the different aspects of the subject and how much the result of the project may improve the current situation.

We conducted the survey in the form of questionnaire. Due to limited number of visually impaired and blind people we have accessed, in order to have reasonable results we sent the questionnaire to many blind associations in different countries as well as we asked it presence from few people in SRF. We gathered 28 results consisting of associations which cooperated and people in SRF. All question results are discussed in this part and the survey questionnaire can be found in appendix D.

The first two questions, we asked age and vision status of participants. The third question is asked to investigate whether vision disabled people prefer to use a normal mobile device with an extra assistive software or a kind mobile phone which is specially made for them. As it is clear from the result, most of these disabled people are interested in using normal phones. It can be because of high cost of the special phones made for them or the limitations exist in functionality of such mobile devices.

Two next questions aim at finding out how many of the participants are already among the multi-touch screen mobile phone users and in case they are, how easy is it to enter a text on such mobile phones. From these two questions, it seems that although many of participants do not have a multi-touch screen cellular phone, they are interested to have one if they feel it is accessible for them. Among few people who already use multi-touch screen mobile phones, only one of them stated that is able to enter a text very fast.

The fifth question is about how much the mobile phone users utilize the short message service (SMS). Almost all of the mobile phone users participated in our questionnaire use short message service as well.

Next two questions were asked to understand how much blind and visually impaired people are familiar with Braille and also how much they are open to use new Braille-based devices. The interesting point of first question's result is although the majority of the participants unable to read Braille fast, most of them have had some contact with Braille and they are not alien with Braille alphabet. The second question specifies that most of them are open to new Braille-based devices.

In the next question we tried recognize how blind and visually impaired people communicate with computer. As we can see most of the people who unable to see even the big font of the screen, use screen reader in order to get feedback from computer.

The last question of questionnaire is about the importance of different aspects of text-entry method. The expectations of the participants from a text-entry method are different. But as final result shows, these aspects are prioritized as follow: most important is easy-to-learn, next is accuracy, then speed and number of screen stroke is located at last.

All of the results can be found in following table in detail:

Table 6.1: Questionnaire results

Question	Answer	Count	Percent
Age	Less than 23	10	35.71%
	23-45	12	42.86%
	Older than 45	6	21.43%
Vision Status	Totally blind	19	67.86%
	Purblind	9	32.14%
What kind of mobile phone Do you use?	Normal mobile phone with speech software	24	85.71%
	A mobile phone made for blind/visually impaired	4	14.29%
How much are you familiar with multi-touch Screen mobile phones?	I'm multi-touch screen mobile phone user	6	21.43%
	I'll buy multi-touch screen mobile phone, if I feel It is accessible for me.	14	50%
	I won't use multi-touch screen mobile phone	8	28.57%
How often do you use short message service (SMS)?	I use SMS everyday	10	35.71%
	I use SMS several times a month	12	42.86%
	I prefer not to use SMS, but I'll use if it would be easier To me	4	14.29%
	I never use SMS	2	7.14%
In case you use multi-touch screen mobile phones, how easy is it for you to enter a text on it?	I can enter a text entry very fast, like sighted users and even better	1	3.57%
	I can enter a text in reasonable amount of time	3	10.71%
	I can't enter a text easily	4	14.29%
	I don't use multi-touch screen mobile phone	20	71.43%
How much are you familiar with Braille?	I'm a fast Braille reader	4	14.29%
	I'm not a fast Braille reader but I know the Braille alphabet	16	57.14%
	I haven't had any contact with Braille	8	28.57%
How much are you open to use a new Braille-based devices to handle your routine?	I know Braille and I prefer to use it wherever possible	6	21.43%
	I'll learn Braille if I can handle my most of the job with it	13	46.43%
	I prefer not to Braille	9	32.14%
How do you access to computer?	By using refreshable Braille display	3	11.11%
	Through the help screen reader program	19	70.37%
	I can see the big fonts	5	18.52%
	I don't use the computer	0	00.00%

Please prioritize the following aspects of text entry from 1 to 4 (1 being the most important) from your point of view	1		2		3		4	
Speed	8	30.77%	5	19.23%	7	26.92%	6	23.08%
Accuracy	6	23.08%	7	26.92%	10	38.46%	3	11.545
Number of screen stroke	1	3.85%	8	30.71%	8	23.08%	11	42.31%
Easy to learn	11	42.31%	6	23.08%	3	11.54%	6	23.08%

6.2 Interview Results

Another user study method we used is interview which was performed in different stages. We visited three visually impaired and blind mobile phone users at SRF in different times and also talked with blind women on the phone. Sometimes we met one person more than once and discuss more about the subject. Our interviewees were in different ages and vision statuses. Also they used different kinds of mobile phones such as multi-touch screen iPhone, button-based mobile phone with the screen reader software or button-based mobile phone with large print font.

In our interviews we generally started to explain our project and its aim and then we tried to find out interviewee's opinions about different aspects of project which are important for us. These interviews mostly were divided to several parts and in each part one aspect of the project was followed. In each step interviewees were free to express any idea regarding the considered topic. These project aspects include:

- A few personal questions
  - Name, age, job, vision status, when they got blind
- Interviewee's current mobile phone
  - What kind of mobile phone do you use?
  - Why you chose this mobile phone? What are the advantages and disadvantages?
  - How do you enter a text in your mobile phone? Please show us.
  - What are the advantages and disadvantages of the text entry method?
  - What kinds of feedback you get form the mobile phone?
- Multi-touch screen
  - Have you had any contact with multi-touch screen devices? If not why?
  - What are the main problems in using multi-touch screen devices?
- Braille
  - How much are you familiar with Braille?
  - What kind of Braille-based devices you use? Please show us.
  - What are the advantages and disadvantages of using Braille?
- Physical state of holding the mobile phone
  - How do you hold the mobile phone when you want to enter a text?
  - How do you prefer to enter a text? (With thumb of your both hands or with one of your point finger, etc.)

We recorded all the interviews performed at SRF and took note in order to capture and collect the data. After that, we red them carefully several times and extracted the meaningful data using the coding technique in two steps. First, we conducted initial coding for each interview by generating numerous category codes as we red responses without worrying about the variety of categories. Below, the result of initial coding for our first interview is indicated. The rest can be found in appendix B.

<table>
<tr><td>Name: Jimmy Petersson
Age: 34</td><td>Gender: Male
Job: Manager of SRF.KNA</td></tr>
<tr><td colspan="2">-He is totally blind
-He got blind when he was a little child
-He has two mobile phones, one button-based Nokia phone (ES1) and one multi-touch screen mobile phone (iPhone)
-He believes that his iPhone is much easier to use than his old button-based phone
-He was forced to buy an expensive speech application for his Nokia phone, while such application is already existed in a normal iPhone and he just turned it on
-He uses SMS everyday and believes that entering a text using VoiceOver iPhone was an exhausting job at first but after almost two month he got use to it
-The learning process of the entering a text in his multi-touch screen mobile phone was too long
-He is a fast Braille reader
-He uses refreshable Braille display in order to access to computer and also a mechanical Braille writer in order to take his daily notes
-He believes that every blind people have to learn Braille and it is much easier for him to communicate with Braille
-He expressed that the low number of good Braille reader among blind people is because they don't feel they can handle all jobs through the Braille
-He hold the iPhone with his left hand and touch the screen with his right hand point finger</td></tr>
</table>

In the second step we performed focus coding, in that we reviewed the codes from initial coding and deleted less useful ones. Below, we illustrated the result of focus coding which is the usable qualitative data that had direct effect on our designs:

- There are some points on the screen that a blind person can correctly tap at first try, if the target is at least as big as a finger pad.
- It is much easier and more desirable for a blind person to tap several times the same target, than tap different targets once each on the screen. Therefore, users do not have to move their finger across the screen as far as possible.
- Corners and sides of the screen are much easier for a blind person to find.
- A blind person is able to perform different gestures like flicking, pinching or dragging, but using similar gestures for different tasks causes confusion for them.
- The number of speech sound feedback should be as low as possible due to the privacy issue.
- The range of vision and amount of experience in working with Braille are different among visually impaired people. Thus, the Braille-based application should be customizable for different abilities and manners.

7 DESIGNING BRAILLE-BASED TEXT ENTRY METHODS

In previous chapters, different kinds of information required for designing Braille-based text entry methods for unsighted users were demonstrated. Information was gathered from users, related researches, related input devices and techniques and correlated knowledge. Some of this information helped us to know the constraints and limitations of designing a text entry method for visually impaired people, some others inspired us new ideas. We laid out the methods step by step with having all information in mind.

This chapter includes the main result of this project. In this chapter, we first have a comprehensive review on Braille language and Braille-based input devices. It assisted us to explore different approaches of entering Braille in different devices. Then, we discuss and extract the alternatives we have for text entry methods regarding to the input techniques may be used and the structure of the Braille cell and also the type of the feedback the user is provided with. In the next part we introduce the potential text entry methods we designed for a multi-touch screen mobile phone in the form of mockups. After that we document them using two techniques commonly used for documenting: gestural modules and swim lanes. The last part of this chapter is allocated to prototyping the text entry methods and evaluating them with the real user. In this part we also refine our methods based on user's feedback and select our best designs. Finally we apply the principles of good gestural interfaces (mentioned in chapter 5) and also the result of user study (mentioned in chapter 6) on the best designs (Figure 7.1).

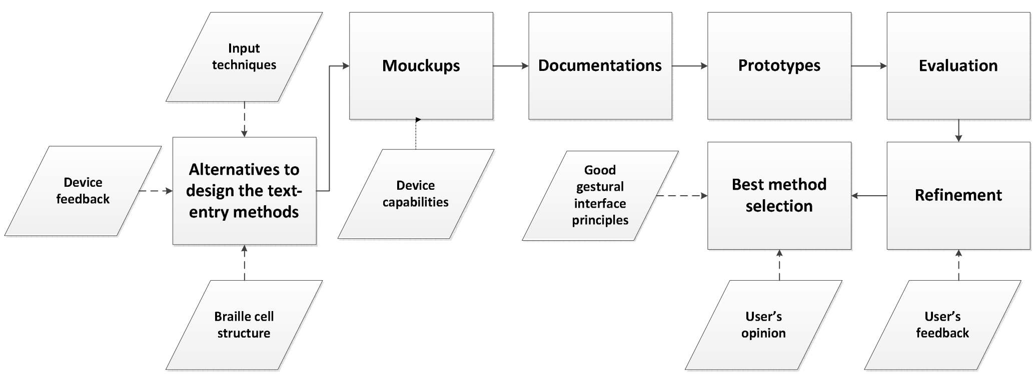


Figure 7.1: Steps of designing the text entry methods

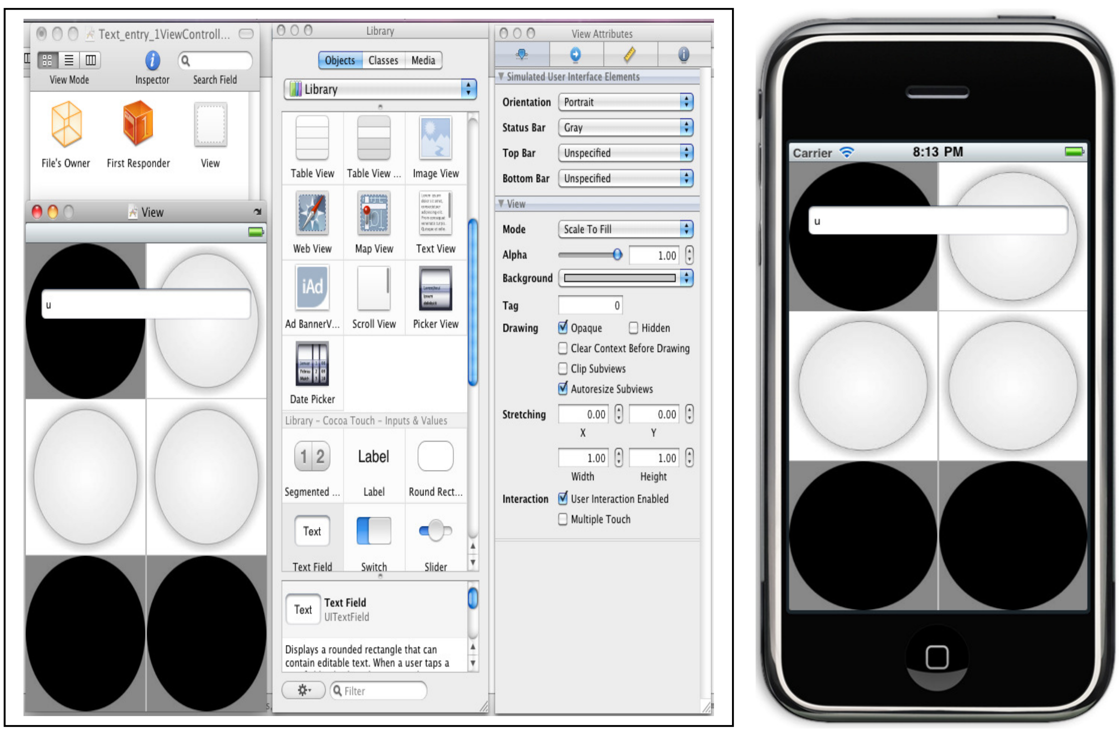
Before starting the designing section we have technical discussions to explain how text entry methods should be converted to the real application. Although a great user interface follows human computer interaction design principles which is based on the way users work and not the device capabilities, this technical study is a necessary step before designing process to recognize what views and features the actual software environment support to be implemented [37].

