# Survey of Eye-Free Text Entry Techniques of Touch Screen Mobile Devices Designed for Visually Impaired Users

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***Abstract:*** Now a days touch screen mobiles are becoming more popular amongst sighted as well visually impaired people due to its simple interface and efficient interaction techniques. Most of the touch screen devices designed for visually impaired users based on screen readers, haptic and different user interface (UI).

In this paper we present a critical review of different keypad layouts designed for visually impaired users and their effect on text entry speed. And try to list out key issues to extend accessibility and text entry rate of touch screen devices.

***Keywords:*** Text entry rate, touch screen mobile devices, visually impaired users.

## I. Introduction

Visual impairment describes any kind of vision loss, whether it's about total blindness or partial vision loss. Some people are totally blind but many others have legal blindness. They don't have enough vision to see the object stands 20 feet away from them (Arditi & Rosenthal, 1998). According to recent statistics of WHO (Chatterjee, 1198) 285 million people are visually impaired. From which 39 million are blind and 246 have low vision.

Touch screen mobile devices known as Smartphone, becoming increasingly common in both sighted and visually impaired people. These devices used not only for entertainment and communication purpose but for learning, browsing, e-billing and many more. But they are highly visual demanding. Touch screen is highly sensitive; it contains lots of tiny icons and requires more concentration as well as fast action. It is not easy for any person with vision problem to handle such devices satisfying above demands. Though there are some touch screen devices available for vision impaired people, it remains inaccessible in many ways. Most of the available devices use screen readers like Jaws, Apple Voice Over, etc; screen magnifiers and support tactile feedback. These techniques help to support navigate the screens and search the desire words or icons. Some devices come with different types of keypad layouts other than traditional one. They also support TTS techniques and tactile feedbacks which help to enter text without watching the screen. Though these techniques try to make touch screen devices more users friendly for visually impaired people, there are some of drawbacks like: lack of clearness in sound, more time consumption in navigation, etc; fails to increase accessibility of these devices. Also the text entry rate is not so good which reduces fast responses on touch screen.

In next section, we discuss about accessibility problems of touchscreen devices faced by visually impaired people. In section III, related work in this area is studied. In section IV, we discuss about various text entry evaluation metrics. In section V, comparative analysis of available devices based on keypad layout is performed. Section VI concluded our survey with providing some key issues to improve text entry technique and accessibility of touch screen mobile devices for vision loss users.

## II. Visual Impairment and Accessibility Problems

Visual impairment ( or vision impairment ) is vision loss to such a degree as to qualify as an additional support need through a significant limitation of visual capability resulting from either disease, trauma, or congenital or degenerative conditions that cannot be corrected by conventional means, such as refractive correction or medication (WHO; Bill Text,2003-2004; Belote & Lary,2006).

Problems faced by vision impaired ;n size which causes inconvenience in handling the device and some have too small to select only one letter at a time.

***Button size***: Some devices have too small buttons that either do not click when pressed or adjacent other button is clicked. Thus provide wrong feedback.

***Keypad layouts***: Every device provides different layouts of keypads. Novice users have to spend more time on learning and being familiar to it.

***Menus***: Large number of menus causes difficulties in understanding and selecting.

***Text size***: Small text size is unable to read.

***Feedback***: Some sound and tactile feedbacks are not clear to easily understand.

***Text entry rate***: Low text entry rate causes obstacles in fast typing and response.

***Time Delay***: Some approaches have more time laps between key touch and recognition which causes irritation and unwanted time loss of expert users.

***Cost:*** Disabled users either have to purchase mobile devices developed for them or have to download various application required making the device accessible by paying large amount. Every user can not afford it.

## I. Touchscreen Mobile Devices for the Visual Impaired Users

From last two decades frequency of evaluating new text entry method increases due to recent and heightened interest in touchscreen ( i.e. Smartphone) and use of SMS. According to statistics 9.8T SMS messages were sent in 2012 (Factbrowser.com, 2012). In 1997 first touchscreen was developed by *Dr. Sam Hurst* of Elographics, now known as Elo TechSystems (Brown et.al, 1971). The design called, “elograph”, was a computer input devices that uses resistive touchscreen technology. Generally touchscreen has two main attributes: first, one directly interacts with what is displayed on screen, rather than using mouse or touchpad; secondly, that does not require any intermediate device that would need to be held in hand (other than stylus).

