# Tangible Interaction for Visually Impaired People: why and how

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***Abstract*— Tangible User Interfaces (TUIs) have been in the focus of research in the field of Human-Computer Interaction for the past years. TUIs rely on manual exploration of physical objects for interacting with digital media. Although visually impaired people demonstrate efficient manual exploration strategies, there is surprisingly little work on non-visual TUIs. This paper presents existing TUIs that have been designed for visually impaired people, introduce the VISTE project and make suggestions for future work in this area.**

## I. Introduction

Visually impaired people encounter important challenges in various areas of their daily lives, such as mobility, and access to information and education. Technical progress has made it possible to develop assistive technology to support these activities. These devices mainly substitute vision with audio and/or tactile cues. Tangible user interfaces (TUIs) enable interaction with the digital world through the use of physical artefacts, making use of touch. TUIs for sighted people have been extensively studied in the field of Human-Computer Interaction (HCI). Although visually impaired people demonstrate efficient manual exploration strategies, there is surprisingly little work on non-visual TUIs. This paper presents a summary of previous work in this area, introduces the VISTE project and makes suggestions for future work.

## II. RELATED WORK

### *A. Tangible Interaction*

TUIs enable interaction with the digital world through the use of physical objects. Those physical artefacts often serve both as input and output devices as they provide users with kinesthetic feedback about the manual manipulations they are doing, as well as digital (audio or visual) information about the state of the associated computer program [1]. Touch, mainly in the form of bi-manual exploration of 3D objects, is an important modality involved in the interaction with TUIs. A famous example of such interfaces is Urp, a TUI for urban planning, which combines physical 3D models with interactive simulation [2]. Within the field of HCI, TUIs have been used in many areas, including education, information visualization, programming, entertainment, musical performance, planning and social communication [1].

### *B. Tangible Interaction for Visually Impaired People*

Most technologies that are accessible to visually impaired people replace vision with audition or touch. Touch is a promising modality for sensory substitution, as previous studies have revealed superior tactile acuity for blind people over sighted people [3]. However, only few TUIs for visually impaired people have been designed, and the existing accessible TUIs are mainly targeting access to geographic maps and diagrams.

Examples of tangible diagrams include a prototype for the non-visual exploration of graphs by McGookin et al. [4]. This system combined a fixed grid and movable objects that represent the top of a bar or the turning point of a linear function. The authors also provide guidelines for designing tangible interaction for visually impaired people. TIMMs by Manshad et al. [5] are tangibles that provide multimodal feedback for the creation and modification of diagrams.

In tangible maps, map elements are represented by physical objects which are often augmented with audio feedback [6]. Those maps allow bimanual exploration. In some cases, users can not only explore the maps, but build and modify them by manipulating and moving the objects. As an example, the prototype by Schneider and Strothotte [7] enabled visually impaired people to construct an itinerary using building blocks of various lengths. A camera tracked the users' dominant fingers during exploration of the virtual map, and guided them along the itinerary with the help of audio cues. Tangible Reels [8] are physical icons on a multi-touch table representing points of interests (cities, bus stops, etc.). These objects contained a retractable reel representing line segments (streets, rivers, boundaries, etc.). The system guided the user with audio instructions to correctly place and link the objects. The user could then retrieve the name of the elements by doing a pointing gesture above the objects or line segements. MapSense [9] was built using a colored raised-line overlay on a multi-touch surface with complementary 3D-printed objects. Some of these

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tangibles could be filled with scents (e.g., olive oil, honey), thus creating a multi-sensory map.

### C. Advantages of Tangible Interaction

TUIs have shown many advantages over standard mouse and keyboard computer interfaces. They foster collaboration [1], [10]. They have also proved to increase participation of students in learning tasks [10]. In the context of visual impairment, TUIs are more dynamic and flexible than raised-line representations which are traditionally used by visually impaired people. Indeed, it is possible to add, move and remove tangible objects whereas a relief map is static [6]. Moreover, constructing tangible maps improves the understanding and memorization of spatial information in the absence of vision [8].

### D. Limitations of Tangible Interaction

Limitations of TUIs include the user's fatigue from manipulating physical objects [1]. Moreover, only a limited number and type of elements can be represented, as tangible objects are generally relatively large (see e.g. [8]). Another limitation concerns scalability: when a user wants to zoom, the whole map needs to be reconstructed by moving the objects [1]. Furthermore, TUIs are subject to technical problems such as offsets in space and time between the position of the tangibles and the calculated response, or occlusions in camera-based tracking [10]. In particular, when a visually impaired person explores an interface with both hands, occlusions are likely to appear.

## III. VISTE: an Accessible Map Prototype using Tangible Interaction and augmented Reality

VISTE ("Empowering spatial thinking of students with visual impairment", http://visteproject.eu) is a European Erasmus+ project. The VISTE resources and tools focus on collaborative learning of spatial concepts and skills for sighted and visually impaired students with the goal to foster inclusion within mainstream education.

At Inria Bordeaux, we will design and implement a Tangible Augmented Reality prototype that will be used as spatial thinking training tool in special education schools for visually impaired people [11]. Our prototype will make use of PapARt [12], an Open Source augmented reality framework (see https://project.inria.fr/papart/). The prototype supports interaction techniques such as tangible interaction and multi-touch, and projects visual information. In line with previous work, we are working on augmenting the prototype by adding audio cues (e.g. verbal, or ambient sound) and tactile cues (e.g. vibrations, or tangible objects with different textures). By providing visual cues (projection) and non-visual cues (audio, tangible objects, tactile feedback) we aim at supporting collaborative learning between sighted and visually impaired people. The system will exploit one of the advantages of tangible interaction: letting users not only explore but also construct the maps. For this, we will make use of magnet boards which are currently already used in mobility and orientation training for visually impaired people. The geographic maps will be projected on these white magnet boards and the magnets will serve as tangible objects.

## IV. Discussion and Research Perspectives

Although TUIs have been in the focus of research in HCI, there is surprisingly little work on TUIs for visually impaired people. We suggest that future work in this area should investigate the following aspects:

*Actuation: A*ctuated TUIs (i.e., TUIs with active haptic feedback [1]) could provide complementary tactile cues to visually impaired people. First steps have been taken in HCI to implement dynamic interfaces using small robots [13], but not in the context of visual impairment.

*Haptic Aesthetics:* Aesthetics are often focused on visual aspects [1]. Yet, recently "feel aesthetics" have been studied in the case of 3D printing [14]. We believe that this aspect should be further investigated in the context of visual impairment.

*Additional Sensory Modalities: A*ccessible TUIs combine physical objects with audio cues. To our knowledge, only MapSense [9] explored the use of additional olfactory cues. Multisensory Interaction has recently attracted attention in the field of HCI and we expect further work in this area in the future.

*Application Areas:* As mentioned above, most accessible TUIs represent geographic maps or diagrams. Other areas where TUIs could be used are easy to imagine. The AccessiDVScratch toolbox (see http://www.ac-grenoble.fr/ecoles/g1/spip.php?rubrique 1094) uses lego bricks for teaching the visual programming language Scratch in the absence of vision. It would be interesting to add interactivity to this toolkit (e.g. audio cues) and turn programming languages in TUIs, as has been previously done for sighted people [1].

In conclusion, TUIs have been extensively studied for sighted people. A few prototypes that we present in this paper have been built for visually impaired people. We hope to see more work in this area in the near future as we believe that it is promising for making technology accessible to visually impaired people.

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