iOS or iPhone OS is the operating system of Apple's mobile phones. Although iOS is a technology inherited from MAC OS, it was designed to meet the needs of a mobile environment, where users' requirements are totally different. The iOS SDK comprises required code, information, and tools for developing, testing, running, debugging, and tuning applications for iOS. The Xcode is the development environment for iOS SDK which provides the basic editing, compilation, and debugging tools for the developers' code. The codes for iPhone applications are written in an object-oriented programming language called

Objective-C. Furthermore, Xcode provides a platform that emulates the basic iOS environment but runs on the local Macintosh computer, called iOS simulator [38].

The iOS's user interface is established on the concept of direct manipulation, utilizing multi-touch gesture. Direct manipulation is a human-computer interaction style which represents objects that, users are able to manipulate them using actions correspond to the real world. Resizing a rectangle by dragging its edges or corners with fingers or mouse, or dragging an item from one to another position on the screen are the example of direct manipulations. Also multi-touch gestures are predefined meaningful actions which enable users to interact with user interfaces of iOS, such as tapping, dragging/sliding, flicking, swiping, holding, pinching or spreading. These gestures have particular meaning in the context of iOS and the multi-touch interface.

An iOS based interface may include different views, such as image, text, table, scroll, web or map view, and also numerous control elements like, buttons, labels, switches, text fields or sliders. Interfaces can be run on the iPhone in different dimensions (i.e. rotated iPhone in different dimensions). Also, internal accelerometers are employed by many iOS applications to the feedback in an efficient way. Figure 7.2a illustrates one sample interface, which is implemented in iOS SDK, and 7.2b shows this design built and run on the iPhone simulator.



a- iOS SDK (Xcode) b- iPhone simulator

Figure 7.2: iOS SDK (Xcode) Braille and iPhone simulator

7.1 Braille

Braille is a method that enables blind and partially sighted people to read and write. It is a code based on six dots (a matrix of 3 dots high by 2 dots wide) called a "cell". Not only all 26 alphabet letters but all numbers, music notation and any other symbol that appears in print can be converted into Braille cells. Braille users touch the cells as raised dots on the thick paper with their fingertips to read the texts.

7.1.1 Why Braille?

In several reasons we believe that a text entry method based on Braille can improve current situation of text input on multi-touch screen mobile phones. Below, we mentioned these reasons that have convinced us to study Braille to employ it in our text entry methods:

1. Statistics derived from different researches have proven that among blind and visually impaired, people who are Braille literate are much more successful from different aspects of their life. According to American Foundation for the Blind "At this time, among the estimated 85,000 blind adults in the United States, 90 percent of those who are Braille literate are employed and among adults who are not Braille literate, only 1 in 3 is employed" [16].
2. For who knows Braille, it is much easier to handle the routine by Braille than learn and memorize an extra method.
3. Although the number of fast Braille reader may not be very high, most of the blind and severe visually impaired people have had some contact with Braille and Braille alphabet. This basic knowledge of Braille alphabet can be enough for using the text entry method.
4. A text entry method based on Braille alphabet can be easy to learn for vision disabled people who has not any contact with Braille as well. The hard part of learning Braille is to be able to read Braille print fast.
5. Blind people must have the chance to be equal with normal people. Braille is the only way these people can directly read and write like normal people.
6. The alphabet, numbers, punctuation marks, music notation, mathematics and any other symbols that be used in print can be translated to Braille cells.
7. Some Braille experts believe that if the opportunities for handling issues using Braille are growing up, more visionless people will eager to learn it.
8. Some well-known manufacturers in mobile phone industry such as Nokia and Samsung are studying using Braille in their products.

7.1.2 The Braille System

In order to design an efficient Braille-based text entry method we need to know how exactly dots are arranged to the cells of each character. As it was mentioned, each cell of the Braille contains six dots arranged in a 3×2 matrix. There are 64 (2^6) possibilities for dots to be placed in a Braille cell (including the blank cell). The combination of these dots can represent different characters and even words. These dots are typically numbered 1, 2, 3 for the left, and 4, 5 and 6 for the right dots from top to down. Braille literates are used to thinking about the Braille cells by their numbers (e.g. 1-2-4 for "f"). Three different versions of Braille exist [23, 24]:

- **Grade 1:** It contains only the 26 basic letters of the alphabet in addition to punctuation marks. It is typically used by beginners of Braille learner (Figure 7.3).

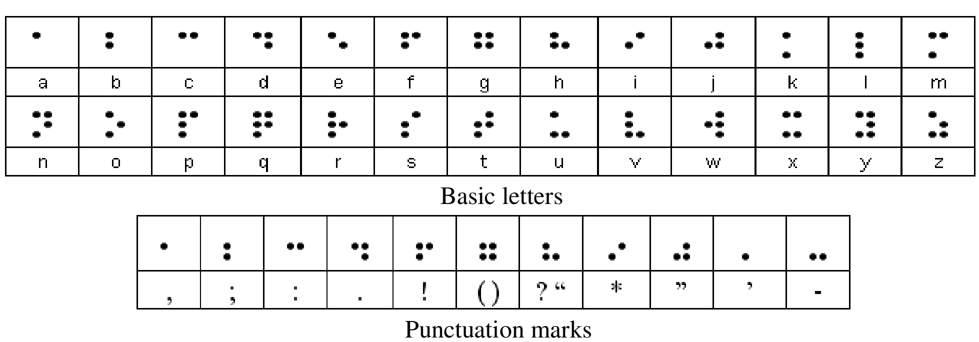


Figure 7.3: Braille grade1

- **Grade 2:** Braille grade 2 is the comprehensive version of Braille which is commonly used by Braille literate. It consist of following components (Figure 7.4):

1. The 26 standard alphabet letters
2. The standard punctuation marks: such as dash, comma, semicolon, slash mark etc.
3. Special composition signs: they are the particular Braille cells that have a specific meaning for the next cells. For example the capitalization sign which capitalizes the next letter or the number sign which makes the next letter a number.
4. Part-word contractions: consisting of part-words commonly used in English, such as “ing”, “ed” or “ble”
5. Whole-word contractions: consisting of whole-words frequently used in English, such as “and”, “can”, “have”, “the” etc. There are almost 190 part- and whole-word contractions available for Braille users to make reading and writing simpler. The contractions are basically created to reduce the size of the Braille texts.

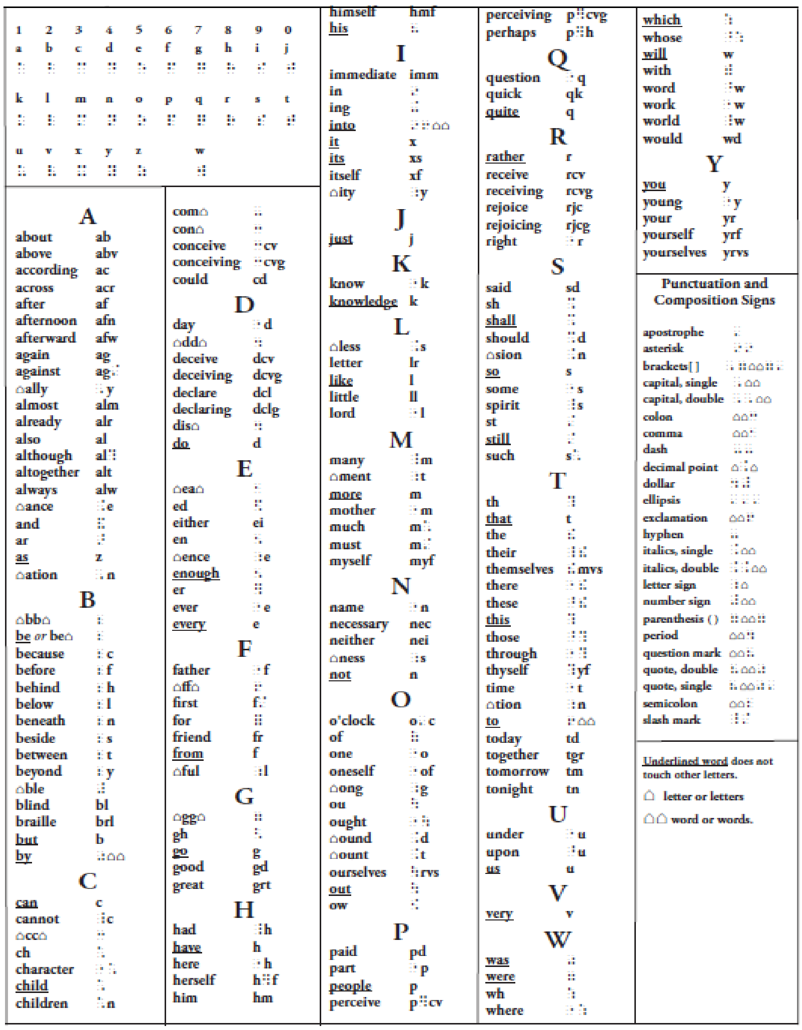


Figure 7.4: BANA Braille chart* [30]

*There are three kinds of standard Braille charts, Braille Authority of North America (BANA) which is used in the United State and Canada, Braille Authority of the United Kingdom (BAUK) which is used in United Kingdom and Unified English Braille (UEB) which is used in Australia, New Zealand, Nigeria, and South Africa. These three standards are different in very little details. In this research we consider BANA as a reference.

- **Grade 3:** In this version Braille users write a few letters of the word instead of whole word. It is used mainly in personal notes and letters.

Above, we mentioned different Braille versions and showed the Braille translation of the characters. By having a closer look on the Braille chart, we perceive that Braille alphabet letters are managed in a special order. The ten first letters of the Braille are created only using top four dots (1, 2, 4 and 5). Adding bottom the left dot (3) to them makes the next ten letters respectively and adding the bottom right dot (6) to 11th till 16th letters, makes the rest of six letters ("w" is an exception, because it was not used in the French language at the time that Braille was created). Being aware of these orders helped us to create innovative interfaces. Louis Braille* exhibited the 63 non-blank characters in a seven-line table. These tables can be found in appendix A [24].

7.1.3 Braille Input Devices

There are many different Braille note-takers and input devices available in the market. After reviewing the Braille alphabet, we studied the following six devices to understand how Braille users enter the Braille cells into the print or electronic devices [25, 26, 27, 28]. This helped us to identify the best alternatives for the order of entering a Braille cell's dots on the device. We also asked some of the SRF members to demonstrate how they operate these note takers. Below you can find a brief description of how they work.