*1). Single-touch based strategies:*

Basic touch screen functionality is single-touch, where you touch the screen like mouse moving around the screen and ‘tap’ the screen like a mouse click. In this strategy a finger or any pointing device (gesture) is used to enter the text

2). Multi touch-based strategies:

Multi-touch refers to ability of touch sensing surface to recognize the presence of two or more points of contacts on the surface. This dual-point awareness is used for pinch to zoom or activating predefined programs.

### *A. Text Entry factors*

Following are some factors on which affects text entry.

TABLE I: TEXT ENTRY FACTORS

| Text Entry Factors | Explanation |
|---|---|
| Speed/Efficiency | Speed of text to be keyed by either using muiltitap or single touch |
| Learnability | Comfortness of user to learn the text entry mechanism. |
| Simplicity | simplicity to use text entry mechanism |
| Navigation | Comfortness for key selection while texting (eg. Punctuation, blank space, capitalization, etc) |

It is seen that all these factors are related with keypad design and hence text entry is strongly affected by layout of keypad of mobile device.

*B.* Keypad Layout

One of the important factors responsible for text entry speed is keypad layout. Researchers proposed different keypad layouts for their applications.

*1) Telephone keypad*

This multi-touch approach is used by Sanchez and *Aguayo* in **2007.** They proposed 9-button virtual keyboard layout called as Mobile Messenger for the blind (Yfantidis & Evreinoy,2006). It is a messaging system for mobile devices having multiple characters on each key supported by audio feedback. It has less number of targets which are placed at easy- to-reference location e.g. near the edge of the screen that make blind user easily find them. But problem increases when numbers of targets are increases. In such target-based system text entering become more difficult.

In **2008** *Guerreiro et al.* (*Guerreiro et al* ,2008) presents 12 button based approach of touch screen mobile known as MultiTap. Each button features a set of characters. It proved to be faster as it offers a more direct mapping between input and desired output. Its text entry rate was 0.88 wpm with 15.28% error rate. But with MultiTap problem arises during searching for a specific character or group of characters along the screen. Also this approach suffers from problem of segmentation, when the character is on the same key as previous one.

In **2011** *Aakar Gupta* and *Navkar Samdaria* implemented **SVIFT** (Gupta & Samdaria,2011) which uses vibrotactile technique for eye-free text entry. The technique involves expanding the text-entry mode to a full screen format and innovating over the old-style T9 and telephone keypad design. It makes use of multiple input and feedback interactions – swipe, pause, circle, hand-waving, audio and vibrotactile. Its text entry speed is 4.75 wpm. But its input mechanism for special character is not efficient. Also number appears in separate mode which is not convenient to select.

*2) Stroke based Keypad*

*In **1993** Goldberg and Richerdson first proposed Unistokes [13] based keypad. They use Single-touch strategy for text entry. These strokes are very simple and user writes it without watching the stylus. Its text entry rate was 16 wpm. But these strokes are different from regular handwritten or printed letters. Hence they must be learned and an expert is needed for fast text entry. Also Unistrokes could not used for number, punctuation, or symbolic characters.*

In **1995** *Palm Inc.* also designed single-stroke alphabets recognition system that uses **Graffiti** strokes (Blickenstorfer,1995). It was used to draw upper-case characters blindly with stylus on touch panel. It is similar with hand written or printed letters. Hence no need of experts.

*Tinawal* and *Mackenzie* uses Graffiti strokes for eye-free text entry method for touch screen mobile phones in **2009** (Tinawal & Mackenzie, 2009) The entire screen is used as drawing surface. Graffiti has strokes for number, punctuations, symbolic characters and mode switches. The entry is guided by speech, sounds and vibrations. The unrecognized entry is guided by phone's vibration actuator pulses. Its text entry rate is 7.30 wpm and error rate is 0.4%. But variations in some strokes are problematic for recognizer for ex. character 'O', 'T', 'E' and 'N' faces reorganization problem.

