How to move from Inclusive Systems to Collaborative Systems: the Case of Virtual Reality for teaching O&M

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ABSTRACT

Inclusive systems can be used both by people with and without impairments. This creates new opportunities for sighted and visually impaired people to collaborate with the same tool. Audio-tactile maps and virtual reality (VR) represent a safe and controlled environment for Orientation & Mobility (O&M) classes. These classes aim to teach visually impaired students to move safely and independently, in particular in urban environments, and can be seen as collaborative activity between teachers and students. To go further regarding collaboration in the classroom, the same virtual environment could be used in parallel by several users. The question of collaboration through awareness from CSCW (Computer Supported Collaborative Work) is extended to VR and accessible interaction. By implementing various facilities for mutual awareness sharing the virtual and physical environment, for users with and without vision, we open the question of inclusive collaboration.

CCS CONCEPTS

• **Human-centered computing** → **Virtual reality**; **Accessibility systems and tools**.

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KEYWORDS

accessibility, visual impairment, virtual reality, augmented reality, mobility training

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INTRODUCTION

Developing spatial skills is a well known challenge for visually impaired people (VIP)[4, 8]. In Orientation and Mobility (O&M) classes, instructors teach visually impaired students how to analyze an environment using audio-tactile cues, how to prepare a journey, and how to cross a street in the absence of vision. As this training is often done in real outdoor environments, the O&M instructors must supervise students in order to avoid accidents (e.g. getting hit by cars) and to deal with unpredictable conditions (e.g. traffic, weather, other pedestrians' behavior). To overcome theses issues, Augmented Reality (AR) based audio-tactile maps and Virtual Reality (VR) street simulator provide a solution[14]. Indeed, tactile maps [21] and virtual environments [7] allow users to experience spaces, possibly in an interactive manner, but in controlled conditions without the exposure to safety risks. Within the VISTE project[1], we implemented and evaluated such solutions. Our objective is to design accessible tools for blind people and to ensure the inclusion for the sighted and low vision people by also providing visual feedback. Indeed, the solutions that specifically address VIP are not necessarily inclusive for sighted people (i.e. they do not provide any visual feedback at all, e.g. in VR[13, 22]).

Related work: visiting virtual environments with a smartphone.
There is existing work on visiting virtual environments using gestures and touch on the screen to move in the virtual world. Cobo et al. [5] propose a system to visit indoor environments (office, pub and bedroom). Guerreiro et al. [10] propose to visit outdoor environments from Point of Interest to Point of Interest, or to follow a similar path virtually step by step.

INCLUSIVE SYSTEMS FOR ACQUIRING SPATIAL KNOWLEDGE: PREVIOUS WORK

Interactive audio-tactile maps for spatial learning

Within the VISTE project, audio-tactile maps (figure 1) have been developed which offer a) interactive captions and b) exercises with automatic corrections: positioning a building or road on the map with instructions (up, down, left or right) in case of errors [2]. The technical system uses the PapARt Augmented Reality framework[16] to add audio information on raised-line maps. PapARt uses a depth camera to detect the contact of the fingers with the map, so maps are made interactive similar to a touchscreen. When the user touches the map, the system plays the audio-caption of the element under the finger. For the exercises with correction, the user positions elements on the map, points to an element with the finger and the system indicates if it is at the correct position, or on the left, on the right, at the top or at the bottom of the expected position. Our contribution to this project is to extend it by an interactive quiz[20]. The same system can be used for any tactile media such as a botanical atlas with real leaves. If the user touches parts of the atlas, the description of what he/she is touching

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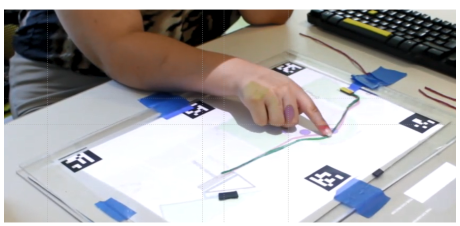

Figure 1: The first VISTE system proposed in [2]: route from a tram station to a public garden on an audio-tactile map. The student uses Wikki Stix (a woolen wire surrounded with wax) sticking on the paper to represent in a tactile manner his/her answer. The student follows then with one finger the Wikki Stix and the system informs him/her with a beep when the finger is on the right path (+/- 1cm).

Figure 2: Content creation for teachers: an O&M instructor associates the TTS information with a tactile map. The instructor uses Inkscape (on the screen on the left of the image) to draw the interactive zones on the picture of the real tactile map (visible on the table on the right).