- **Slate and stylus:** is the basic tool for writing the Braille in a paper. A heavy paper is placed in the slate, the back pins of the slate pinch the paper and user start to write using the stylus by punching the proper cell's dots. (Figure 7.5)

Figure 7.5: Slate and stylus [46]

- **Perkins Brailler:** is a Braille typewriter which has 7 keys, 6 keys responsible for 6 cell's dots of Braille and 1 key for entering the space. Three left keys are for three left (1, 2 and 3) and three right keys are for three right (4, 5 and 6) dots of the Braille's cell. The user pushes the proper keys simultaneously and respective dots are punched on the paper. (Figure 7.6)

Figure 7.6: Perkins Brailler [46]

- **Braille 'n Speak:** is a small and portable Braille note-taker with the keys very similar to Perkins Brailler. Braille 'n Speak has the memory enough to save about two thousand pages of Braille note. Also, it can be connected to the computer or Braille printer and be used as an input terminal. Again the user pushes the appropriate buttons together and the respective Braille character is saved in the device. It provides users with the voice feedback as well. (Figure 7.7)

Figure 7.7: Braille 'n Speak [26]

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*Louis Braille (1809-1852) was the inventor of Braille. He was born in a small town near the Paris. He got blind when he was three-year-old child by an accident.

- **Braille stapler:** is a combination of Braille board and Braille printer into a single unit. It is an easy, quick and portable device. The user inserts the paper inside the device and pushes one or more buttons of the stapler's six buttons. (Figure 7.8)

Figure 7.8: Braille stapler [47]

- **Braille Buddy:** is the device with six keys which can be used as a Braille cell or a Braille keyboard. The user can enter the Braille letters through the keyboard and feel the respective letter by touching the cell. It also provides users with the sound of the letters. It is created to make Braille learning easier. (Figure 7.9)

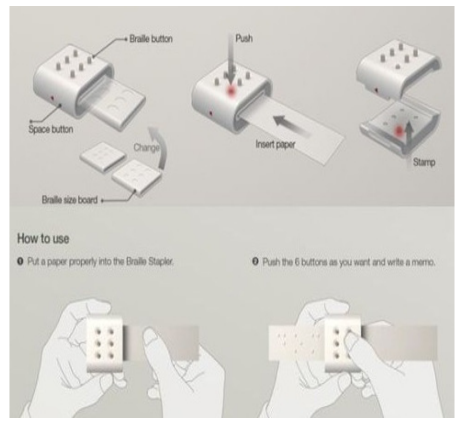


Figure 7.9: Braille Buddy [49]

- **Touch messenger:** is a mobile phone won the Gold Award at the Industrial Design Excellence Awards (IDEA) 2006. It is lunched by Samsung based in Shanghai, China, a country with about 9 million visually impaired people. Touch Messenger is an innovative product enables vision disabled users to send and receive text messages in the form of Braille. The user can enter two Braille cells through the 3×4 button keypad on the mobile phone simultaneously and text messages can be read through the Braille display screen in the lower part [44]. (Figure 7.10)

Figure 7.10: Touch messenger [44]

There is also a software that allows the users to enter Braille into computers through a regular keyboard. It enables users to use keys 'F', 'D', 'S' for entering three left dots (1, 2 and 3) and keys 'J', 'K' and 'L' for entering three right dots (4, 5 and 6).

7.2 Text Entry Method Alternatives

In this part we discuss different alternatives we have to lay out the Braille-based text entry methods. At the first step we discuss what input techniques we can employ to design the text entry methods. In chapter 3, we investigated different type of text input techniques include *keyboard and keypad, gesture recognition, speech recognition* and *text recognition.* They helped us to be aware of different alternatives exist to enter a text on mobile phones. However regarding to our specific goal which is *designing a text entry method on multi-touch screen mobile phones for visually impaired and blind people* and principles we should consider to achieve this goal, some of them are omitted in early stage:

- **Keyboard and keypad:** Many of the computer users are able to type the texts through the keyboard very well, and visionless users can do the same subsequently. However, situation is changed when it is a mobile phone keyboard. The small buttons of the mobile phone keyboard are very close together; hence it becomes highly vision demanded. One other objection using keyboard as text input device for blind and visually impaired have is the large number of keys (between 30 to 50 keys) it uses. Obviously how the number of options of the application target is lower, it is easier for a visionless person to find them, and as a result it is easier to operate them. Most important, since our research is focused on multi-touch screen device and also buying and carrying external assistive device like keyboard is not desirable for users, using keyboard and keypad is not a suitable technique for this research.

- **Speech recognition:** Each of voice recognizer producers has tried to offer a higher range of noise immunity product. However, these applications are still prone to error specially when a user does not have a pure accent, or when a user is in noisy area. Regardless to efficiency, employing speech for the mobile phone input has one tough problem, privacy. Almost nobody wants other people in public places to know about his or her messages content. Hence, it may suitable for some situations, but in some other situations it is definitely needs to be improved. Therefore, due to high error probability for different accents and most important low privacy, speech recognition is not among our potential input techniques.

- **Free-form gesture reconition**: In order to using a gesture to perform a special task seems wise; complexity of gesture should match to complexity of the intended task. In respect to this rule a user expects to perform some simple action to enter a text to the mobile phone. Therefore few designers prefer to use free-form human gestures in performing basic functions of mobile phones like text entry. Perhaps these sorts of gestures like tilting the phone can be used in more complicated applications such as animated games.

- **Off-line text recognition:** Text entry method on mobile phone should support real-time action that enable the user to use short message service in any time and places, so any kind of off-line text recognition will not help.

As a result our potential input techniques are the *first kind of gesture recognition* (i.e. performing gestures using fingers or stylus on sensing screen) and *on-line text recognition*.

After deciding about type of the input techniques, two factors which have direct effects on Braille-based text entry method efficiency should be clarified: first the strategy of entering a Braille cell, second the feedback user should be provided with. In previous chapters different kinds of Braille input devices and also feedbacks are explored. In this part, we investigate different possible ways to enter the 3*2 matrix Braille cell on a screen.

As it was explained in this chapter, a Braille cell includes six dots formed in a matrix with three rows and two columns. The combination of these dots creates different characters. A blind person can select the intended dots in different orders whether dot by dot, row by row, column by column or even all the six dots at the same time (Figure 7.11). For example, a blind person punch a cell of Braille dot by dot using slate and stylus while all of the dots are entered simultaneously when this person uses Braille note takers.

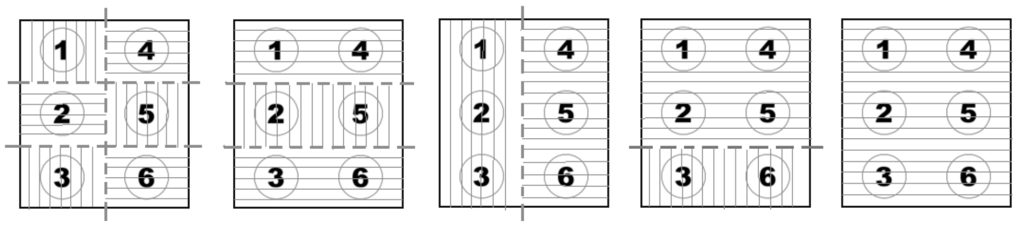


Figure 7.11: Different possible ways to select a Braille cell

Moreover, three types of feedback are existed that most suitable ones should be chosen for different actions to keep informed users what happening on the screen. As it was justified in chapter 3 a feedback can be whether in a form of tactile or speech and non-speech feedback. Each kind of feedback can be best for some moves and worst for others.

7.3 Text Entry Mockups

In this section, we explain six text entry methods designed in the form of mockups. Mockup is a demonstration of a user interface which simply illustrate the features and content that should be appear on the page [41]. It completely makes clear where each item should be placed on the page. Each design is the demonstration of one of the possible way for entering the Braille cells on a multi-touch screen mobile phone explained above. In the first five designs we used *gesture recognition* and in the last one we used *text recognition* as the input technique.

1. **First design – six dots on the screen at the same time:**

The first strategy we investigate to enter the Braille cells on the mobile phone is to have all six dots of the cell on the screen at the same time. This method works similar to BrailleTap but implemented on multi-touch based mobile phone. (Figure 7.12)

In such a method screen is divided into six equal parts just like 3×2 matrix. The user should consider these parts as a cell of the Braille and touch the respective parts to enter the desired character. For instance touch two top corners of the screen to enter a ‘c’. These touches can be performed asynchronous.

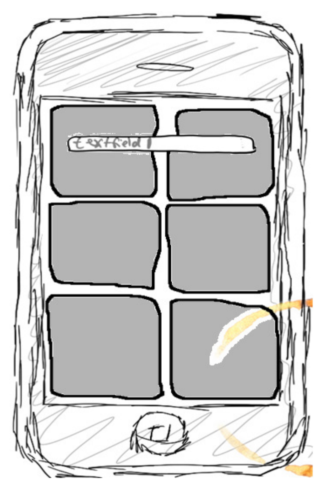


Figure 7.12: First design

2. **Second design – a row on the screen at the time:**

In the second strategy we proposed, the user enters the Braille dots row by row. In other word, the user selects the 6 dots of the cells in 3 steps. In the first step two top, second step two middle and in the last step two bottom dots of the cell are appeared on the screen. In each step screen is divided into two equal parts beside each other and each part is allocated to on dot. In this way the user can find each dot quite easily and tap it correctly. To move between 3 steps, users flick their finger bottom-up and top-down (Figure 7.13), in that they feel these three rows of cells are located under each other (exactly how they are in a real Braille cell).

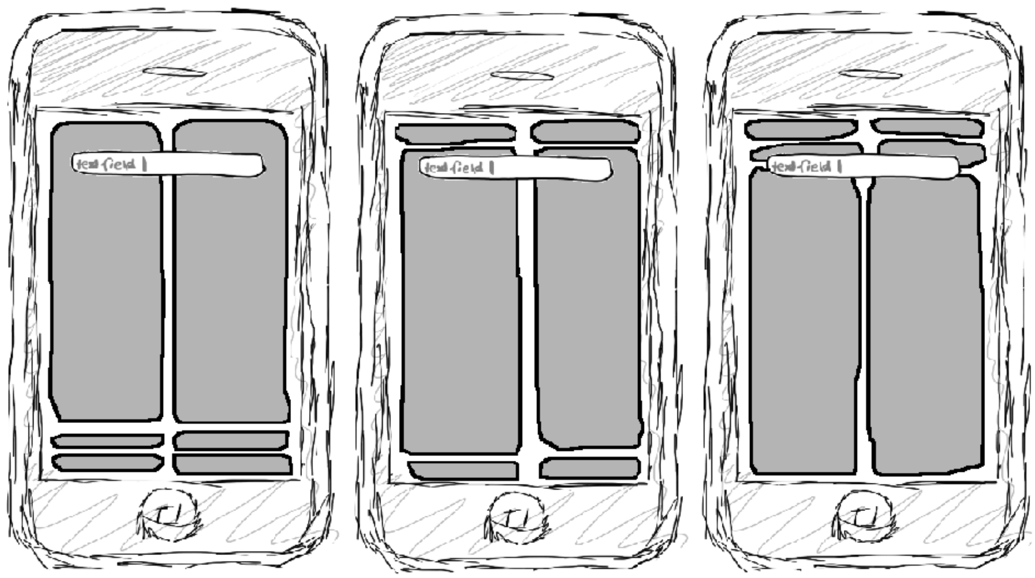


Figure 7.13: Second design- three steps of entering a character

The user is capable to enter a character whether with two hands or one hand. Probably using two hands is faster and more comfortable but entering the text by one hand is still quite accurate. Moreover, the user has this opportunity to rotate the device and use the method even easier (Figure 7.14).

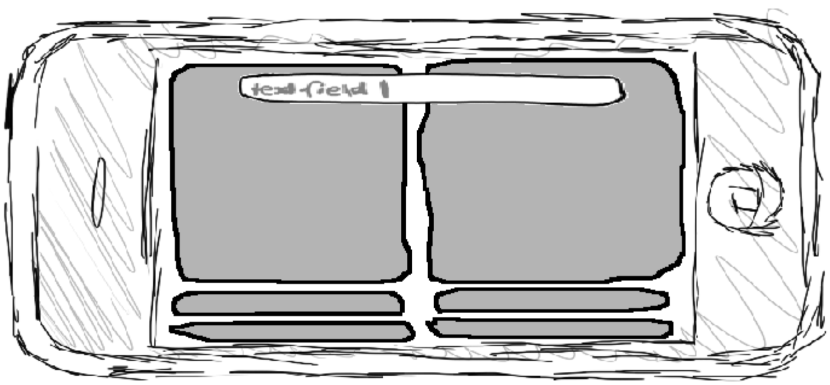


Figure 7.14: Rotated style of the second strategy

3. **Third design – two first rows on the screen:**

As it is demonstrated in chapter 5, Braille alphabet is designed in a special order. First ten letters are using only for top dots (1, 2, 4 and 5), by adding down left dot (3) next ten letters are created and by adding two down dots (3 and 6) last six letters are produced. In this design we use this feature and introduce a strategy to enter Braille easy and fast.