*3) QWERTY Keypad*

In **2008** *Kane et al.* proposed soft QWERTY keyboard approach **Slide Rule (**Kane et.al, 2008). It is gesture-based approach for multi-touch text entry. It was designed specifically for list-based application like music player and phonebook. Slide Rule uses four basic gesture interactions: (1) use one-finger scan to browse list, (2) use second-finger tap to select item, (3) to perform additional action use multi-directional flick gesture and (4) to browse hierarchy of list use L-select gesture. Its interface is entirely speech-based and it does not support any visual feedback. Its text entry rate is 27 with 14.1% error rate. The major problem with Slide Rule is that it has no visual representation. It does not display item labels and its targets are small and densely pack.

In **2011** Apple announced a system called **VoiceOver** (Buzzi et.al, 2011) based on one graphical QWERTY keyboard layout. It offers a function to correct an error. User can adjust its speed depending upon preference. Also when it is activated other phone related sounds are automatically lowered. Its text entry rate was 0.66 wpm and error rate is 9.7%. But it displays a large number of targets in small size, which can be difficult to find, particularly for those who are not proficient with the QWERTY layout. Similar to VoiceOver, *Oliveria et al*. and *Azenkot et al.* both evaluated accessible soft **QWERTY** keyboard (Oliveria et.al,2011; Azenkot et.al, 2012). It uses split-tap interaction. First tap produces a voice output of the touched character and a second tap select the character. Its text entry rate was 2.11 to 3.99 wpm with 5.2% to 6.4% error rate.

*4) Braille based Keypad*

In the year **2011**, *Joao Oliveira* introduced a single touch Braille keypad based mobile texting scheme called **BrailleType** (Oliveria et.al, 2011) for visually impaired. It has six large dot representing Braille cells. These dots are mapped to the corners so that from edge of the screen user easily find it. Each dot gives auditory feedback on touching it. As compared to traditional Braille typewriter it has less number of keys. Its text entry rate is 1.45 wpm with 9.7% error rate. But it requires multiple gestures and inputs to access a specific character, which resulted in slower performances. Its timeouts causes error. The time elapse is more which affect text entry. This resulted in trying to accept incorrect Braille cells. It lose track of text. It doesn't explain reading of whole message. It is designed especially for visually impaired people who know Braille.

In year **2011** *Caleb Southern et al*. present six-key chorded Braille soft keyboard for smartphone called **BrailleTouch** (Southern et al. , 2011). They provide two hints to spell or remember words and phrases. The first hint (chord 4-5-6) spelled out the entire phrase, letter by letter before the timer started. The second hint (chord 1-4-5-6) repeated the entire phrase. Its text entry speeds is 23.2 wpm with 14.5% error rate. The difference between BrailleType and BrailleTouch is that the latter requires the user to input all dots for a character simultaneously. But its software failed to accurately recognize the flick gesture for the space character. This approach is useful only for the user who knows Braille.

Recently, in **2012** *Mascetti et al.* developed **TypeInBraille** (*Mascetti et al.* ,2012). Here user types the Braille cell one row (2 dots) at a time. Space is entered by a flick gesture. Its text entry rate is 6.3 wpm with error rate 3%. *Azenkot et al.* presented an IFD technique for text input on touchscreen called **Perkinput (***Azenkot et al.* , 2012). It uses 6 bit Braille encoding bits with audio feedback. It allows one-handed and two-handed entry. Its text entry rate is 6.1 wpm with 3.5% error rate.

