Braille Matrix: A new text introduction method for the blind

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Abstract — **We present a new mobile text-entry method that relies on the Braille alphabet and dismisses memorizing, offering visually impaired individuals an easy writing mechanism. Current mobile text-entry interfaces are not suitable for blind users and special Braille devices are too heavy, large and cumbersome to be used in a mobile context. With the enormous growth of mobile communications and applications it was urgent to offer visually impaired individuals the ability to operate this kind of devices. Evaluation studies were carried and validated the method as a new mobile text-entry interface for the target population.**

I. Introduction

Nowadays, the mobile phone is an essential tool for most people. Tasks like making calls, using the Short Message Service (SMS), managing contacts and using the agenda are executed on a daily basis. SMS, in particular, have had an enormous growth in the past years: in 2000, 17 billion SMS messages were sent; in 2001, the number was up to 250 billion and 500 billion SMS messages in 2004. More than one trillion text messages were sent in 2006 [1]. This growth is related with the low costs to the user and social factors – it doesn't disturb the receiver, it provides diffusion and it doesn't demand an immediate answer. The number of services accessible by SMS has also been growing in the past years, including alerts, quizzes and advertising. However, for visually impaired individuals this service is very difficult or impossible to use. This is also true for the majority of applications available on a cell phone. Nowadays, mobile device potentialities are diverse and cell phones are commonly used as clocks, notebooks, and agendas, among others. As for SMS, the visually impaired are also deprived from using these services.

Traditional mobile devices are not equipped with keyboards adapted to those users' needs nor do they provide any kind of feedback for their actions. Special hardware devices, although making possible for blind users to use mobile services, are too heavy and cumbersome to be carriable and especially, be used on a mobile context. Currently, visually impaired individuals have limited access to mobile devices, particularly, text-entry-based applications.

Fig. 1**.** Regular Mobile Phone Keypad

We present an interface that relies on Braille system, a method that is widely used by blind individuals for reading and writing. It only requires a regular mobile phone and doesn't require any additional extra hardware. It dismisses the memorizing effort, offering visually impaired individuals an easy writing mechanism.

II. Related Work

A. Mobile Devices Text-Entry Methods

Text introduction in mobile phones is done through a 12 key keypad (Fig. 1). Most keypads follow the ITU E.161 standard, featuring number keys 0-9 and two additional keys (* and #). The letters are spread through keys 2-9 alphabetically ordered, forming groups of three or four letters. The space character is usually assigned to the 0 key, but it depends on the mobile phone model. Several methods have been developed to introduce text in these devices and can be divided in two main categories: multi-press systems and predictive systems.

Multi-Press systems

Multi-press systems categorize all systems that require one or more key presses to enter a character. These systems don't use word or phrase prediction to help the user. The most known and used multi-press system is multi-tap which requires one or more button presses to obtain a certain character. A disambiguation problem arises when the user wants to enter two or more consecutive characters present in the same key with two possible solutions: key press timeout, an acceptance button.

Less-Tap technique uses language knowledge to rearrange the letters within each button (Fig. 2). This

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rearrangement is obtained from the letter frequencies for certain language. This way, the most frequent letter (from each group associated with the key) requires only one key press [3]. Two-key Input requires exactly two key presses for each letter. The first press selects the group of letters (for example, ‘4’ selects IHG). The second press selects the letter from the group (for example, ‘2’ selects ‘h’). This approach solves the disambiguation problem present in other methods.

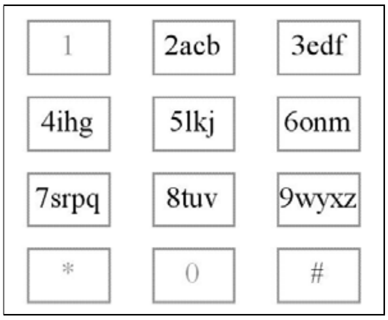

Fig. 2. Less-Tap: English keyboard

The Thumbscript method uses mnemonics to associate letters to the mobile phone’s keyboard: the letters are “drawn” on the keyboard. To enter each letter, presses the “Start” and “Stop” buttons, allowing Thumbscript to have a KSPC value of 2. Fig. 3 features the Thumbscript alphabet. All letters go from top to bottom and left to right. For symbols and punctuation, re-verse directions are used. Notice that vowels ‘e’, ‘i’, ‘o’, and ‘u’ are made with straight strokes. Experienced users may go directly from “Start” to “Stop”.