Here, we divided the screen in four equal parts; each part is located in one corner of the screen. Since these parts are located in the corners of the screen, they are quite accessible for visually impaired people. These four parts are allocated to four top dots of the Braille cell.

The user should tap one or more corners of the screen first (regarding the desired letter), in case the user's intended character is among ten first letters, they flicks a finger to the right to submit the letter. If it is among the next ten letters the user flicks a finger top-down and if it is among six last letters flicks two fingers top-down. While the user flicks top-down, one or both bottom dots are selected and letter is submitted simultaneously. Flicking one or two fingers top-down are meaningful gestures to add dot 3 or dots 3 and 6 respectively and the use can easily remember it (Figure 7.15).

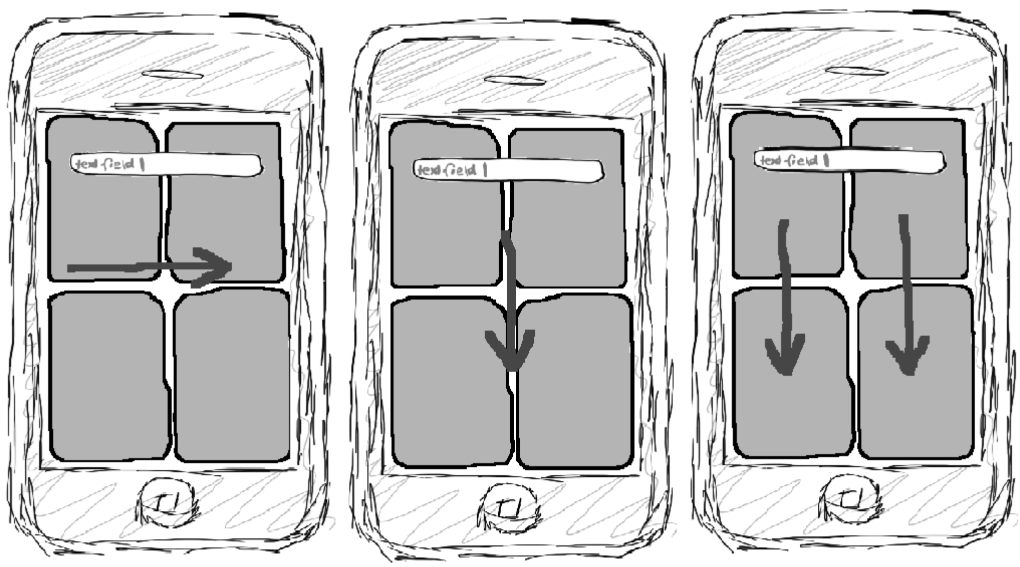


Figure 7.15: Third design- first, selecting one or more of top four dots, for example dot 1 and then performing one of above three gestures leads to enter letters 'a', 'k' or 'u' respectively

4. Fourth method – a dot on the screen at the time:

The Nokia Braille Reader is a technique to read a received text in Braille. The idea behind the Nokia Braille Reader is that the application produces a special pulse as *output* every second to read a Braille cell dot by dot. In our fourth method we use this idea to give *input* to the device for any Braille characters dot by dot.

In this method, an empty Braille cell is appeared on the screen which has a cursor. The cursor moves between dots every second (from dot 1 to 6) and the user hear number of the dot the cursor is currently placed. For each cursor moves the user can fill the dot by a single tap anywhere on the screen or wait a second for the next dot (Figure 7.16). By using this strategy entering some characters takes six seconds but not all of them. Six seconds is for the characters which include the last dot (dot 6). The user is able to submit the character and open a new cell in any stage by perform a double-tap gesture or taping with two fingers. For example, if the user wants to enter an 'a', he taps the screen at the first second and then double-taps to open a new cell immediately (he does not have to wait six seconds to enter a new character).

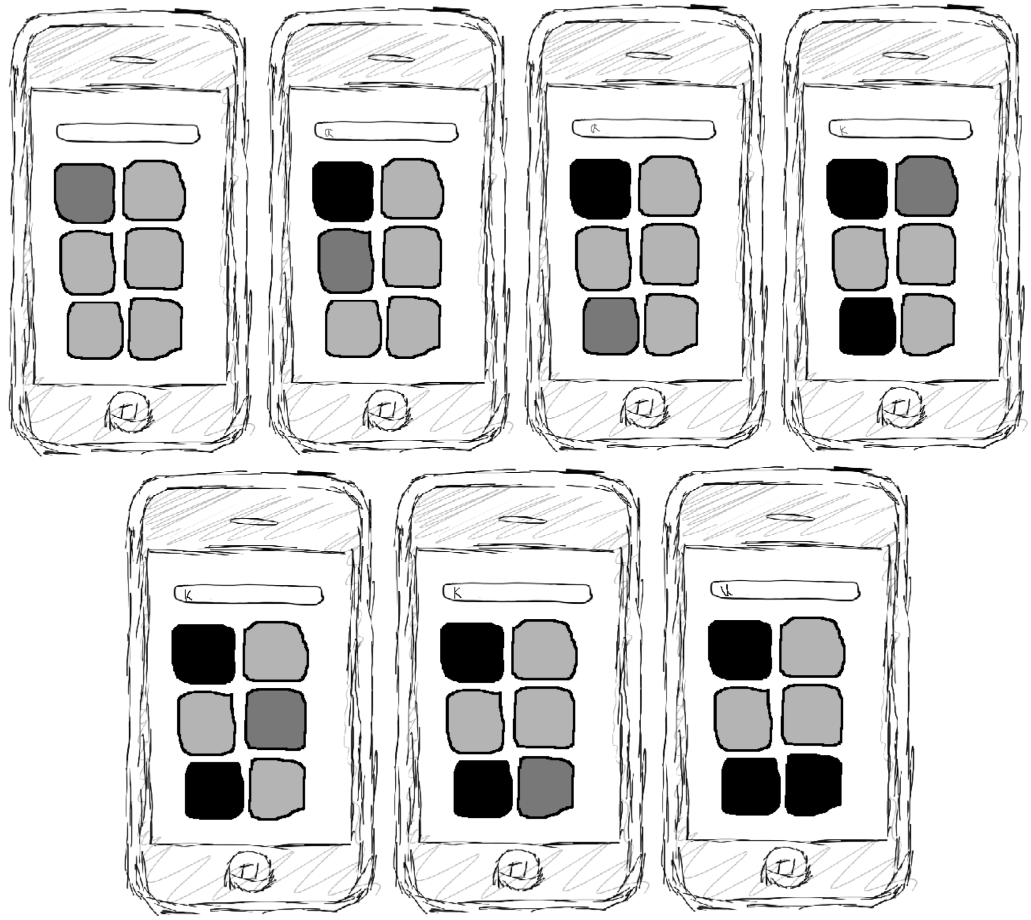


Figure 7.16: Fourth design- six steps of entering the character ‘u’ after opening a new cell

5. **Fifth method – a column on the screen at the time:**

As it was explained in chapter 5, there are many Braille input devices. These devices are utilized regularly by many of Braille users who are get used to work with such devices. Therefore, we try to capture these devise’s structure in multi-touch screen phones in this method.

Braille typewriters and note takers mostly follow one single structure despite typewriters are mechanical and note takers are electrical, Perkins-style. This structure consisting of six same size buttons in a row for six dots of the Braille cells in addition to one bigger button between these six buttons which is allocated for entering the space. These buttons and the distance between them are designed in a way that the users can put their three middle fingers on the buttons comfortably (Figure 7.17).

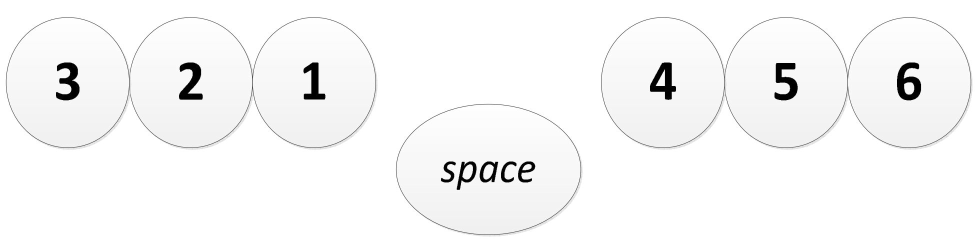


Figure 7.17: Perkins-style

Using Perkins-style to design a text entry method makes that method fast, because all of six dots of a Braille cell are selected simultaneously and in fact characters are entered directly in one step. However, six buttons beside each other in a row on regular multi-touch screen mobile phones will be too small and close together even if the phone is rotated to the side. On the other hand, the user should keep a phone with one hand and perform the task with the other hand. As a result performing the exact Perkins-style layout on the screen does not work. The solution we propose in this method is to perform mentioned layout in two pages. First page includes three first and second page includes three next dots. The user can move between two pages by flicking a finger to the left and right. This method works well only for rotated style.

First, the users tap the screen by one, two or three of their middle fingers depends on what dots they want to select. If none of three first dots are raised in intended character then user just flick the finger to go to next page. Also, if it the desired character only includes one or more of three first dots then the user does not need to go to the next page and can consider the screen as one more empty first page to enter the next character. After that, the user can go to the second page and select three last dots. As soon as the user taps the second page, application read the entered character and one more of first page is opened automatically (Figure 7.18).

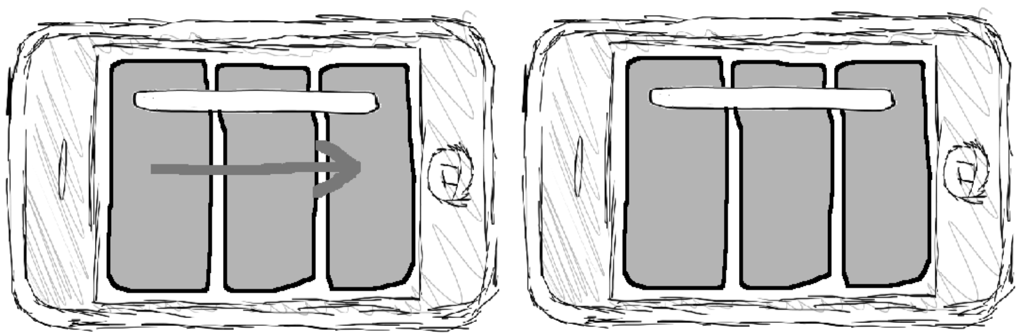


Figure 7.18: Fifth design- user hold the device with one hand and select the cell's dots at last two in steps

6. **Sixth method – a method using text recognition technique:**

As it was aforementioned, our sixth text entry method employs text recognition as the input technique. This method works like graffiti stroke explained in chapter 5. First the visually impaired user touch the screen in the form of Braille cell and then the application should capture these touches as the dots and guess what the desired character is. The application should be able to recognize different inputs, in that a user may draw a Braille cell with long distances and another user draw it with short distances between dots.

The first objection of this method is that how device distinguish between similar orders of dots in different location, for example all of the characters in fifth line table of Luis Braille are the lowered of the characters in first line table (these table are demonstrated in appendix A), like character period'.' (dots 2, 5 and 6) Is the lowered form of character'd' (dots 1, 4 and 5). To solve this problem, we define a gesture in that, each row of the cell the user wish to keep empty, should draw a short horizontal line instead. For instance, when the user wants to enter a '.' (dots 2, 5 and 6), first should the line and then tap the screen in the form of dots 2, 5 and 6. This line for entering the character 'd' (and similar characters) that the empty row is lower than the dots, is not necessary. This strategy is true for the characters with similar dots in different columns (Figure 7.19).

