A Tangible Visual Accessibility Tool for Interactive Tabletops

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Abstract: Thanks to being highly multimodal, interactive tabletops show great potential for edutainment. But in order to meet the world spreading inclusive school policies requirements, they need new and dedicated accessibility tools which would take into account both the specificity of the platform and the needs of its users. We present here the design methodology we adopted to design one of the said tools and the results we obtained.

1 INTRODUCTION

Serious gaming is gaining increasing importance in classroom settings. Many works have shown that games provide a motivating and error proof environment for learning (De Freitas & Smith, 2007). Moreover, it has been shown that direct manipulation and collective work have a good impact on learning (Verhaeg, et al., 2008). It is therefore not surprising that in classrooms, educational games usually come as board games. Other works also stress out that videogames are efficient at motivating pupils and can simulate highly complex situations that would be difficult to access otherwise (Knibbe, et al., 2015). Consequently, many teachers include the use of high-tech devices, such as computers and tablets in their curriculum.

Along with these tools, several past works pointed the potential of Interactive Tabletops as they start to reach the general market (Kubicki, et al., 2015). Like board games, Interactive Tabletop games can benefit from direct tangible interaction (Kaltenbrunner, 2009). Furthermore the layout of the table itself facilitates collaborative applications (Scott, et al., 2003).However, since many countries adopted inclusive classroom policies (UNESCO, 2017) regarding disability, teachers also need to take into account accessibility requirements when proposing edutainment activity to their pupils.

When considering retail interactive tabletops as a mean to ease the integration of these requirements, we find out that most of them provide the same accessibility features as those embedded in traditional devices, such as magnification, text to speech, colour switch, contrast enhancing, etc. But all of these adaptations have been designed for personal and individual use. They often apply changes to the full interface and take inputs from only one user at a time. Therefore, they paradoxically have limited use in a multi-user mixed-experience environment, such as in classrooms.

Consequently, there is a need for new accessibility features and modalities specifically designed for Interactive Tabletops.

Also, previous studies show that teachers often feel unequipped to teach to disabled students, and sometimes feel they lack training on the topic of digital content accessibility. Especially, they often lack the technology skills to help their students use assistive technology and therefore access ICT lessons or educational technology tools (Smith & Kelly, 2014). Therefore, we decided to include teachers into the design process of accessibly features for Interactive Tabletop games.

Since there are many different kinds of disability, and different ways to cope with these issues, the needs regarding digital content accessibility on Interactive Tabletops are numerous. As most of the Interactive Tabletops only use their screen as their feedback interface, visual accessibility is an important matter for these devices. We have selected as a first step a visual accessibility tool to study tangible aids on tabletops by focusing on the zoom modality. This work benefits from a user centred approach to define the basic design. This tool takes into account not only the specific needs of intended users but also those required to collaborate around a shared interface, based on teachers' and special needs

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education specialists' inputs.

In the first part of this paper, we will discuss related work regarding ICT accessibility and Interactive Tabletops. After which we will describe the design method we used and its result. Then, we will present the tool itself and its implementation. Finally, we will discuss the results and the future steps of this study.

2 RELATED WORKS

2.1 Digital Content Accessibility

According to the World Health Organization (World Health Organization, 2012), about 246 millions of people around the world, among which 17.6 millions of children, have low vision. Vision impairments can be of a lot of different nature, ranging from refractive error to photophobia including tunnel vision and scotoma. Among 8% of the world population is also color deficient or color blind (Chan, et al., 2014).

Visual impaired people often have to face social inclusion challenges (Duquette and Baril, 2008) which may be increased by their difficulty to access digital content (Smith and Kelly, 2014) .

On smartphones or tablets, users are able to magnify content through application related features or the operating system accessibility tools (American Foundation for the Blind, 2017). These features are often gesture activated: e.g. “pinch to zoom” is a common gesture to magnify content in applications and Apple, Android and Microsoft all use multi-finger multi-taps on screen to activate or deactivate full-screen magnification. The operating system can also provide contrast enhancing or other visual improvements, Apple's one even allows their users to use a magnifying window instead of full screen magnification.

