Teaching spatial thinking to visually impaired students using augmented reality

Introducing the VISTE project

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RESUME. Les personnes non-voyantes et malvoyantes font face à des défis importants liés à l'orientation et à la mobilité qui pourraient notamment les empêcher de voyager en autonomie. En effet, il est difficile de naviguer dans un espace inconnu en l'absence de vision ou d'acquérir des connaissances sur les espaces avant de voyager. Historiquement, les cartes en relief avec du texte en braille ont été utilisées pour enseigner la géographie aux élèves déficientes visuelles, mais ces cartes présentent des limites importantes, comme par exemple un nombre limité d'informations pouvant être présentées. Des cartes interactives accessibles ont été conçues dans le but de surmonter ces limitations. Dans le projet VISTE, nous visons à explorer une technologie novatrice de réalité augmentée pour concevoir une carte interactive accessible qui sera ensuite utilisée dans les écoles spécialisées pour enseigner la géographie à des enfants déficients visuels.

ABSTRACT. People living with visual impairments face important challenges related to orientation and mobility which might even prevent them from travelling autonomously. Indeed, it is difficult to navigate in an unknown space in the absence of vision or to acquire knowledge about spaces before travelling. Historically, raised-line paper maps with braille text have been used to teach geography to visually impaired children, but these maps possess significant limitations. Accessible interactive maps have been designed with the aim to overcome these limitations. In the VISTE project, we aim at exploring an innovative augmented reality framework to design an accessible interactive map that will then be used in special education schools for teaching spatial thinking to visually impaired children.

Mots-clés : Réalité augmentée, technologies éducatives, accessibilité, déficience visuelle, cartes interactives, géographie, cognition spatiale

KEYWORDS: Augmented reality, educational technologies, accessibility, visual impairment, interactive maps, geography, spatial cognition

1. Introduction

Worldwide, 285 million people are visually impaired, including 39 million blind people (WHO, 2014). Those people face important challenges related to orientation and mobility (O&M) which might even prevent them from travelling (C2RP, 2005). Indeed, most visually impaired (VI) people—and in particular those who are born blind—possess perceptive and cognitive differences from sighted people that generally reduce their spatial capabilities (Cattaneo & Vecchi, 2011). It is also difficult for them to acquire knowledge about spaces before travelling, as most maps are visual. In special education schools, VI children receive training regarding spatial thinking, i.e. the capability to analyze and understand spatial information and to make decisions based on this information. Raised-line paper maps with braille text have mainly been used for teaching spatial thinking to VI people. These maps possess significant limitations, as for instance only a limited amount of information can be presented on those maps. Recent technological progress has enabled the design of accessible interactive maps, e.g. audio-tactile maps, which overcome these limitations. In the VISTE project we aim at designing an accessible interactive map prototype based on an innovative augmented reality framework which will be used in special education schools for VI children.

2. Current practices of teaching spatial thinking to visually impaired people

Today, VI students in many countries receive education in order to prepare them for autonomous participation in society. The current trend goes towards integration in mainstream schools (see Charcharos et al., 2017 for current practices of teaching spatial thinking to VI people). With the help of special education schools, these children receive O&M training. This provides them with spatial skills for their daily lives, such as knowing where one is in space and where one wants to go, or how to use input from the different senses for navigation. Besides O&M, academic progress in subjects such as geography, mathematics, social sciences, and history requires the understanding of spatial concepts and the use of spatial skills. Raised-line paper maps with braille text which are commonly used for teaching spatial thinking to VI people come with downsides. For instance, they can only present a limited amount of information, they are static and they require users to read braille.

3. Previous work on interactive maps for visually impaired people

In the past thirty years, several researchers have investigated the design of interactive maps for VI children with the aim to overcome these limitations. Using digital technologies, visual information can be replaced by audio, haptic or cutaneous feedback, tangible interaction or even smell (see Ducasse et al., 2017 for a review). In our previous work, we have designed several prototypes using different technologies. First, we built a prototype that uses a tactile paper map as overlay over a multi-touch screen and provides audio feedback. We demonstrated that this prototype was more usable than traditional tactile paper maps with braille (Brock et al., 2015). A formative study at the Institute of the Young Blind in Toulouse showed promising results and the prototype has been used in class since then (Brulé et al., 2016). Then, we introduced MapSense using the same hardware and interaction techniques with additional 3D printed tangible objects. Some of these objects could be filled with scents, such as olive oil or honey, thus providing additional olfactory cues. A study on the use of the prototype in a classroom showed that the tangible objects and olfactory cues triggered strong positive emotions and stimulated spatial learning as well as creativity of the VI students (Brulé et al., 2016). While these prototypes have proved to work well, their technical possibilities remain limited as they depend on the use of a multi-touch screen which has a rather small exploration size and can only recognize certain types of tangible objects. This is why we intend to use an augmented reality toolkit for our future work.