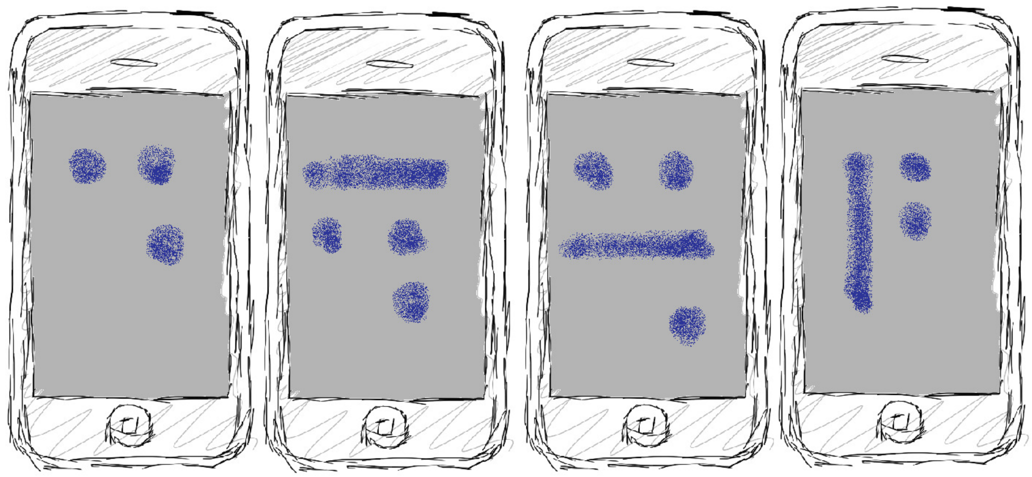


Figure 7.19: Sixth design- entering characters ‘d’ (1, 4, 5), ‘.’ (2, 5, 6), ‘%’ (1, 4, 6) and ‘^’ (4, 5) from left to right

7.4 Documentations

In this part we document the potential text entry methods for multi-touch screen mobile phones mentioned in the last part. Performing the documentation makes clear to understand what is being built and what decisions are made in the system. The definitions of documenting and prototyping a system is very close. The only difference between them is that, in the most system developments a prototype is an object which users can interact with in some manner while documentations does not have this capability [8]. As it was explained in chapter 4, two kinds of documenting techniques were employed in this research: gestural modules document and swim lanes. Gestural modules documents make clear what meaning various actions have, and swim lanes documents clarify the steps of performing different texting related moves (e.g. entering a letter, entering a space, moving the cursor across the text or deleting a letter) from different aspects. In the next part we demonstrate implementation of these two documentation techniques for the first designed mockups. The documentation for rest of the mockups are illustrate in appendix B.

7.4.1 Gestural Modules Document

Following table is the gestural modules for the first design which includes common gestures in use across the whole system.

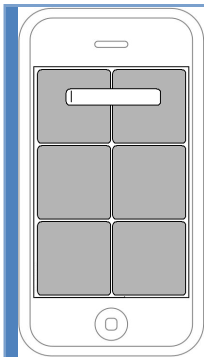
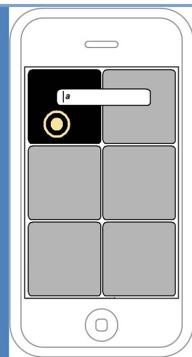
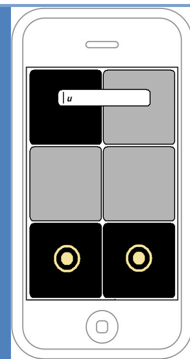
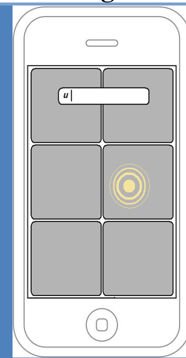
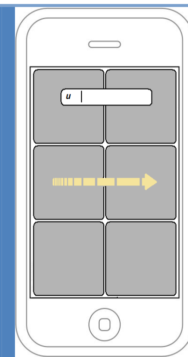
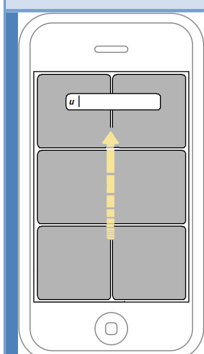
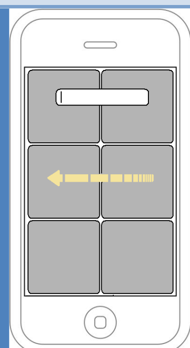
Table 7.1 Gestural modules document for the first design

Gesture	Action
Tap	To select or unselect the dots
Double tap	To submit a character and open a new cell
Flick one finger up and down	To move the cursor across the text
Flick one finger right and left	To enter a space/ To delete a character

7.4.2 Swim Lanes

Following table is the swim lane framework for the first design which includes an overview of a scenario from different perspective: the user, the text entry application and the feedback. In this sample scenario, the user enters the letter ‘u’, submits it, enter a space, move the cursor to the left and delete the letter ‘u’.

Table 7.2 Swim lanes for the first design

				
User hold the device with two hands	User tap the up left corner of the screen	User tap the two bottom corners of the screen	User double-tap anywhere on the screen	User flick a finger to the right
Application is selected from the main menu	Dot 1 is selected and letter ‘a’ appears in the text field	Dots 3 and 6 are selected and letter ‘u’ appears in the text field	Letter ‘u’ is submitted and a new empty cell is opened	A space is entered
Feedback: “Please select the dots”	Feedback: tactile feedback	Feedback: tactile feedback	Feedback: “u”	Feedback: non-speech sound proper for the space
				
User flick a finger bottom-up	User flick a finger to the left			
The cursor moves to the left	Letter “u” is deleted			
Feedback: “u”	Feedback: read the letter before “u” if any			

7.5 Prototypes

After designing the models we feel they can be good potential text entry methods for a multi-touch screen mobile phone based on information gathered in former stage, we need to present them to the real user and extract the weaknesses to improve them. Then we created paper-based prototypes of the methods in the form of wireframes (explained in chapter 4). Next, we contacted with SRF and arranged a meeting with Jimmy Petterson. In this meeting we followed a specific technique to evaluate our designs, pluralistic walkthrough.

In the first part, we demonstrate our prototypes, and in the second part we explain how we presented them to the person who took the test and the results of the evaluation.

7.5.1 Low-fidelity prototypes

In this part we illustrate the paper-based prototypes we made to present them to the user. The prototypes are created in the form of wireframes, which means that the items that are presented to the user in the prototype should be the exact size as corresponding ones in the real application. Also, it should be clear for the user what happen if different points of the screen are touched. In order to obtain this goal and also the user has better understanding of the items place and size on the screen, we used cardboard to make the objects in the prototypes. The user can feel the cardboards and recognize the place and size of the buttons and generally imagine how the designs are look like (Figure 7.19).

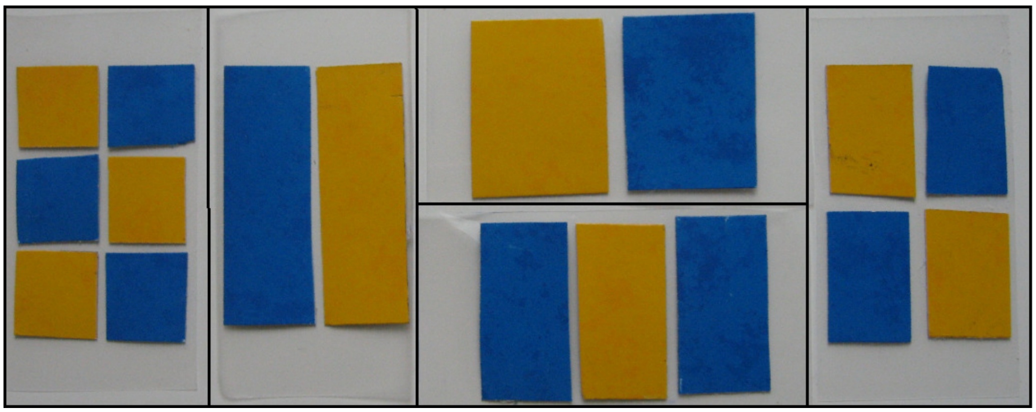


Figure 7.19: Paper-based prototypes of the text entry designs

During the testing process we paste each of these paper-based interfaces on the real iPhone, in that the user can hold the device and understand the location of the items on the real screen.

7.5.2 Pluralistic Walkthrough Evaluation

To evaluate our designs, we pasted paper prototypes one by one on the iPhone screen and asked our participant to feel the buttons' location first, and then we explained to him how the methods work. Next, the user has tried many of Braille alphabets on the prototype and expressed his comment about that specific method. During the test we informed him with different feedbacks that device provide for each gesture. Finally, the user compared all of the methods and informed us with his preferences (Figure 7.20).

Figure 7.20: Jimmy Petterson is testing the prototypes

Generally, the main goal we were looking for by testing and evaluating the low-fidelity prototypes was to find out what design a visually impaired person feels much comfortable to work with. However, there are many useful results obtained during the testing process. We recognized some of the designs are easier to operate in terms of the way users should hold the device and perform the gestures. We identified some of the designs are more similar to the devices blind people use in their daily lives and as a result they are much easier to learn and memorize. We also noticed that some of the designs have more accessible objects on the screen. Except these we got numerous comments on each design which are mentioned bellow in detail.

For the first method with 6 buttons, the participant believes that it is most learnable method since it is a simulation of a real Braille cell. He also mentioned that the buttons are big enough for him to find and tap correctly. However he expressed, "because I am already among the iPhone users, I get use to the device and perhaps for beginners it is not that easy to find the middle row and they may touch the unwanted points." But for the second method with 2 buttons on the screen, he accepts that although speed is a bit decreased in comparison with the first one, it is very hard to make an error.

Moreover he mentioned that "I have never tried to hold the phone with the both hands and touch the screen with the thumbs", when we asked him to do so in second design. After several minutes that he tested the second method in this way (both horizontally and vertically), he realized that he can find different point of the screen much easier, he taps the screen two times faster and his hands and fingers get tired less in this way.

About the third design, the volunteer who took the test believes that, although four buttons on the corner of the screen are very easy to find, the gestures in this method makes him a bit confuse. Then we realized that since there are some similar gestures for different action in this method, it is rather hard to learn and user may accidentally perform unintended gesture instead of the other.

As it was predictable, speed of the fourth design was the first issue participant highlighted. From his point of view six seconds are too much time that the user should spend to enter some of the characters on mobile phone. He expressed that "Perhaps this method is the easiest one to handle because you should just perform some single taps anywhere on the screen to enter a letter but it is not the best in comparison with other designs." Furthermore, he criticized highly dependency of this method to the voice feedback and believes the user will face with some difficulties in noisy environment.

The fifth design was one of the best in participant's opinion. He believes that due to the innovation existed in this method, it is completely learnable and memorable. He assessed the speed of this method very high and mentioned that it is hard to make an error using it.

After introducing the methods to the user and have a comprehensive discussion of each, we asked him to compare all the designs in terms of accuracy, speed, learnability and accessibility. Moreover we requested him to prioritize the designs in general. The table bellow includes this information (These criteria are numbered from 1 to 5, in that 5 is the best):

Table 7.3: The user opinions about different aspects of the designs

Designs	accuracy	speed	learnability	accessibility	Priority
First design	3	4	5	3	**3**
Second design	5	4	4	5	**1**
Third design	3	3	2	4	**4**
Fourth design	4	1	4	5	**5**
Fifth design	4	5	4	4	**2**

At the end of the meeting, we discussed with Jimmy Petterson about the current text entry method (VoiceOver) he uses on his iPhone in comparison with his favorite methods among our designs. In the next chapter the results of this discussion are illustrated in addition to some collations we performed between these methods.