But the digital accessibility effort cannot be sustained by the operating system developers alone. Applications' content itself has to be made accessible by their developers, either because of the multimedia nature of the content (like videogames for example), or because of the need to follow certain rules of development to allow most accessibility tools to work properly (like websites). These last years, these matters gained more awareness from many different actors. Associations and organizations such as AbleGamers (AbleGamers Foundation, 2016) or the W3C (W3C, 2017) published accessibility guidelines aimed at digital content developers for computer games and online websites, and many actors of the digital content industry started to develop accessibility settings for their products (IGDA Game Access SIG, 2017). In addition to these settings, many third-party assistive technology exist such as text-to-speech software, lenses or braille terminals. Also, many start-ups and research teams work on new interfaces and devices to enhance digital accessibility such as braille tablets (BITLAB, 2017) or special controllers (Evil controllers, 2016).

The wide range of solutions and devices available reflects the different sight impairing disabilities and the different solutions disabled people might choose from. They are usually very specialized pieces of equipment.

2.2 Interactive Tabletops

Interactive Tabletops are relatively new on the market.

They can use different kind of technology. Some of them are only tactile and use the same capacitive sensing method found in tablets, smartphones and computer screens (Barrett and Omote, 2010). Others use optical sensing, and are able to sense both touch interaction and object interactions (Maxwell, 2007). There are also some tabletops which use resistive RFID sensing technology (Kubicki, et al., 2009) and are only able to sense objects.

The available literature shows the opportunities given by bringing together touch sensing technology, objects recognition and tracking on a large surface display. Also, many works emphasize on how Interactive Tabletops can sustain collaborative activities (Scott, et al., 2003) and on the affordability of tangible objects interaction (Tuddenham, et al., 2010).

However, due to their expensive price, their use is still mainly restricted to public areas such as museums, restaurants, and schools. Most of them do not benefit from a dedicated operating system and use the same OS as personal computers which have been designed for individual users and therefore cannot offer different accessible multi user experiences

2.3 Interactive Tabletops and Accessibility

Several research groups already worked on the topic of accessibility on Interactive Tabletops.

Ortea et al. (2011) designed and developed several frameworks dedicated to prototyping educational games for young children. Their research included different use cases, including the design of those games for children with cognitive impairments.

Kunz et al. (2014) worked on an inclusive brainstorming interface for Interactive Tabletops that would allow both sight impaired and not sight impaired users to collaborate.

Some other works also focused on other specific situations such as graph design tools (McGookin, et al., 2010), rehabilitation (Duckworth, et al., 2015) or map exploration (Ducasse, et al., 2015)(Brock, 2013).

2.4 Magnification and Interactive Tabletops

Although not specifically designed for accessibility purposes, many papers describe the use of magnification (or similar feature) tools on Interactive Tabletops.

These works mostly include data visualisation (Tominski, et al., 2014) and map exploration (Forlines and Shen, 2005) applications. Many of them (Tominski, et al., 2014) rely on the Magic Lenses concept, introduced by Bier et al (1993) a few years ago, which allow users to access different layers of representation of one same information. They use virtual (Forlines and Shen, 2005) representations of lenses or tangible ones such as transfer paper (Kim and Elmqvist, 2012), cardboard (Spindler, et al., 2010) or more or less transparent plastics (Büschel, et al., 2014).

2.5 Contribution

While there have been quite a number of works on interactive tabletops accessibility, most of them are focused on very specific applications and do not really aim to provide personalized accessibility features. This is also true for quite a part of the available literature on visual transformation lenses for interactive tabletops. Moreover, we are not aware of any work focusing on the use of this kind of visual transformation lenses for accessibility purposes on interactive tabletops.

We conducted some focus groups and interviews with inclusive or specialized school teachers and two brainstorming sessions with education accessibility and rehabilitation specialists. The results of these interviews and creativity sessions gave us a first insight of our users' needs and we would like to propose a tool which could be embedded in many different kinds of educative multimedia applications while also providing a more personalized accessibility feature to its users.

