# Enriching the Lives of Deafblind Individuals Through Sensory Substitution (Interfaces to Interact, Communicate, and Entertain)


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## Abstract
For deafblind individuals, the absence of visual and auditory communication channels can prevent meaningful interactions with the people and world around them, leading many to suffer with both mental and social issues. To utilise the available sensory channels (e.g. taste, haptic, and olfactory) of deafblind individuals, tactile stimuli are one type of feedback that can be employed to enable communication with the outside world. Thus, this workshop paper discusses the development of digital communication tools for deafblind individuals through the technique of sensory substitution and introduces one of our current solutions based on the concept of Finger Braille. We have developed a wearable assistive device that converts speech and text into tactile stimuli, and vice versa, to enable efficient communication between deafblind and non-impaired individuals. In addition to employing tactile stimuli, we believe that olfactory and taste stimuli may also be incorporated into future versions of the system in order to deliver non-time sensitive information, such as local navigational data.



## Author Keywords
haptic; tactile; sensory substitution; deafblind; finger braille

## ACM Classification Keywords
H.5.2 [User Interfaces]: Haptic I/O

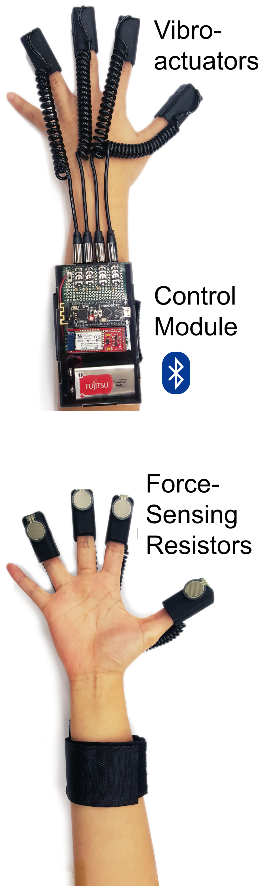


**Figure 1:** The wearable Finger Braille device with control module (communication and text-to-braille conversion), vibro-actuators (input), and force-sensing resistors (output/typing).

## Introduction

Effective communication and interaction with the people and objects around us is essential to our well-being and achieving an optimal quality of life. Performing these interactions requires us to constantly engage and process information from all of our sensory channels. Although the human body is typically capable of simultaneously sensing and handling information from a range of modalities, including visual, auditory, tactile, olfactory, taste and vestibular, people who suffer from deafblindness are heavily restricted by the absence of visual and auditory information. Due to the frequent difficulties that deafblind people experience, and the unavailability of a platform that enables them to clearly express their emotions and thoughts with others, the alienation caused by this condition leads many deafblind people to suffer from depression and, in severe cases, even commit suicide [9].

Deafblindness is a combined sensory disorder wherein individuals possess varying degrees of both visual and auditory impairment. An estimation from 2010 suggests that there are approximately 358,000 individuals in the U.K. who suffer from some form of deafblindness [8]. These individuals often find many everyday tasks extremely challenging and require support when interacting with people or their surroundings, specifically requiring intensive support in education, navigation and other key activities throughout their lives.

Addressing these issues, sensory substitution is one method that can provide deafblind people with a means of communication. Sensory substitution is a non-invasive technique for circumventing the loss of one sense by feeding its information through another sensory channel to shift the cognitive load between available human senses [1]. For deafblind people, sensory substitution is required to convert inaccessible visual and auditory information into a form where it can be displayed via the individual's haptic, taste and olfactory senses. A commonly utilised form of sensory substitution is Finger Braille, a type of tactile communication where the sender dots Braille code on the fingers of the receiver using the thumb, index, middle and ring fingers of each hand. Finger Braille is predominantly favoured for assisting deafblind people due to the speed and accuracy with which it can be used to communicate. Skilled users of Finger Braille can also express certain emotions through the prosody of their dotting [3]. However, this form of communication requires the presence of a non-disabled interpreter who is also skilled in Finger Braille. Due to the small number of Finger Braille interpreters, accessibility is a still a key factor that causes extremely restricted communication and expression for the deafblind.

