TACTBACK: VibroTactile Braille output using Smartphone and Smartwatch for Visually Impaired

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ABSTRACT

In this paper, we present TACTBACK, a novel way to haptically represent braille characters on a off-the-shelf mobile device and a smartwatch using vibration. TACTBACK can be used for a wide variety of scenarios such as training braille characters to the deaf-blind, providing secure non-audio feedback for pin/password entry, and as an educational tool for learning braille. We discuss the details of design and implementation of TACTBACK, and report on a preliminary user study with 15 participants. Our evaluation shows that participants could recognize individual braille characters with minimal training using TACTBACK. We present some of the scenarios where TACTBACK could provide substantial benefit over traditional talkback.

1 Introduction

High proliferation of smartphones in last two decades have made access to information as well as multitude of different services easier than before. Smartphones have also penetrated into lives of diverse set of users and as a result, many visually impaired are using them for different kinds of information access scenarios. However, current set of smartphones and wearable devices are designed for clear sighted (normal vision) people where most of the interactions happen using visual modalities i.e. touch screen. The accessibility features such as talk-out-loud features of these devices are severely limited in their functionalities as well as it can not be used in many social and environmental conditions such as noisy places.

In the last few years, wearable devices are becoming mainstream where such devices can be paired with smartphones to provide gestural inputs, which could be one of the alternative to touch-screen based interaction provided by smartphones [5]. There have been research works on enabling interfaces for braille or gesture-based input(s) using smartphones with subsequent auditory feedback. However, auditory feedback is insufficient in multitude of scenarios such as environmental conditions (i.e. noisy surroundings) or privacy concern (i.e. messages, chat) and sensitive information such as passwords, PIN, etc. Using headphone is one of the solutions to minimize information leakage, but is infeasible as it blocks out other ambient sounds, which is crucial for visually impaired people to navigate and interact. Hence, there is a need for the investigation of new interfaces which can provide them implicit feedback in different environmental and social settings.

One of the ways to provide implicit feedback is to use vibration-based tactile feedback which can encode braille representations of English alphabets and numbers [1]. The tactile feedback is hard to miss even in noisy surroundings and can be achieved without instrumenting current set of devices. Therefore, we present an *exploratory* system TACTBACK, which is an alternative to conventional talkback feature in several use case scenarios where security and privacy of information is a major concern. TACTBACK is designed to work with off-the-shelf smartphones and wearable devices seamlessly and learning curve is smooth considering all the visually impaired users have rudimentary training to recognize braille.

USER STUDY. We conducted a qualitative user study to understand the mobile device and technology usage of the visually impaired people. We visited a blind school in Bangalore, India and conducted semi-structured interviews with 20 participants (two faculties and rest students). Apart from the study we asked the participates to enter alphabets (a-z) on an Android device with the Android talkback enabled.

OBSERVATIONS. We observed that only two blind faculties use mobile phone (one being *Android* and another *feature phone*) with talkback feature regularly. Interviewing the students revealed only 1 out of 16 has prior experience of using only a feature phone. This posed significant challenges in operating modern touch based smartphone for the students. In the text-entry task, we observed that none of the participants were able to enter characters without frequent typing errors. Only one student could able to finish the task in reasonable time. The major challenge was to follow and decode the talkback feedback in noisy surrounding. Moreover overlapping audible feedback while correcting the typo contributed to their confusion.

The overall feedback we got is that the talkback feature is often misleading and confusing and does not facilitate efficient text correction mechanisms. Our work draws inspiration from these observations to design and build alternate output modalities for the visually impaired that can run on off-the-shelf mobile and wearable devices and complement the existing solution such as talkback.

PRIOR RESEARCH. There have been efforts in using the mobile devices' built-in motor to provide vibro-tactile patterns that represent the six-point Braille cell [2] [4]. However, these approaches require users to explore each dot of the Braille cell on the screen in order to decode the information. This method is inherently slow (4-27s). Our work draws inspiration from previous research such as *Holibraille* [3] and wearable design probes [5] to design, build and evaluate TACTBACK.