3 DESIGN METHOD

Because of healthcare and child safety and privacy regulations, visually impaired pupils are a difficult public to have access to. Literature review also shows that one of the most important factors in the lack of adoption of assistive technologies and use of ICT with disabled pupil is the feeling of lack of competencies of their teachers. Therefore, we decided to focus on teachers' insights first, in order to better understand what are their needs regarding accessibility of educational games. We also have access to previous data from interviews, conducted by our collaborators, of 19 teachers. Four of the interviewed teachers answered being working in lambda schools. Two others reported being working with hospitalized children. And the other recruited answered teachers being working either in inclusive or specialized classrooms and had pupils in their class who were either sight impaired of hearing impaired or had cognitive disabilities.

While the interviews did not focus on accessibility issues, some teachers still expressed some of the difficulties they encounter while working with inclusive classes. Some of the concerns expressed include: the need for an adaptation of the study material to each student's specific situation, the lack of available accessible digital resources *"There are plenty [educative video games] I don't use [...] they are not made for sight impaired pupils"*, the cost in time of the preparation of ICT.

This data helped us design our own user study, and we conducted three focus groups on accessibility on interactive tabletops in serious games. These focus groups and their results are described in the following subsections.

3.1 Focus Groups

Half of the teachers previously interviewed were recruited for three new focus groups. All of them worked either in specialized or inclusive classroom or with hospitalized children. In order to make those groups a little bit bigger and to get a better group dynamic, two disabilities and teaching experts and one serious game experts were invited to join the process.

After a short technical demonstration of an interactive tabletop working with tangible objects, they were encouraged to discuss the use they would make of Interactive Tabletops as a game installation in their classrooms.

During these discussions, they talked about the different kind of games they would like to use, proposing simple applications (e.g. quiz, timeline-based games, maze exploration, collaborative story creation) as well as more complex ones (e.g. treasure hunt, construction game, virtual world with many different quests).

They also specifically evoked the software features they would like to be able to propose to their pupils to make their digital learning activities accessible on interactive tabletops. Ideas that were mentioned included functionalities such as sign language subtitling, sound producing objects, brightness and contrast tuning, or the possibility to magnify specific areas of the tabletop.

Furthermore, they underlined that given the fact that each child is different and has different needs regarding their impairment situation, the teachers need to be able to adapt the content of their applications to each individual situation.

They expressed the desire that their pupils be able to explore the content displayed on the interactive tabletop surface both collaboratively and individually.

They also emphasized that the tangible objects proposed would *"need to be steady"* (a teacher) because pupils are not always cautious with their tools.

3.2 Creativity Sessions

After the focus groups, we conducted two creativity sessions with 6 special education specialists based on the results of the previous interviews.

3.2.1 First Creativity Session

For the first brainstorming, we presented the teachers a simple demonstration with a virtual magnifying window as a way to fuel the discussions. This magnifying window enabled enlarging the underlying

Figure 1: Magnification demonstration.

content simply by moving it to different locations on the screen using a tangible pointer. (See Figure 1).

During this first session, several interaction modalities were discussed, such as tangible object manipulation, touch gestures, split screen use or virtual objects manipulation. All participants also evoked the importance of the need for more accessibility features than only the magnifying one (as did the teachers in the preliminary studies) and the need for personalized tools.