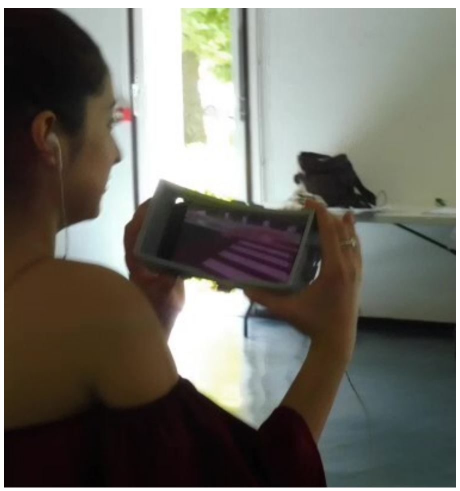

Figure 3: A student crosses the virtual street. It is possible to see on the screen that she is on a pedestrian crossing and no car is in front of here. The cars not visible on the screen are audible with pseudo-3D audio sources (the motor engines of the cars driving).

is played. The quiz questions are about pointing to an element on the tactile graphics (e.g. "Where is the laurel leaf?"), or about following lines (e.g. "follow the lower branch"). We also contributed a method to add audio feedback on a physical tactile support (instead of swellpaper) so the teachers could implement new scenarios. This enhances acceptance of our system outside of the research environment. Indeed, one of the challenges in creating audio-tactile maps is that they rely on expert knowledge regarding digital drawing tools [6, 9]. The presented process in [20] uses a scanner to annotate interactive audio content on an existing tactile content without digital models or electronics. We asked teachers to create tactile content from existing objects, e.g. small scale models, and then to add text-to-speech (TTS) content using the Inkscape drawing software (Figure 2). We evaluated the method and the usability of the produced maps for visually impaired students [20]. While this method was rated with a "good" to "very good" usability with the UEQ [15] and rated without important workload with Nasa-TLX [11], it requires users to switch between tactile content, the computer, and the PapARt AR toolkit used to make it audio-tactile. To avoid this need for switching tasks, our future work is to develop a system to make surfaces interactive directly using the toolkit. The content zones will then be hand-drawn directly on the tactile support without drawing software.

X-Road VR street simulator for O&M classes

As is the case with tactile maps, virtual environments are safe and controlled alternatives for visiting physical spaces, supporting therefore learning through trial and error and adaptation of the difficulty level of an exercise [7, 14, 21]. We introduce here our VR prototype called X-Road. It is a street simulator working with a smartphone app on mainstream hardware, thus facilitating adoption in educative contexts [3, 18]. We designed X-Road to recreate a street setting with visual and audio modalities. Users move in the virtual world with the same scale as in real world, without any specific devices nor limited interactive space. The simulator controls the number of vehicles or pedestrians, interactive events, etc. Immersion, an indicator for presence rating in VR [17, 22], has a direct impact on the use of our system. Indeed, the teacher collaborates with the student and is not represented by an avatar in the virtual world.

OPEN QUESTION

Inclusive Systems as a step towards collaboration

Digital solutions and interfaces allow users to have various modalities for the same content: text can be displayed with various fonts and sizes, read by TTS, displayed on a Braille tablet, etc. Computer solutions are then key elements in inclusive systems. As sighted people and VIP can use the same inclusive system, at different moments at least, it is a starting point for collaborative systems used simultaneously by people with and without impairment.

Collaborative Activities and Mutual Awareness in Collaborative Systems

For now our systems only support awareness between teachers and students by sharing the same tool, e.g. the same map or the same smartphone. But as defined in the CSCW research field, mutual "we"-awareness has to be ensured for good collaboration through digital interaction [19]. This mutual awareness is multi-contextual (**environmental**, **user and interaction**, **action**, **organization** [1]). This awareness contexts depend on the collaborative activity distance (local or remote), the configuration (centralized, distributed) and the structure (hierarchical, horizontal, roles).

From inclusive systems to inclusive collaborative systems, implementing support for the subcategory of mutual awareness becomes a challenge. **Environmental** awareness concerns sharing the same virtual space, which can be totally shared (the same screen for all participant), or not (a social network). **Action awareness** concerns being aware of the concurrent actions of the other users [12] for local or remote collaborative activity, possibly only for the remote actions related to the local ones. This awareness may also concern sending characteristics about the actions, or constraints in relation with the actions (such as timing and deadline, resources and productions of the actions) [1]. **Interaction and user awareness** concerns knowing the available interactions and knowing who are the other users using the system. Finally, in collaborative activity, it is important to know and to share the implications of context on the group. This is called **organizational awareness**.

How to ensure inclusive mutual awareness in collaborative system ? The case of VR

Inclusive VR is particularly relevant for this open question, as the environment is totally shared and the other users are a part of the environment if several people use it in parallel. For now, our system only offers sharing the tool. The next stepwould be sharing the virtual world (**environmental**). In this case, the available actions for the user should be made perceptible for each user, therefore should not rely only on visual highlights (**user and interaction**). Beyond sharing the environment, the possibility of having the representation of the teacher in the virtual world can be a solution for enhancing realism of the representation without breaking the pedagogical link between the student and the instructor (**user and interaction**). This poses the question of how to recognize other virtual users (avatars) in VR in particular if some are "non-player characters" such as virtual pedestrians (**user and interaction**). Then, the actions of the players and non-player characters should be perceptible in the same environment (**action**). In the case of collaboration with multiple students and teachers in the same virtual worlds, the roles of the users and impact on the group of their actions should be perceptible as well (**organization**).

To conclude, collaboration in inclusive VR for VIP brings challenges on environment, actions and users perceptions. This includes the fields of VR: sharing the same virtual space; CSCW: sharing various contexts; Human-Machine interaction and cognitive sciences: representing humans in VR.

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