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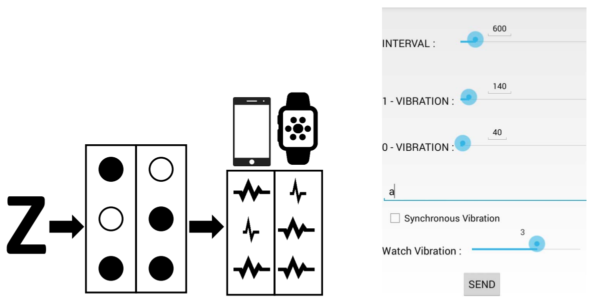
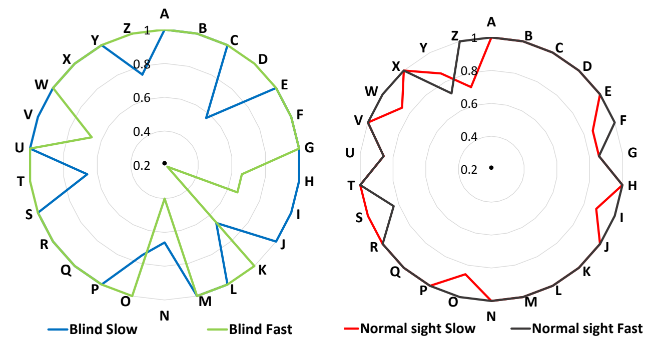


(a) (b)

Figure 1: TACTBACK design.



(a) (b)

Figure 2: TACTBACK evaluation.

2 TACTBACK

The design of the proposed system TACTBACK is focused to manifest three prime objectives: (i) Easy learning curve for the beginner blind users, (ii) Fast recognition of braille symbols with least number of typos and (iii) Ability to seamlessly integrate with existing application ecosystem.

IMPLEMENTATION. We implemented TACTBACK prototype for smartphones and smartwatches running the Android Operating System. We used Google's Wear API to relay the commands and vibrational patterns from the mobile device to the paired smartwatch. Our system decodes an entered character to its 6-bit binary braille version (for e.g 'a' translates to a bit pattern `100000`). For enabling fast and intuitive feedback the first 3 bits the bit-pattern (e.g.,"`100`" in 'a') vibrates on the mobile device while the rest (e.g.,"`000`" in 'a') is relayed on the smart-watch. One such example for *z* is demonstrated in Figure 1a.

WORK-FLOW. The TACTBACK prototype facilitates two modes of operations (training and testing) and provides different configurations for vibrations. It emulates a number of use-cases such as (i) Braille training for beginner, (ii) TACTBACK training for both beginner and experienced users and (iii) Scenarios replicating inputs such as password/pin entry, phone dialing (testing mode). The first two cases are simulated in testing mode by enumerating over English alphabets and their corresponding vibrations. Screen shot of the Android application is depicted in the Figure 1b. The prototype application can pair up with any smartwatch running Android Wear operating system and can divert specific haptic feedback to that.

3 Evaluation

We have conducted detailed experiments to evaluate TACTBACK. We evaluated TACTBACK Android prototype both with visually impaired and clear sighted users to produce a comparative result. All the blind users have using braille since their childhood and are proficient with it. All the clear sighed users never used braille before. So these experiments show that TACTBACK could be useful tool for teaching braille. We used Moto 360 smartwatch paired with Moto G Android device for our experiments.

PROCEDURE. We evaluated TACTBACK with two different vibrational intervals 700ms and 550 ms on 15 participants where 10 of them were blinds and 5 being clear sighted. The blind participants consist of both student (age group 13 to 17 with avg 14.8) and two faculties (aged 29 and 50). Initially participants were trained with TACTBACK (in training mode) and once they were comfortable and learned all the braille characters (a-z) we started our evaluation. Each participant was asked to answer the alphabet for the corresponding braille vibration. The alphabets were presented at random and had two trials. Hence each participant had 2 (vibrational intervals: 700 (*slow*) and 550 (*fast*) ms) $\times$ 2 (alphabet recognition trials) = 4 trials. The vibrational intensities were maintained constant at 140ms for embossed dot and 40ms for flat dot. Our pilot tests with various intensities showed that participants were comfortable and accurate in differentiating embossed and flat dots with these intensities.

ACCURACY PROFILE. Fig. 2a & 2b represent accuracy profiles for visually impaired and clear sighted participants respectively for both in slow and fast settings. Both of the circular graphs shows accuracy of recognizing English alphabets using TACTBACK. The center of the circle represents accuracy level of 20% while the perimeter being 100%. All the above experiments were conducted inside a classroom and office space in regular hour to simulate real world scenario. We experienced lower accuracy for a number of alphabets with blind participants for fast setting. This clearly shows trade-off that reducing recognition time may compromise accuracy of decoding a number of characters correctly. Another rationale behind that is most of the blind participants have no prior experience with smartphone/smartwatch and haptic feedback where the clear sighted participants could able to recognized better as all of them use mobile devices regularly.

RECOGNITION TIME. Reducing recognition time is one of a critical aspects of TACTBACK (refer Section 2). We measure the recognition time using a stopwatch while conduction the accuracy measuring experiment. For the slow and fast settings the average recognition time of the braille was 4.5 and 3 seconds respectively. Even the users with no prior knowledge of braille were able to recognize braille under 4 seconds with minimal training.

4 References

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