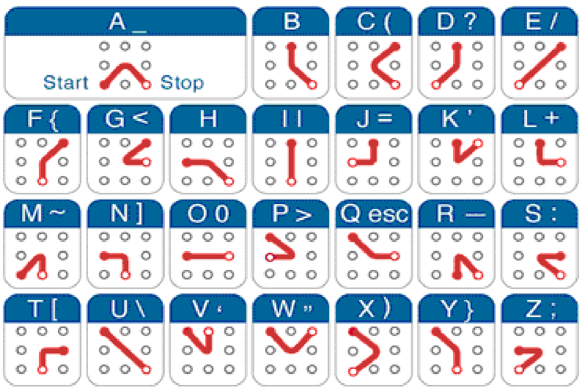

Fig. 3. Thumbscript Alphabet

For blind individuals, multi-press systems are rather difficult to use as the user must memorize the letters associated with every key (or get used to unusual mnemonics, as in Thumbscript) and must always be very careful with the amount of presses to achieve a given letter. As feedback is inexistent, the user can’t have a notion on the message evolution. Multi-press frequency-based approaches are even worst that multi-tap as the alphabet sequence is lost and therefore memorizing needs increase.

Predictive Systems

Predictive input technologies use language knowledge to predict what text the user is going to enter. Letter anticipators predict the next letter based on the prefix entered by the user. Word completers predict the suffix of the introduced word or the remainder or even the entire phrase, featuring suggestions to the user. Hybrid systems combine the letter anticipators and the word completers [4].

T9 (Text on 9 keys) [5] is the most widely used predictive system on mobile phones. The system compares the sequence of keystrokes to words in a dictionary, in order to determine the intended word. If the user ends the word introduction and the displayed word isn’t the desired, a “Next” button should be pressed, and all the words sharing the same key sequence are shown. If the word doesn’t appear, the user should switch to multi-tap mode to entry the desired word. Using LetterWise, a text introduction method created by MacKenzie et al. [6], the user presses the key that features the desired letter. If the letter doesn’t appear on the display screen, the user presses a “Next” key until the letter shows up. The prediction is done letter by letter, according to letter prefixes probabilities. The WordWise method is similar to the T9, although in WordWise, when certain word isn’t in the dictionary, LetterWise is the method in use to introduce the word (instead of Multi-tap). iTap, developed by Motorola, is very similar to T9: as the user writes, it compares the sequence of keystrokes to words in a dictionary, in order to determine the intended word. However, iTap also completes the words, featuring a list of possible suffixes of the word entered, and this is the main difference between the systems. eZiTap system, from Zi Corporation, combines multi-tap text introduction with word prediction, allowing an expert multi-tap user to improve performance without requiring any learning effort. As the user enters the desired word, a list of words sharing the same entered suffix is displayed. A “Next” key is used to navigate among the list.

Predictive systems with no visual feedback are prohibitive for blind people as the user isn’t aware of the actual evolution of the system and the current message state. For example, using the T9 system, there isn’t a relation between the key press and the letter appearing at the screen (it is affected by the predictive system frequencies) and it is not certain that, even when the correct keys are pressed, the word appears.

B. Visually Impaired focused Approaches

Alternative devices were developed to overcome the difficulties arising from visual impairments. Typically, these products' goal is to serve as a Personal Digital Assistant (PDA) providing functionalities like Contact Management, Calculator, Notes, Clock or SMS (sending and receiving).

Fig. 4. Braillino

They normally allow connection to a desktop computer or a cell phone, acting as an interaction bridge between the visually impaired individual and the device.