With respect to the current need for new assistive technology, we present an overview of our work on developing a communication and information exchange platform that utilises sensory substitution techniques to aid the visually and auditorily impaired. The system consists of two main modules: 1) a computer-mediated device that utilises tactile feedback to provide a practical user interface and extends the existing Finger Braille language, and 2) a mobile software application that converts text, speech and image data into a form where it can be displayed to deafblind individuals through tactile stimuli from the Finger Braille device.

## Related Work

With regard to developments in assistive tools for deafblind people, the majority of existing projects have focussed on creating different types of tactile displays that employ a wide range of actuation methods to provide haptic feedback on the deafblind person's fingers, hands or wrists. As noted by Velázquez, these actuation methods include the

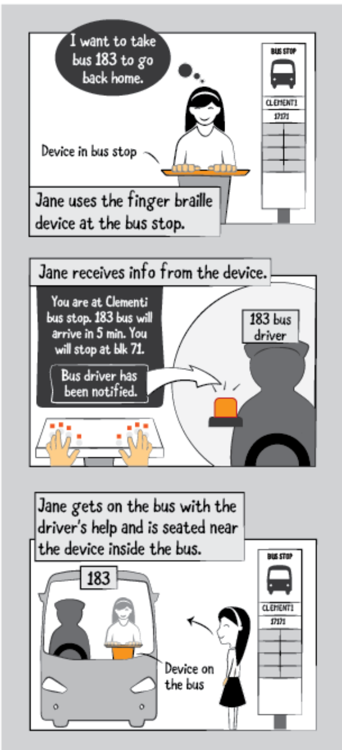


**Figure 2:** An illustration showing how the proposed assistive platform may be integrated into public transport services to provide accessible information.

use of servomotors, electromagnetic coils, piezoelectric ceramics, pneumatics, shape memory alloys (SMAs), electroactive polymers (EAPs), electrorheological (ER) fluids and airborne ultrasound [11].

As Finger Braille is already an established form of communication that is known by many deafblind people, several hand-worn tactile displays have been developed to enable users to send and receive Finger Braille-based messages. By incorporating Finger Braille, these assistive tools aim to 1) minimise the time it takes for users to learn the system and 2) provide efficient communication with non-deafblind people who do not have strong knowledge of Finger Braille. These systems exist in multiple forms where accelerometers and actuators can be mounted on the user's fingertips [10, 6], rings on the user's fingers [2], the finger's middle phalanges [5] or on bracelet-like wearables [7]. Alternatively to systems that are mounted on the user's fingers, some assistive tools for deafblind people, such as the Mobile Lorm Glove [4], cover the user's entire hand. This glove-based system translates touches on the hand, in the Lorm touch alphabet, into text and vice versa. In contrast, our approach utilises the Braille language, which is both simpler and more widely accepted.

## Our Current Work

We have developed an assistive platform to enable effective communication with and between deafblind, blind, deaf and vocally impaired individuals. The platform comprises of a tactile feedback interface in two form-factors: a desktop version and a wearable version, which are linked to a mobile software application (see Figure 1 for the wearable device).

Both versions of the system contain a set of 8 input/output points (for the thumb, index, middle and ring finger of each hand) that generate and sense vibro-tactile events on the

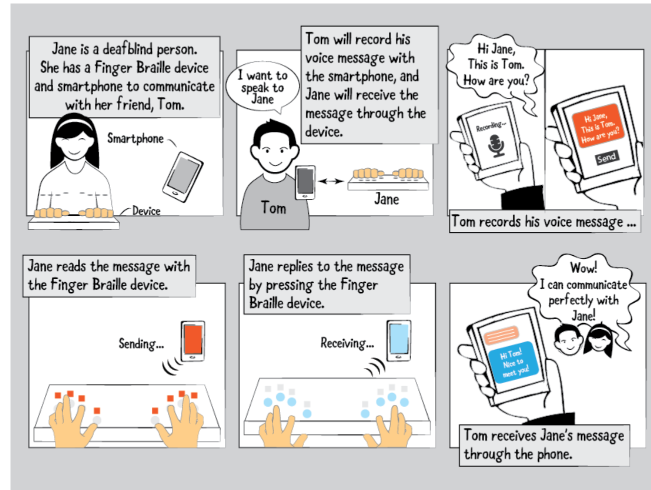


**Figure 3:** An illustration showing how the proposed assistive platform enables communication between impaired and non-impaired individuals by handling text, speech and Finger Braille.

user's fingertips. By utilising this configuration, the system can provide the user with Finger Braille in both 6-dot and 8-dot forms depending on the user's preference and ability.