4. The VISTE project

VISTE—or “Empowering spatial thinking of students with visual impairment”—is a European Erasmus+ project that runs from 09/2016 to 08/2019 and is coordinated by National Technical University of Athens (Greece). Partners in this project are Inria (France), Intrasoft International SA (Luxembourg), Casa Corpolui Didatic Cluj (Romania), Liceul Special pentru Deficienti de Vedere Cluj-Napoca (Romania) and Eidiko Dimotiko Sxolio Tiflon Kallitheas Athens (Greece). VISTE builds on the previous development of the GEOTHNK platform (Kavouras et al., 2016; http://www.geothnk.eu/index.php/en/). The VISTE framework and associated resources and tools will focus on collaborative learning of spatial concepts and skills for sighted and VI students to foster inclusion within mainstream education. VISTE will empower students with VI to acquire spatial skills through specially designed learning activities as well as through an augmented reality prototype.

At Inria Bordeaux, we will design and implement an augmented reality prototype that will be used as spatial thinking training tool in special education schools. This prototype will make use of the PapARt technology, an OpenSource augmented reality framework (Laviole & Hachet, 2012). The system provides different ways of interaction, such as tangible interaction using physical objects and touch-based interaction. While these interaction modalities have been explored in augmented reality maps for sighted people (Chatain et al., 2015), no previous study has investigated how this framework can be beneficial for VI people. In line with previous work, we envision 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). We hypothesize that a system providing both visual cues (projection) and non-visual cues (audio, tangible objects, tactile cues) should be well adapted for enabling collaborative learning by both sighted and VI people. When working with people with special needs, e.g. VI people, it is especially important to involve this target user group during the design process. Similar as in our previous projects (Brock et al., 2016; Brock et al., 2010), we will make use of participatory design methods to involve students and teachers all along the design process. We intend to evaluate the usability and accessibility of our prototype using an experimental protocol similar to the one we used in our previous studies (Brock et al., 2015). We hope that VISTE will make a contribution to advance teaching of spatial thinking to VI children.

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Appendix – Photographs

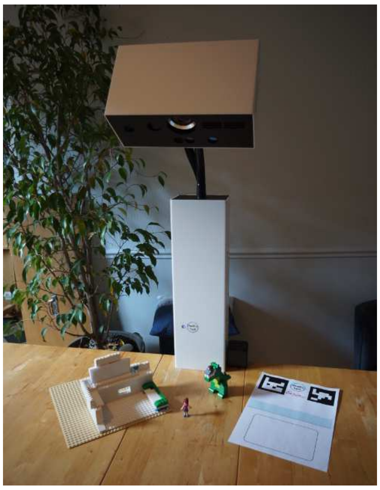

Figure 1. Photograph of the PapArt hardware by Inria Bordeaux: the prototype includes a projector, a RGB camera and a depth camera.

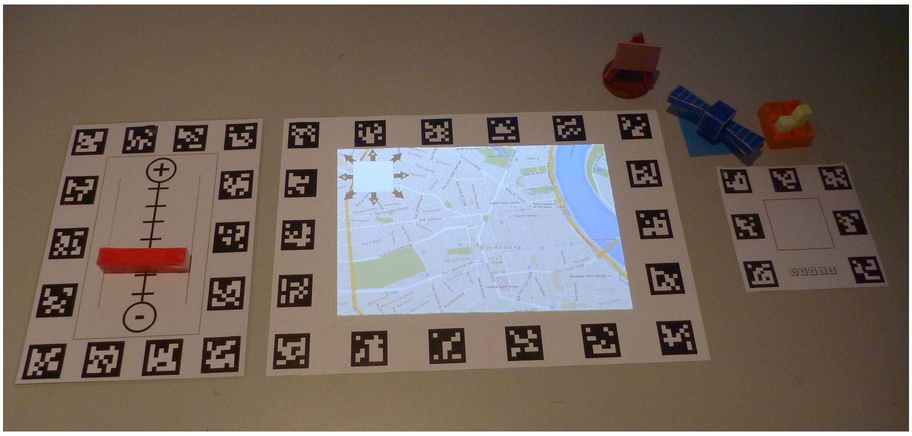

Figure 2. Photograph of an interactive geographic map for sighted people implemented using the PapArt OpenSource framework and hardware. The prototype projects a map on a paper sheet, and provides tangible, touch-based and spatial interaction techniques (Chatain et al., 2015). In the VISTE project we aim at extending this prototype with supplementary non-visual cues (e.g., audio output).