Braillino, from Handy Tech Elektronik GmbH, is an electronic notebook adapted to the visually impaired that allows the connection to regular mobile devices through a docking station or bluetooth. It is also possible to connect it to a personal computer (Fig.4). It is based on a Braille keyboard for input. It uses a software package called Talks&Braille that permits access to mobile phone functionalities, offering Braille output support and voice feedback (synthetic speech).

Touch Messenger, a Braille Mobile Phone by Samsung, enables the visually impaired to send and receive Braille text messages. It features a 12 button keypad which is used as two Braille keypads (Fig. 5). Text messages can be checked through the Braille display screen in the lower part. This product has not been commercialized and its special characteristics limit the availability and probably increase its cost.

There are several devices similar to Braillino and they all share the same flaws: the large size and weight and the prohibitive costs when compared with regular mobile devices. Although it is true that blind users can use Braille-based devices to accomplish their goals, it is also true that these devices are too heavy and large to be carriable and used while on-the-move. Also, considering a usual scenario where a blind user handles a cane with one hand, it is impossible to operate this kind of devices (Fig. 5).

Fig. 5. Samsung's Touch Messenger

In a totally different scope are the screen readers, solutions that can be used in a regular mobile device, giving the users feedback on screen evolution and replacing visual feedback. Nuance Talks is an example of this type of assistive technology for the visually impaired. Although screen readers make possible for a blind user to use a mobile device, they still require for the user to memorize letter's placement. Although experienced users can operate mobile devices using this technique, newly impaired individuals or users with little mobile device experience suffer big obstacles as no feedback on letter displacement is offered. Considering performance issues, predictive systems are still very difficult to use.

Voice recognition is a great promise as an assistive technology. However, in a mobile context the voice recognition systems characteristics and limitations are even more relevant: user's privacy is highly restricted and user and social acceptance issues arise.

III. Task Analysis

To identify the users' needs and capabilities as well as their common use of mobile phones, 12 visually impaired individuals were interviewed. The interviews were conducted at Raquel and Martin Sain Foundation, a learning center for blind people, to 8 male and 4 female individuals, with ages between 21 and 64 years.

Considering mobile phone use, it was curious to verify that all users possess a cell phone and use it once or more a day to make calls. Only two of the users reported having problems to dial a number due to the lack of feedback and small keypad size. Normally, dialing isn't problematic and therefore this task is not the main concern of our work.

Almost 60% of the users stated to send text messages (SMS) from which half stated to do it on a daily basis. All users that send SMS use Talks Screen Reader to get voice feedback but only one uses a predictive system (T9). The users generally agree that menu navigation is difficult and cumbersome and that the feedback is limited taking them to recurrently make mistakes.

Concerning Braille, 10 of the 12 users were able to read and write Braille, and 50% stated to do it on a daily basis. One of the users had learnt the Braille system recently (less than 2 years ago), while all the others had learnt the system 5 or more years ago. All the texts read and written by the individuals have accentuation and capital letters.

IV. Our Approach

Regular mobile device text-entry methods are suitable for visually capable individuals and seek to improve user's performance. Hence, it is possible for someone, with no experience, who doesn't remember the location of a letter, to easily look and recognize the key where that letter is. Those methods imply that the fingers *dance* through the keyboard, choosing letters and special characters, among ten or more keys. Once again, we easily overcome this issue appealing to vision. A blind user can't do that. The mark present at key '5' gives blind users the notion of the keypad layout but not feedback on the selected letter and, although users can make an effort to memorize a letter's placement, feedback is essential. Even SMS experts need to occasionally look at the words being written to ensure message correction. Moreover, expertise is acquired by using the method and receiving the feedback. Only after an extensive and successful use of the writing mechanisms the users can get used to them and, in some cases, no longer need constant visual feedback. Screen readers (such as Talks) overcome some of the issues as they offer the user feedback on the screen progress. However, keypad feedback is still inexistent which often leads to mistakes and sometimes giving up. Although users make sense on the message progress, they still have to know where to press to get the desired letter/action.

We can only offer visually impaired individuals mobile device accessibility if those devices can be easily available and usable. Therefore, based on user needs, capabilities, and available devices we decided that our method should be compatible with regular mobile phones and, therefore, with the regular 12 key keyboard layout requiring no-extra hardware (i.e. expensive and heavy Braille keyboards).