*5) Different UI*

In **2008** *Tiago Guerreiro et al.* proposed single touch gesture-based approach called **NavTouch**. **(***Guerreiro et al.* , 2008**)**. It is based on a navigational approach. To navigate alphabets use left to right gesture i.e. in horizontal direction and to navigate between vowels move the finger up and down i.e. vertically. Speech and vibrotactile feedback is given. Its text entry rate was 1.37 wpm with 9.87% error rate. But it gives slower performance because of its multiple gesture and inputs to access a specific character. Also an accidental touch loses the track of text and gives wrong result.
One other multi-touch text entry method is **No-Look Notes** introduced in **2009** designed by *Matthew Bonner* (Bonner et al. , 2009). The characters are present in pie menu supporting audio feedback. Its text entry speed is 1.33 wpm with 11% error rate. But in No-look note, the text entry takes much time

because all characters are not present at a time; they are grouped into 8 character set. User faces difficulties in understanding pronunciations of characters. It does not have haptic (vibration) feedback. The system was not design for symbols and numbers entry.

Another development is **EasyWrite** in **2011** by *P.A.Candado et al.* (Candado et al. , 2011)**.** It is a small virtual keyboard with less and bigger keys. In EasyWrite alphabets are grouped into central key and user has to navigate through directional keys. This approach is developed to improve typing accuracy and accessibility of mobile device. Its text entry rate was 2.7 wpm. Its crucial aspect is that all characters are not appear for immediate choice, so user has to search the desire one by navigating through the interface on each time.

## I. Text Entry Evaluation

The analysis of keypad design can be performed by measuring the metrics of text entry and effectiveness of keypad layout.

### *A. Text Entry Metrics*

For evaluation of text entry two metrics are used. These are Speed and Accuracy (Soukoreff & Mackenzie , 2003).

*1) Speed*

Text entry speed is number of characters entered per second. To calculate speed in Word Per Minute (WPM) following formula is used:

$$\frac{(Transcribed\ text - 1) * (60 seconds\ time\ in\ seconds)}{(5\ characters\ per\ word)} \qquad (1)$$

*2) Accuracy*

Accuracy of text entry depends on number of error occurred during entering text. There are two method used to analyse text entry error: MSD error rate and KSPC.

a) MSD error rate

The Minimum String Distance (MSD) between the strings is number of primitives (insertion, deletion or substitution) to transfer one string to other . It is calculated by

$$MSDerrorrate = \frac{MSD(P,T,)}{\max(P|,|T|)} * 100 \qquad (2)$$

Where $P$ and $T$ are the presented and transcribed text strings, and the vertical bars | | represent the length of the strings.

*b) Key Stroke Per Character (KSPC)*

There are two classes of errors: 1) those are not corrected, and 2) those are corrected. MSD error rate measures not corrected error. To measure corrected error KSPC is used.

KSPC is calculated as:

$$KSPC = \frac{|\text{Input Stream}|}{|\text{Transcribed Text}|} \quad (3)$$

Input Stream|

Where | | represent the length of string (including insertions, deletions, or substitutions). If text is entered without error, KSPC will be 1.00 (Soukoreff & Mackenzie , 2003)

*B. Effectiveness of text entry methods*

Theoretically the effectiveness of a keypad design used with predictive disambiguation text entry method is measured by Disambiguation Accuracy and Key Stroke Per Character. These two metrics used to tell how much effort user have to take for particular text entry method.

*Disambiguation Accuracy*

DA evaluates the probability of displaying desired word after any keystroke sequence is entered. When any ambiguous keystroke is entered, with this process the matching word with highest frequency of occurrence will be displayed. Larger DA implies better keypad design.

## I. Discussion

In above section authors discussed problems faced by visually impaired users while using touch screen devices, text entry factors and available research in this field. The comparative analysis of all this available research is performed according to keypad layouts in given table (Table II). It is seen that for high text entry rate Unistroke is best one. But for minimum error rate, Graffiti is good one. Feedback is also important feature of mobile device; according to table only VoiceOver and Graffiti have audio as well as tactile feedback. From above discussion it should be clear that not a single device has all features. So how can a visually impaired user choose a mobile device for effective text entry? Hence, authors list out some key issues that may help to develop more effective and accessible as well as affordable text entry technique for mobile device.

- The keypad should be of standard layout so that user should familiar to it.
- Eliminate non-essential buttons and menus.
- Screen size should be of appropriate size.
- Component like text boxes, menus and buttons must be of suitable size, so that they can be easily seen and pressed.