7.5.3 Refinement

Regarding to the user's comments we did some modifications. These changes are described as follow:

- ✓ For the first design, user's comment is about access to the middle row of the cell. He believes that although the buttons are big enough in this method, users who are beginner to multi-touch screen mobile phones may make an error when they want to tap the buttons which are not in the corner (middle row). To overcome to this issue, we add a confirmation tap to the application after the speech sound feedback of the submitted character. In this way, users are asked to perform a confirmation tap if they hear the sound of their intended character. Since this extra move increases the number of screen stroke and as a result reduces the speed to some extent, it can be an optional function in that beginners use it and professionals dismiss it.

- ✓ For the second design, the user expressed that he prefers to 'double-tap' on the screen to submit a character instead of 'flicking' a finger. It makes more sense regarding to his previous experiences.

- ✓ Although the third design works for Braille grade 1 easily, it does not support all characters mentioned in grade 2 of Braille, for instance, a cell includes dots 1, 5 and 6 which is contraction of word "which" or any other part- and whole-word contractions that include dot 6 but not dot 3. To be able to enter all character and contractions using the above method some gestures should be added. For this purpose, we can divide the screen into a couple of columns. Up to now, each top-down flicking with one finger leads to add dot 3, but in refined method users should flick a finger on the left column of the screen if they want to add dot 3 and on the right column if they want to add dot 6.

- ✓ The objection user made about the fourth design was it's highly dependency on voice feedback. We can improve this issue somehow by replacing the voice feedback with vibration feedback. For each cursor movement, the mobile phone is vibrated instead of voice feedback.

- ✓ The biggest risk, the fifth method might have is that the user misses the correct place of the fingers during the text-entry. So, a special gesture with a proper feedback should be provided to show the correct place of the dots. For this purpose a function should be added to the application that whenever the users feel that they missed the location, touch and hold a finger anywhere on the screen and then examine different places on the screen till they hear a specific sound which means they are in a correct place.

In conclusion, we recognized that although all of our models are possible from the user point of view, there are two methods among our designs which will satisfy users' need more: the second design with two buttons on the screen at the time and fourth design which is simulation of Braille note taker. We called these two methods BrailleTouch and Note-Taker Touch respectively.

At the final step of our designing process, we apply the principles of a good gestural interface on our two selected text entry methods. These principles are explained in chapter 5 in detail and investigated in various related text entry methods. We perceived how some of these methods satisfy the principles to employ them in our selected designs. In two following tables the 6 principles of a good gestural interface are studied for our elected text entry methods:

Table 7.4: Good interface principles for BrailleTouch

Second design: BrailleTouch	
Being learnable and memorable:	• Due to the low number of items on the screen and also simple interface it has, this model is an easy to learn method. • Learning a Braille-based method is independent of any specific language knowledge. • The user can memorize the location of items quite easy, because it has only two buttons on the screen at the time. • This method is memorable due to the similarity structure of the method has with a real Braille cell.
Being responsive:	• Highly responsive • Provide a proper non-speech sound or soft pulse vibration* for selecting and unselecting the dots • Provide speech sound for submitting or deleting the characters or moving the cursor across the text
Being meaningful:	• Highly meaningful • It is designed in the form of a Braille cell
Being clever:	• When the user select intended dots from the third page, the character is automatically submitted and a new empty cell is opened**
Being playful:	• Two very big buttons on the screen prevent the user to make a mistake • Users can unselect the dots which were chosen by mistake • Users can delete the characters which were entered by mistake
Being good:	• Extremely good for visionless users since it is based on the their knowledge • Not only do not make them appear foolish in public, but it make them appear skillful • None of the gestures are difficult to perform

*Choosing non-speech sounds or tactile feedback can be optional for the user. In the noisy environment tactile feedback can be selected and in other situations non-speech sounds.
**This feature can be optional as well, in that professionals use it to speed up their text input and beginners can perform a double-tap confirmation to make sure they entered the character correctly.

Table 7.5: Good interface principles for Note-Taker Touch

Fifth design: Note-Taker Touch	
Being learnable and memorable:	• Due to the low number of items on the screen and also simple interface it has, this model is an easy to learn method. • Learning a Braille-based method is independent of any specific language knowledge. • For users who have experience in working with Braille note takers or typewriters, it is highly memorable
Being responsive:	• Highly responsive • Provide a proper non-speech sound or soft pulse vibration* for selecting and unselecting the dots • Provide speech sound for submitting or deleting the characters or moving the cursor across the text • Provide a proper non-speech sound for moving between pages
Being meaningful:	• Highly meaningful • It is designed in form of the Perkins-style
Being clever:	• When the user select intended dots from the second page, the character is automatically submitted and a new empty cell is opened
Being playful:	• Three big buttons on the screen prevent the user to make a mistake • When the user feels that the correct place of the button is missed can hold a finger on the screen for a couple of seconds and examine different places on the screen to find the correct one. The application produce a special non-speech sound for the correct position • Users can unselect the dots which were chosen by mistake • Users can delete the characters which were entered by mistake
Being good:	• Extremely good for visionless users since it is based on the their knowledge • Not only do not make them appear foolish in public, but it makes them appear skillful • None of the gestures are difficult to perform

8 DISCUSSION

After designing and testing our methods, we need to compare them with an existing one to show how much an application based on our designs can improve the current situation of text entry on multi-touch screen mobile phones. We selected two out of our six Braille-based text entry designs (BrailleTouch and Note-Taker Touch), as most efficient and usable designs. In this chapter Usability Testing technique is used to compare them with an existing iPhone text entry method for blind people, called VoiceOver.

8.1 Braille-based Text Entries versus VoiceOver

Usability testing is an evaluating method aiming at determining how well a product meets its intended goal [42]. In this project, the goal is entering characters on multi-touch screen mobile phones in the form of Braille. This technique particularly measures how well a product covers four major aspects of usability: efficiency, accuracy, recall, and emotional response.

- Efficiency: how much time and effort does the user spend to perform the task? In our case, how much time does the user spend to enter a word or a letter? How many gestures and in particular screen strokes does it take to enter different characters
- Accuracy: how many errors happen during entering a text? How likely is a user to enter an unintended character?
- Recall: for how long does the user remember the method's instructions over a period of non-use?
- Emotional response: does the user feel confident while he or she is entering a text? Will the user recommend the method to others?

Performing a usability testing involves creating a scenario in which the user fulfills a set of tasks using the product being tested. The scenario we defined for the usability testing is to perform the following tasks: *selecting numerous characters, submitting the characters, entering a space, deleting a character* and *moving the cursor across the text*. These tests can be carried out whether by paper or an implemented prototype. The person who participated in our paper-based test, Jimmy Petterson, is both a Braille expert and an iPhone user. Hence, he was able to give us reliable judgments.

In terms of efficiency, the participant claims that the performance of the VoiceOver extremely depends on how much you practice. "At first, it took an extravagant amount time to enter the characters. But now, after months, I can point at the approximate location of the intended button at the first touch and find it in 2-3 seconds", Jimmy said. Obviously this time is for the people who are familiar with the QWERTY keyboard layout. On the other hand, he believes he is able to select the dots of a cell in 2 seconds on average (characters with no dot in the bottom or middle row take less time and characters with a dot in the bottom row take more) on his first try of BrailleTouch. For the Note-Taker Touch this time will be even less. He added that looking for a letter among 32 small sticking buttons is more time consuming than tapping a few times on the screen. One other difference that can affect the performance, is that the user should perform an extra gesture (double-tap or tap with another finger) to submit the selected character, but in Braille-based methods as soon as the user taps the last dots, the character is submitted and a new empty cell is appears on the screen.

Generally speaking, there are two major factors that directly influence the accuracy of a text entry method: the number and the size of the targets on the screen. The size of a button on the iPhone keyboard is 30 mm², while this number in the BrailleTouch is almost 64 times and in the Note-Taker Touch 43 times bigger. Moreover in VoiceOver the user must find the target among 32 different items, while there are 2 and 3 buttons on the BrailleTouch and Note-Taker Touch screens respectively. For a blind person corners of the screen are quite accessible, therefore BrailleTouch is more accurate in comparison with Note-Taker Touch which has a button in the middle.

In terms of how easy these methods are to remember, for a Braille literate person, remembering how to enter a text in the Braille-based methods is like remembering the alphabets, but VoiceOver highly depends on the QWERTY keyboard knowledge of a person. If a person does not use QWERTY keyboards regularly, he or she may forget the order of the letters on the keyboard after a non-use period of time.

In terms of emotional response, the participant says, "I prefer to enter the letter directly on the phone instead of searching for them. This makes me feel more confident. My current text entry method extremely relies on voice feedback, which I'm unable to operate it crowded or noisy places."

Beside the four main aspects of usability, we also discussed the following criteria with the test taker and asked him to rank them for the above text entry methods (1 being the highest rank).

Table 8.1: User's priority from different aspects

Criteria	VoiceOver	BrailleTouch	Note-Taker Touch
Physical comfort	**2**	**1**	**3**
Easy to use	**3**	**1**	**2**
Fun to use	**3**	**2**	**1**
Easy to learn	**3**	**1**	**2**
Familiar	**3**	**2**	**1**
Like the feedback	**3**	**2**	**1**
Would use the method	**3**	**2**	**1**

BrailleTouch is the most comfortable technique because the user is able to hold the device with two hands and enter texts. Also, due to the small size of the VoiceOver buttons, users must touch the screen with their fingertip and not with the pad of their finger; therefore they will be in trouble if they have long fingernails.

As one of our participants mentioned, a method with two or three items on the screen is definitely much easier to use than a method with lots of small items. He also expressed, "Looking for something on the screen is not fun at all and I almost quit learning several times at first". By using our methods users do not have to look for any item on the screen and can enter the characters directly.

Learning process and also the degree of familiarity, in both VoiceOver and our Braille-based methods, highly depend on how much a person has experience with QWERTY keyboards or knows Braille respectively. For our special participant, who has good understanding of both Braille and QWERTY keyboard, Braille-based methods were still easier to learn due to their simpler structure.

In terms of device feedback, VoiceOver leads to hearing the voice of unwanted letters, when users are looking for a character. If they cannot find it very fast, the sound feedbacks of the undesired letters will become annoying. On the other hand, in both BrailleTouch and Note-Taker Touch the users only hear the sounds of the characters they entered to ensure characters are entered correctly. The mobile phone provides tactile feedback when the user is entering the Braille cells in these text entry methods.

At the end, the person who tested our text entry methods mentioned, “I hope one day I get a chance to use an application with one of these Braille-based text entry methods”.

8.2 Future Work

An interesting future work that we were unable to do, due to lack of time and financial support, can be implementing the BrailleTouch and Note-Taker Touch methods on a real device and conducting an experiment to recognize how much they improve the current situation of text entry on multi-touch screen mobile phones.

9 CONCLUSION

In this thesis project, we designed several text entry methods that enable visually impaired and blind people to enter a text, in the form of Braille, in multi-touch screen mobile phones. We began with evaluating the current text entry methods and based on their limitations (such as screen accessibility, proper feedback, limited features and cost), we designed six new methods. Out of those six, two, called BrailleTouch and Note-Taker Touch form our main results. They best matched good gestural interface principles and were very appreciated by the users. If these prototypes get implemented, they could improve the existing text entry methods. It is expected that all multi-touch screen devices including mobile phones, be accessible by visually impaired people in future.

9.1 Outcomes

The following outcomes are achieved during this research:

- A collection of hints for designing eyes-free text entry methods, as a result of our user studies and reviewing the related works
- Possible alternatives to input Braille in a multi-touch screen device
- Braille-based text entry models and their Low-fidelity prototypes, based on our guide lines

9.2 Research Questions' Answer

In this part, our research questions are briefly answered:

<u>RQ1. What are the disadvantages of using the current text entry methods for blind people?</u>

There are many text entry methods available for both button-based and touch-based mobile phones. Most of them are designed for the use of sighted people and visually impaired users are not able to operate them. The ones that can be used eyes-free, may propose different interfaces, but fundamentally they all follow one strategy: *looking for a character in a list*. This list can be either a set of buttons on the keypad or items on the screen. In other words, a blind user has to find the desired character among buttons or items (e.g. Multi tap or VoiceOver respectively), or navigate a list of letters (e.g. No-Look Note, NavTap and TiltText). Looking for something is a time consuming job and most of the users find it tedious.