A. The Braille Matrix

One of the important facts that came up with the task analysis is that most of the visually impaired users subject to the interviews are familiar with the Braille system, and use it regularly for both reading and writing. Statistically, around 20% of adult blind read Braille, but it is also true that 90% of the world's blind people live in developing countries (China, India and African countries) [10].

Having this in mind, we looked at the regular mobile's phone keypad to find out a way of permitting Braille input without the needs of additional hardware.

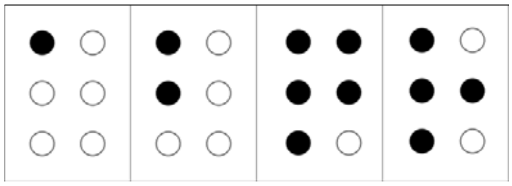

Fig. 6. Letters 'a', 'b', 'q' and 'r' in Braille

If we take a look at the Braille alphabet (Fig. 6), we notice that each letter is formed from a group of 6 dots. Without much effort, it's possible to imagine those six dots making correspondence to six keys of a regular mobile's phone keyboard. Adding extra functions to the keyboard, the layout is shown on Fig. 7.

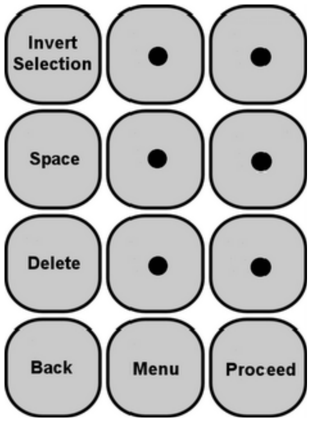

Fig. 7. Braille Matrix keyboard layout

The six dots were mapped on keys 2, 3, 5, 6, 8, and 9. Each press on each key fills the dot, or blanks it if it was already filled. Sound feedback is associated with both actions (filling/blanking the dot).

Key 1 is associated with an invert selection function. This key fills all the blank dots and blanks all the filled dots, again with appropriate sound feedback. The main purpose of this function is to reduce the number of key presses for certain letters - letter 'q', for example. Starting from an empty cell, the user presses key 1 and then key 9 to blank the bottom right dot – otherwise it would require 5 key presses (check Fig. 6).

Key 4 is the acceptance key: after filling the Braille cell, the user presses this key and the system reads the introduced letter, appends it to the text and blanks all the dots. If all the dots were blank, a space character is appended to the text. For example, to introduce letter 'b', the user should press the 2 and 5 keys followed by the 4 key. This acceptance key is an alternative to the timer solution used in Multi-tap, where the user has to wait (usually 1-2 seconds) until the letter is accepted. Although increasing the necessary keypresses for each letter, it allows faster input from the user.

When the user needs to blank the Braille cell, the 4 key should be used. If the all the dots were already blank, the last introduced letter is deleted. All these actions have sound feedback.

Key 0 provides context-awareness to the blind user: at any time, when this key is pressed, all the introduced text is read by the system.

Table 1. Theoretical key presses for the Braille Matrix

	Without Invert Selection	Using Invert Selection
Space	1	1
a	2	2
b, c, e, i, k, í, â	3	3
d, f, h, j, l, m, o, s, u, õ, ó, ê	4	4
g, n, p, r, t, v, w, x, z, ã, à, é, ô	5	4
q, ç, á, ú	6	3
Average	4,282	3,564
Average (considering English letter frequency)	3,398	3,1068

Table 1 is a theoretical study of the necessary key presses for each letter, including the acceptance button. The right column reflects the best use of the invert selection function – whenever the number of necessary keypresses is more than 4, it is valuable to use this function. The value for the last row, referring to the average key presses considering the English language [7], does not consider the accentuated characters (like 'ç' or 'ã') as these characters are not used.

V. Evaluation

Tests were made with five users, four of them with total blindness and one with partial blindness, who was also the individual who had learnt Braille more recently (less than 2 years). The ages averaged 46, and the younger individual was 37. All the users had a mobile phone which was used only to make calls, with exception of one user who stated to use the SMS service on a daily basis.