- Screen reader and magnifier should be there so those with vision loss get advantage from it.
- If there are more buttons or menus appear on the screen then while interacting there should be tactile feedback to sense the boundaries of each one. Also screen boundaries should be represented by other feedbacks.
- The screen should appear on any direction so no need to hold the device in specific direction.
- For text entry there should be word completion, letter prediction and message translation techniques.
- Accidental key pressing and errors should be detected and responses by feedback like sound or vibrations.
- For text deletion some gesture or tapping technique should be provided.

The important thing is to consider that the design should be simple, clear and specific.

## I. Conclusion

As available related work in the field of touch screen mobile devices for visually impaired users, we have found that different touch screen strategies, keypad layouts and explorer methods are used to make the devices more accessible. Out of all available techniques either they are not easy to use or time consuming. Also their text entry rate is not efficient for fast texting. So authors are suggesting some important factors which will help in developing more accessible, affordable and fast text entry technique for new user interface.

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TABLE II: COMPARATIVE ANALYSIS OF TEXT ENTRY TECHNIQUES

| Keypad Layout | Device Name | Author | Features | Layout | Explorer | Selection | Screen Size | Audio Feedback | Tactile Feedback | Text Entry Rate (WPm) | MSD Error Rate (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Telephone Keypad | MultiTap | Guerreiro et al. (2008) | 1) Twelve medium size buttons representing set of character.<br>2) Split or double tap used to enter character.<br>3) Offers a more direct mapping between input and desired output. | 12 medium size buttons | Scan | Split/ double | Medium | Yes | No | 0.88 | 15.28 |
| | SVIFT | Aakar Gupta and NavkarSamdaria (2011) | 1) Vibrotactile technique is used.<br>2) Swipe, pause, circle, hand -waving, audio and vibrotactile feedback is used.<br>3) Increases speed and accuracy | Similar phone keypad | Scan | Split-tap | Large | Yes | Yes | 4.75 | - |
| Stroke Based Keypad | Unisroke | Goldberg and Richardson (1993) | 1) Unistrokes alphabets are entered with stylus.<br>2) Strokes are simple.<br>3) Provide audio feedback. | Unistroke Keypad | Stylus | Single-stroke | Small | Yes | No | 32 | - |
| | Graffiti | Tinwala and Mackenzi (2009) | 1) Graffiti strokes are entered by stylus.<br>2) Strokes are for number, punctuations, symbolic characters and mode switches.<br>3) Feedbacks are given by speech, sounds and vibrations. | Adaptive | Stylus | Single-stroke | Large | Yes | Yes | 7.60 | 0.4 |
| QWERTY Keypad | Slide Rule | Kane et al. (2008) | 1) Vision less keypad<br>2) Designed specifically for list-based application like music player and phonebook.<br>3) Use four basic gesture interactions for navigating and selecting characters. | No visual display | Gesture | Split/ double | Small | Yes | No | 27 | 14.1 |
| | VoiceOver | Apple co. ltd.(2009) | 1) Screen displays QWERTY keyboard layout<br>2) Offer a function to correct an error.<br>3) Give audio output.<br>4) Speed can be adjusted depending upon preference.<br>5) Offers a more direct mapping between input and desired output | QWERTY keypad | Scan | Spilt/ double-tap | Medium | Yes | Yes | 0.66 | 9.7 |
| | QWERTY | Olieria et al and Azenkot et al. (2012) | 1) Provide soft QWERTY keyboard.<br>2) Use split-tap interaction. | Fixed QWERTY keypad | Scan | Split/ double | Small | Yes | No | 2.11 | 5.2 |
| Braille Based Keypad | Braille Type | Joao Oilveria (2011) | 1) Screen displays 6 dots as Braille cells.<br>2) Double tap is used to accept Braille character.<br>3) Audio feedback is given. | Braille cells ( 6 dots) | Scan | Large press and double tap | Large | Yes | No | 1.45 | 9.7 |