<u>RQ2. In what ways does a blind person employ the Braille to write words?</u>

During our interviews with professional Braille readers, we found out that there is no rule for the order of selecting six dots of a Braille cell to write a character. However, most Braille literates memorize the Braille characters by their dot numbers, therefore, it is much easier for them to select the dots in order of their number (i.e. first the left column, dots number 1, 2 and 3, and then the right column dots number 4, 5 and 6). Their second preference is to select dots row by row from top to down.

<u>RQ3. Do our prototypes enhance the usability of mobile phones in terms of text entry for visually disabled users?</u>

According to the discussion in chapter 8 and the result of our usability testing, a Braille-based text entry has a lot of usability advantages over the current methods. These advantages include but are not limited to efficiency, accuracy and ease of text entry on multi-touch screen mobile phones for visually impaired and blind users.

9.3 Contribution

The contribution of this thesis project can be explained as follow:

This project introduces six designs for entering the Braille characters on multi-touch screen mobile phones. These designs have been appraised by real users and tested against usability principles. A couple of them, with highest usability score, can be used as templates for developing Braille-based text entry applications on multi-touch screen mobile phones. This research can also be a useful guidance for Braille text entry on other touch-based input devices such as note takers and computer input apparatuses for visually impaired people.

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Appendices

Appendix A – Line Tables of Louis Braille

Table 6.1: Seven-line tables of Louis Braille [31]

Braille	Dot Numbers	Function	ASCII
□	dot 1	letter a, digit 1	a
□	dots 1-2	b, 2, contraction "but"	b
□	dots 1-4	c, 3, contraction "can"	c
□	dots 1-4-5	d, 4, contraction "do"	d
□	dots 1-5	e, 5, contraction "every"	e
□	dots 1-2-4	f, 6, contraction "from"	f
□	dots 1-2-4-5	g, 7, contraction "go"	g
□	dots 1-2-5	h, 8, contraction "have"	h
□	dots 2-4	i, 9	i
□	dots 2-4-5	j, 0, contraction "just"	j

Line 1 (one or more of dots 1, 2, 4 and 5)

Braille	Dot Numbers	Function	ASCII
□	dots 1-3	k, contraction "knowledge"	k
□	dots 1-2-3	l, contraction "like"	l
□	dots 1-3-4	m, contraction "more"	m
□	dots 1-3-4-5	n, contraction "not"	n
□	dots 1-3-5	o	o
□	dots 1-2-3-4	p, contraction "people"	p
□	dots 1-2-3-4-5	q, contraction "quite"	q
□	dots 1-2-3-5	r, contraction "rather"	r
□	dots 2-3-4	s, contraction "so"	s
□	dots 2-3-4-5	t, contraction "that"	t

Line 2 (line 1 plus dot 3)

Braille	Dot Numbers	Function	ASCII
□	dots 1-3-6	u, contraction "us"	u
□	dots 1-2-3-6	v, contraction "very"	v
□	dots 1-3-4-6	x, contraction "it"	x
□	dots 1-3-4-5-6	y, contraction "you"	y
□	dots 1-3-5-6	z, contraction "as"	z
□	dots 1-2-3-4-6	contraction "and"	&
□	dots 1-2-3-4-5-6	contraction "for"	=
□	dots 1-2-3-5-6	contraction "of"	(
□	dots 2-3-4-6	contraction "the"	!
□	dots 2-3-4-5-6	contraction "with"	)

Line 3 (line 1 plus dots 3-6)

Braille	Dot Numbers	Function	ASCII
□	dots 1-6	contraction "ch"	*
□	dots 1-2-6	contraction "gh"	<
□	dots 1-4-6	contraction "sh"	%
□	dots 1-4-5-6	contraction "th"	?
□	dots 1-5-6	contraction "wh"	:
□	dots 1-2-4-6	contraction "ed"	$
□	dots 1-2-4-5-6	contraction "er"	]
□	dots 1-2-5-6	contraction "ou"	\
□	dots 2-4-6	contraction "ow"	[
□	dots 2-4-5-6	w, contraction "will"	w

Line 4 (line 1 plus dot 6)

Braille	Dot Numbers	Function	ASCII
□	dot 2	comma (,), contraction "ea"	1
□	dots 2-3	semicolon (;), contraction "bb"	2
□	dots 2-5	colon (:), contraction "cc"	3
□	dots 2-5-6	period (.), contraction "dis"	4
□	dots 2-6	contraction "en"	5
□	dots 2-3-5	exclamation (!), contraction "to"	6
□	dots 2-3-5-6	opening or closing round parenthesis, contraction "gg"	7
□	dots 2-3-6	opening quote, contraction "his"	8
□	dots 3-5	contraction "in"	9
□	dots 3-5-6	closing quote, contraction "was"	0

Line 5 (line 1 "lowered")

Braille	Dot Numbers	Function	ASCII
□	dots 3-4	slash (/), contraction "st"	/
□	dots 3-4-6	contraction "ing"	+
□	dots 3-4-5-6	numeric indicator, contraction "ble"	#
□	dots 3-4-5	contraction "ar"	>
□	dot 3	apostrophe (')	'
□	dots 3-6	hyphen (-), contraction "com"	-

Line 6 (dots 3, 4, 5, 6)

Braille	Dot Numbers	Function	ASCII
□	dot 4	accent indicator	@
□	dots 4-5	prefix for certain contractions	^
□	dots 4-5-6	prefix for certain contractions	_
□	dot 5	prefix for certain contractions	"
□	dots 4-6	decimal point, emphasis indicator, prefix for certain contractions	.
□	dots 5-6	letter indicator, prefix for certain contractions	;
□	dot 6	capital indicator, prefix for certain contractions	,

Line 7 (dots 4, 5, 6)

APPENDIX B – Survey Questionnaire

Text Entry for Visionless Mobile Phone Users Questionnaire

Dear participant,
Following questions aim at assist us to get familiar more, with visually impaired mobile phone user needs, to improve the future of text entry method on multi-touch screen mobile phones. Please answer all of the questions, there is no incorrect answer.
Your participation in this study is completely voluntary and it takes about 15 minutes. There are no risks associated with this project. However, if you feel uncomfortable answering any questions, you can withdraw from the survey at any point. It is very important for us to learn your opinions.

Age:

a) Less than 23
b) 23-45
c) More than 45

Vision status:

a) Totally blind
b) Purblind

What kind of mobile phone do you use?

a) Normal mobile phone through the help of speech software
b) A mobile phone specially made for visually impaired users

How much are you familiar with multi-touch screen mobile phones?

a) I'm multi-touch screen mobile phone user
b) I'll buy multi-touch screen mobile phone, if I feel it is accessible for me
c) I won't use multi-touch screen mobile phone

In case you use multi-touch screen mobile phones, how easy is it for you to enter a text on it?

a) I can enter a text very fast, like sighted users and even better
b) I can enter a text in reasonable amount of time
c) I can't enter a text easily
d) I don't use multi-touch screen mobile phone

How often do you use short message service (SMS)?

a) I use SMS everyday
b) I use SMS several times a month
c) I prefer not to use SMS, but I'll use if it would be easier to use
d) I never use SMS

How much are you familiar with Braille?

a) I'm a fast Braille reader
b) I'm not a fast Braille reader but I know the Braille alphabet
c) I haven't had any contact with Braille

How much are you open to use a new Braille-based devices to handle your routine?

a) I know Braille and I prefer to use it wherever possible

b) I'll learn Braille if I feel I can handle my most of the job with it
c) I prefer not to use Braille

How do you access to computer?

a) By using refreshable Braille display
b) Through the help screen reader program
c) I can see the big fonts
d) I don't use the computer

Please prioritize the following aspects of text entry from 1 to 4 (1 being the most important) from your point of view:

a) Speed
b) Accuracy
c) Number of times you should tap the screen for entering a single word
d) Easy to learn

Other comments:

We really appreciate your participating in our survey. Please enter your email address if you are interested in the results and future work of this project.
Email address:

APPENDIX C – Interview Results

Name: Jan Ake Hanssan Age: 59	Gender: Male Job: Secretary of SRF, Karlskrona
-He is purblind -He is able to see a subject from close distance -He has a mobile phone with the big font print screen, he has to keep the phone very close in order to be able to see the letter on the screen -He is not comfortable with entering the text on his mobile phone, he prefer not to use SMS -He doesn't like the voice of the blind phone's feedback -He has examined the multi-touch screen mobile phone and he feels that he cannot operate it easily -He prefers to finding his aim point to click or tap on the mobile phone without looking -He believes that corners of the screen is easy to find for blind people -He is familiar with the Braille alphabet, but he hasn't had the experience of reading Braille prints	

Name: Nancy Johansson Age: 61	Gender: Female Job: Member of SRF, KNA
-She is totally blind -Got blind when she was born -She has a LG button-based mobile phone -She can send message with auditory feedback on her mobile phone -She knows Braille but not a fast reader -She gets used to her mobile phone -The big problem she suffers from is the lack of privacy when she gets the feedback of entered word	

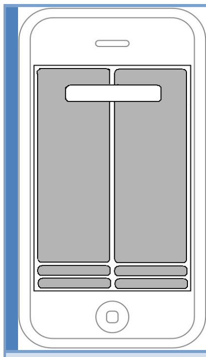
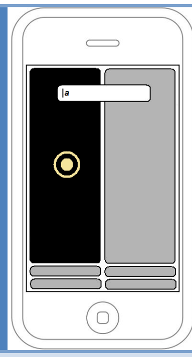
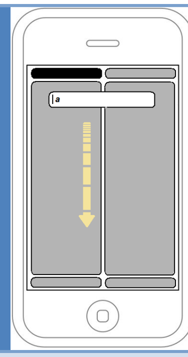
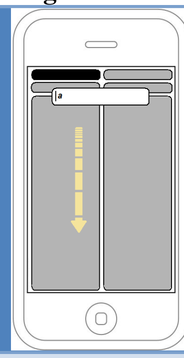
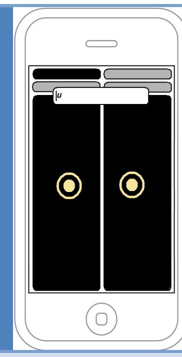
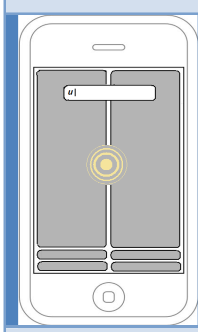
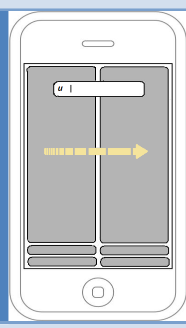
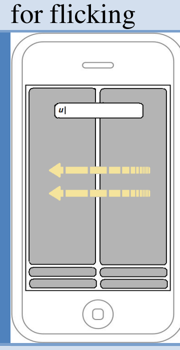
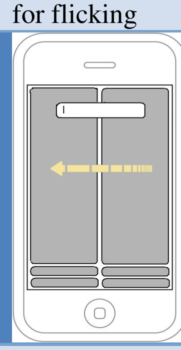
Name: Maryam Karimi Age: 26	Gender: Female Job: Musician-Violinist, Tehran, Iran
-She is totally blind -She got blind when she was born -She is currently an iPhone user, before that, she had a button-based with voice feedback -She is able to find different points of the screen with her thumbs easily, specially the sides of the screen -She thinks it is time consuming job to enter the text with the current text entry method -She believes that there should be an easier way to enter a text -She expressed that it would be easier if she does not have to move her fingers around the screen very often when she wants to enter a text -She is fast Braille reader -She believes that Braille give her the chance to be successful in her professional life -She composes many music and document all of her notes with the help of Braille	

APPENDIX D – Documentations

Gestural modules document for the second design

Gesture	Action
Tap	To select or unselect the dots
Double tap	To submit a character and open a new cell
Scroll one finger up and down	To move between different rows of the cell
Flick one finger right and left	To enter a space/ To delete a character
Flick two fingers right and left	To move the cursor across the text