The tests were carried at Raquel and Martin Sain Foundation in a quiet room with no disturbances, with each student individually.

The test session included a brief presentation followed by an ambientation phase. This ambientation phase varied between 3 and 20 minutes, depending on the user's initial aptitude.

The task consisted in writing the Portuguese sentence – *Estou atrasado e não chego a tempo de almoçar*. The metrics chosen to analyze the results were WPM (words per minute) and KSPC (keystrokes per character), as described by Sirisena [8] and MacKenzie [9].

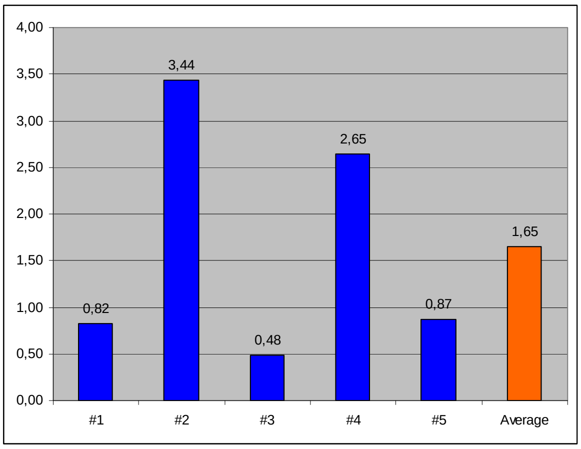

Fig. 8. Words per Minute

The results were as follows: 2 of the users had results of around 3 WPM (3.44 was the highest result) while the other 3 users featured some difficulties and did not reach the 1 WPM mark (Fig. 8). The average was 1.65 WPM.

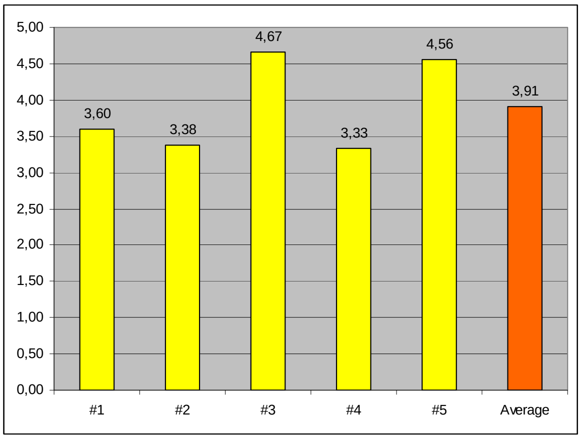

Fig. 9. Keystrokes per Character

Considering KSPC, the average was 3.91, which reflects poor use of the invert selection function and a relatively high error rate from some users (the average error rate was 3.9).

In general, all users were satisfied with the system and showed improvements throughout the ambientation phase and even during the test. The poorer results are in part justified by some inherent difficulties with the Braille alphabet revealed by one of the users and also by the mental model present in some users: they associate the Braille dots with 1-6 numbers, and there was a tendency to press the correspondent number in the keyboard, which led to a high error rate and consequent low WPM rate.

It is important to notice that, although all the users had a cell phone, only one was capable of writing messages before. With the presented system all the users completed the task, after a short ambientation time. These preliminary results show that an easy writing mechanism can be created if we focus on the user's capacities and available overdeveloped senses.

Fig. 10. Blind user testing the system

VI. Conclusions and Future Work

While today mobile phones are a common tool used in everyday life, they strongly rely on visual feedback for their correct operation. As such, visually impaired users have trouble using them, contributing to frustration and social exclusion. Existing alternatives are not practical or depend on memorization, often leading to mistakes. We developed a new text-entry interface that requires no memorizing and no extra hardware making possible for any visually impaired individual to use all the mobile phone's features that require text input. We evaluated the interface with the target users and validated the approach, showing that users input words with an acceptable rate improving their performance with almost no previous experience. As future work, we will study other text-entry interfaces and prediction mechanisms (letter and word prediction), focusing on performance improvement. We will also explore the developed technique with a wider population.

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