In partnership with the device, the mobile software handles data and performs conversions between different modal stimuli (including image-to-speech (visual to auditory), image-to-braille (visual to tactile), image-to-text (visual to textual), speech-to-braille (auditory to tactile), speech-to-text (auditory to textual), braille-to-speech (tactile to auditory), and braille-to-text (tactile to textual)). By combining these two components, this platform provides users with an interface that can be used to support effective communication and that can also enable improved accessibility to other

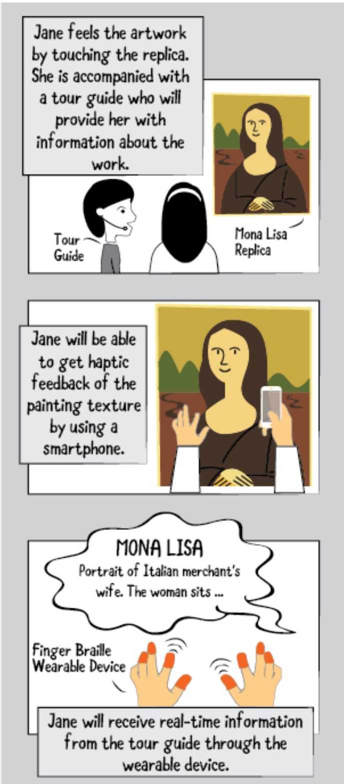


**Figure 4:** An illustration showing how the proposed assistive platform may be incorporated into museums and galleries in order to provide accessible information regarding exhibits.

forms of information interaction.

## Usage Scenarios

The proposed technology has potential applications in many different environments and scenarios. Possible applications for this platform include:

**1. Smart Communication Tools:** Deafblind individuals mainly use Finger Braille or other types of tactile sign language to communicate. However, only a small number of people are familiar with these languages and this can mean that a deafblind individual's social interactions are severely restricted. The proposed assistive platform may help users to directly communicate with others by translating speech, text and image data into Finger Braille, and vice versa (as shown in Figure 3).

**2. Smart Technology for Mobility:** Due to their impairments, deafblind individuals require others to accompany them whilst travelling. By integrating the proposed assistive platform into public transport services, users will have the opportunity to access information that could enable them to select transport routes and explore more independently (as shown in Figure 2).

**3. Accessibility to Information on Surrounding Landmarks and Objects:** In the example of a museum or gallery (as shown in Figure 4), an exhibit may include a 3D replica that acts as a textural representation of the original work. At the same time, just as a non-impaired person may rent an audio guide, or listen to a docent (tour guide), deafblind visitors can receive the same real-time information via the proposed Finger Braille device. Furthermore, the assistive platform may be incorporated in such a way that users can also scan exhibits, using smart phones, to obtain additional tactile feedback information on the work.

**4. Delivering Additional Information via Alternative Multisensory Stimuli:** Alternative feedback, such as taste and olfactory stimuli, may be provided alongside tactile stimuli to give additional context to an interaction. Examples of this could include providing scents to indicate a location (e.g. mint represents a bathroom, lavender represents a bedroom, jasmine represents a hallway etc.) or providing flavour and scent previews when the user is selecting food options from a menu.

## Conclusion

In this workshop paper, we have discussed the importance of developing digital communication tools for deafblind and impaired individuals, providing a brief review of existing assistive communication systems and highlighting that many systems utilise Finger Braille (or similar tactile formats) to optimise effective communication. Following this, we have described our current work on developing an assistive platform that incorporates mobile computing to handle text, speech and image data, and convert this into an accessible Finger Braille-based form. To provide real-world applications of the platform, we have included and illustrated several everyday scenarios in which the proposed system could be employed to enhance accessibility for individuals with visual and auditory impairments. To preserve effective, crucial and meaningful interactions with the people and objects around us, we believe that the development of assistive platforms must be continually explored and supported by the emergence of new, more accessible technologies.

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