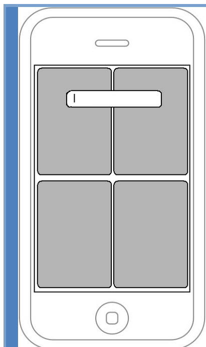
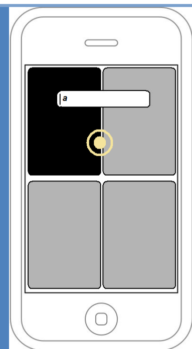
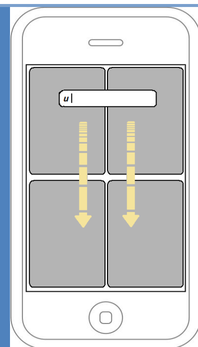
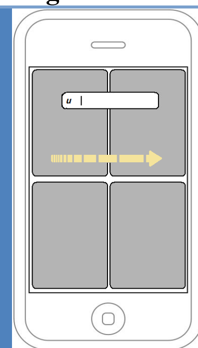
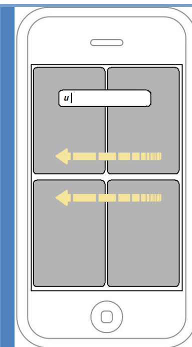
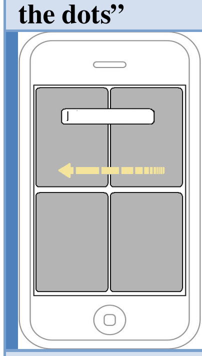
Swim lanes for the second design

				
User hold the device with two hands	User tap the left side of the screen	User flick a finger top-down	User flick a finger top-down	User tap the both sides of the screen
Application is selected from the main menu	Dot 1 is selected and letter 'a' appears in the text field	Second row of the cell is appeared on the screen	Third row of the cell is appeared on the screen	Dot 3 and 6 are selected, letter 'u' appears in the text field
Feedback: "Please select the dots"	Feedback: tactile feedback	Feedback: Proper non-speech sound for flicking	Feedback: Proper non-speech sound for flicking	Feedback: tactile feedback
				
User double-tap anywhere on the screen	User flick a finger to the right	User flick two fingers to the right	User flick a finger to the left	
Letter 'u' is submitted, a new empty cell is opened	A space is entered	The cursor moves to the left	Letter "u" is deleted	
Feedback: "u"	Feedback: a non-speech sound for space	Feedback: "u"	Feedback: read the letter before "u" if any	

Gestural modules document for the third design

Gesture	Action
Tap	To select or unselect the dots
Double tap	To submit a character and open a new cell
Flick one finger top-down	To select dot 3 or 6
Flick two fingers top-down	To select dots 3 and 6
Flick one finger right and left	To enter a space/ To delete a character
Flick two fingers right and left	To move the cursor across the text

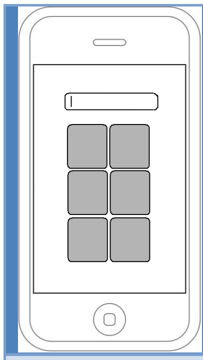
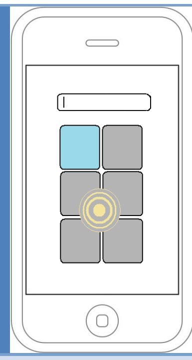
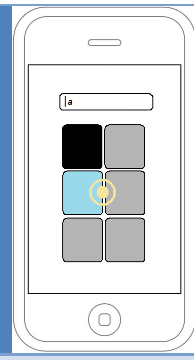
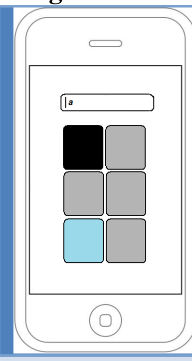
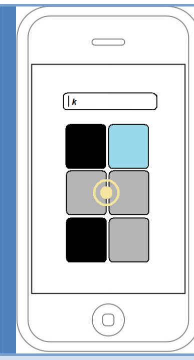
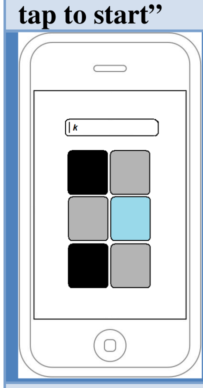
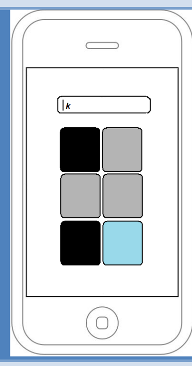
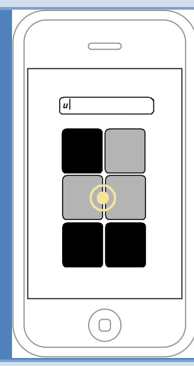
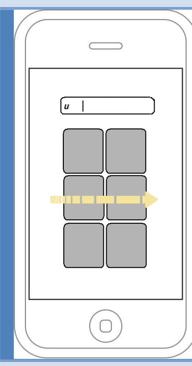
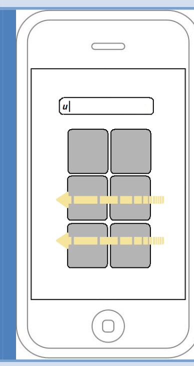
Swim lanes for the third design

				
User hold the device with two hands	User tap the up-left corner of the screen	User flick two fingers top-down	User flick a finger to the right	User flick two fingers to the left
Application is selected from the main menu	Dot 1 is selected and letter 'a' appears in the text field	Dot 3 and 6 are selected, letter 'u' appears in the text field, new cell is opened	A space is entered	The cursor moves to the left
Feedback: "Please select the dots"	Feedback: tactile feedback	Feedback: "u"	Feedback: a non-speech sound for space	Feedback: "u"
				
User flick a finger to the left				
Letter "u" is deleted				
Feedback: read the letter before "u" if any				

Gestural modules document for the fourth design

Gesture	Action
Tap	To select the dots
Double tap	To submit a character and open a new cell
Flick one finger right and left	To enter a space/ To delete a character
Flick two fingers right and left	To move the cursor across the text

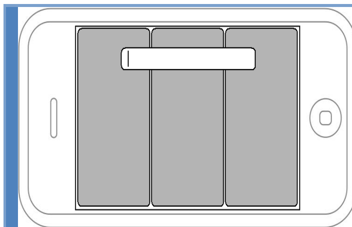
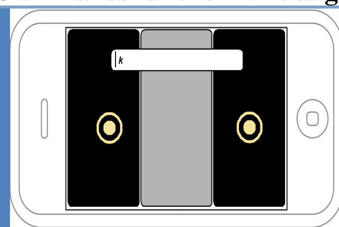
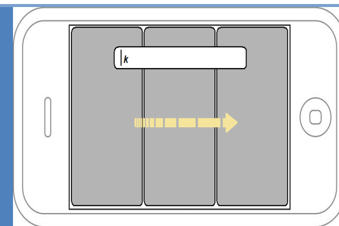
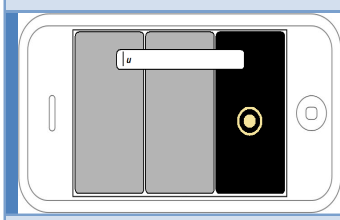
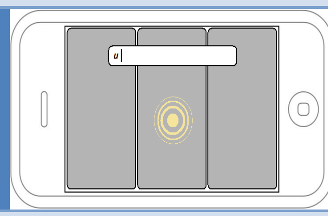
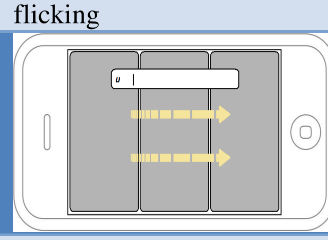
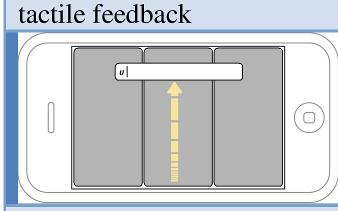
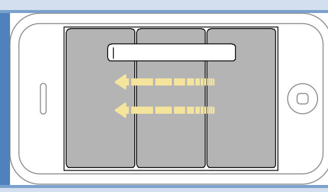
Swim lanes for the forth design

				
User hold the device with one hand	User double-tap anywhere on the screen	User tap anywhere on the screen	User do nothing	User tap anywhere on the screen
Application is selected from the main menu	Cursor on the first dot	Dot 1 is selected, cursor on the second dot, 'a' is appeared on the text field	Cursor on the third dot	Dot 3 is selected, cursor on the fourth dot, 'k' is appeared on the text field
Feedback: "Please double-tap to start"	Feedback: "one"	Feedback: "two"	Feedback: "three"	Feedback: "four"
				
User do nothing	User do nothing	User tap anywhere on the screen	User flick a finger to the right	User flick two fingers to the right
Cursor on the fifth dot	Cursor on the sixth dot	Dot 6 is selected, 'u' is submitted, new cell is opened	A space is entered	The cursor moves to the left
Feedback: "five"	Feedback: "six'	Feedback: "u"	Feedback: a non-speech sound for space	Feedback: "u"

Gestural modules document for the fifth design

Gesture	Action
Tap	To select or unselect the dots
Double tap	To submit a character and open a new cell
Flick one finger up and down	To move the cursor across the text
Flick one finger right and left	To move between two columns of the cell
Flick two fingers right and left	To enter a space/ To delete a character

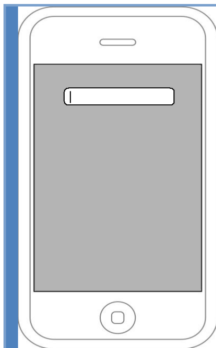
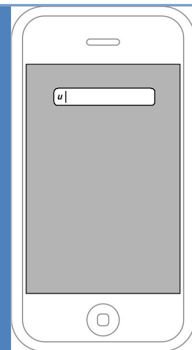
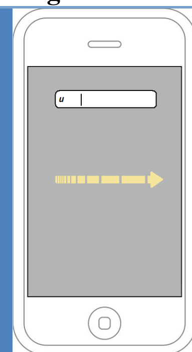
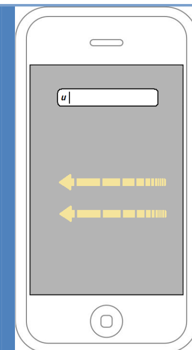
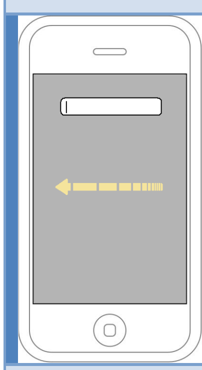
Swim lanes for the fifth design

		
User hold the device with one hand	User tap the screen with the point and ring fingers	User flick a finger to the right
Application is selected from the main menu	Dots 1 and 3 are selected and letter ‘k’ appears in the text field	Screen column of the cell appears
Feedback: “Please select the dots”	Feedback: tactile feedback	Feedback: Proper non-speech sound for flicking
		
User tap the screen with ring finger	User double-taps anywhere on the screen	User flick two fingers to the right
Dot 6 is selected and letter ‘u’ appears in the text field	Letter ‘u’ is submitted	A space is entered
Feedback: tactile feedback	Feedback: “u”	Feedback: a proper non-speech sound for space
		
User flick a finger bottom-up	User flick two fingers to the left	
The cursor moves to the left	Letter “u” is deleted	
Feedback: “u”	Feedback: read the letter before “u” if any	

Gestural modules document for the sixth design

Gesture	Action
Tap and hold for less than a sec	To draw the dots
Flick a finger and hold for less than a sec	To draw the lines (for empty rows or columns)
Flick one finger right and left	To enter a space/ To delete a character
Flick two fingers right and left	To move the cursor across the text

Swim lanes for the sixth design

				
User hold the device with one hand	User draw intended dots and a line in the place of any empty row or column	User wait 2 seconds	User flick a finger to the right	User flick two fingers to the left
Application is selected from the main menu		Recognize the letter is "u"	A space is entered	The cursor moves to the left
Feedback: "Please draw the dots"	Feedback: Soft for the dots and sharp tactile feedback for the lines	Feedback: " u"	Feedback: Proper non-speech sound for the space	Feedback: "u"
				
User flick a finger to the left				
Letter "u" is deleted				
Feedback: read the letter before "u" if any				