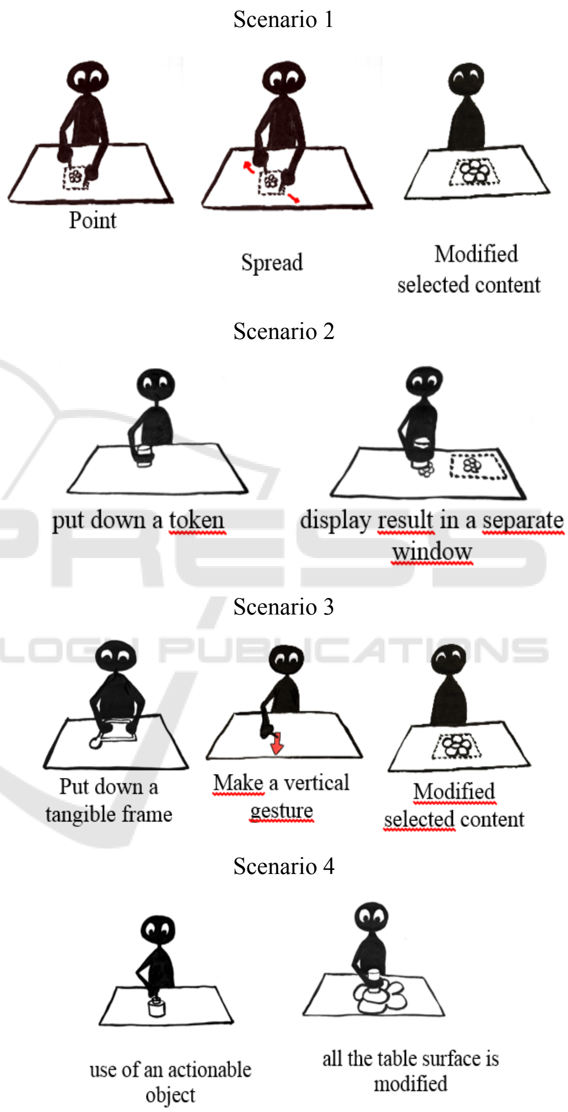

Figure 2: Demonstration Scenarios, one scenario per row, from top to bottom:
Scenario 1: Common pinch to zoom gesture
Scenario 2: point with a token and display adapted content on the side
Scenario 3: Put down a tangible on the table and make a gesture to activate adaptation of content
Scenario 4: Use a button to switch on content adaptation.

From this first session, we extracted several interactions modalities (based on both touch and tangible interactions) that we gathered into a first interaction modality dictionary. Second creativity session

During the second creativity session, we illustrated four magnifying action scenarios, after the propositions made during that first brainstorming session (see Figure 2) and presented them to the same panel for the second brainstorming session. This gave the experts to brainstorm based on existing ideas rather than from scratch in order to help spark ideas. For instance, they could simply discard solutions by crossing them (e.g. only touch based interactions) and make some new recommendations.

Specifically, the use of a tangible frame as a zone of interest pointer seemed to reach consensus.

These exchanges also emphasized the need for a fine step decomposition of interaction scenarios as they expressed difficulties to detail the exact steps needed to perform the scenario.

3.3 Intermediary Results

3.3.1 Recommendations

Those discussions lead up to the redaction of a first list of recommendations for the design of a tangible visual accessibility tool for interactive tabletops.

The tangible object has to be non-obstructive, in order to make collaboration around the table easier, while still being visible for a sight impaired person, which means it has to be preferably be large with bright colors. The same constraints apply to the limits of the window that displays the adapted content. These limits can be represented either as a tangible frame or a virtual one.

Also, following insights from the brainstorming, displaying the adapted content on a fixed and separate window (see 3rd line in Figure 2) should be avoided since it can lead to more cognitive load and be confusing in a multiuser settings.

In order to facilitate the use of such an object without monopolizing either both hands of the user or their attention, the object should consist of one single piece of hardware.

Finally, so that users could move freely around the table and share their work more easily, they should be allowed to change the orientation of the part of the screen they are visualizing.

3.3.2 Magnifying Step Decomposition

During the brainstorming sessions, we identified the need for a decomposition of the "accessing accessible content" action into five more specific sub-actions.

We defined five of them:

- "point": select the item or zone of interest on the surface
- "display": apply accessibility settings on the zone of interest of the surface and render the transformed output
- "change the display": change the transformation settings of the zone of interest
- "share": make the zone of interest visualized visible for other users
- "back to normal state": remove any accessibility transformation applied in order to bring back the zone of interest to its first state.

In a scenario, the sub-action "change the display" and "share" are optional in the sense that it is possible to purposely have a scenario that does not make these options available (for example in the case of usage by students with cognitive disabilities who could be disabled by this kind of features).

4 FINAL CONCEPT

Figure 3: The content inside of the frame is directly adapted.

While the interviewees proposed diverse solutions (split-screen, taking turns on being the main user of the screen, making the tap gesture a magnifying interaction by default…), the one that reached the best acceptance was about using a tangible frame. It answered most of their recommendations. If is flat thus not obtrusive. Its tangible borders make it a good way to separate the adapted content (inside of the frame) from the original one (outside of the frame). It also allows for direct and clear interaction with the tabletop, since the adapted content is linked with the frame position.

We used the five steps decomposition and the inputs we got from the interviewees and the preliminary study to expand on this idea and propose the following scenario:

- Point: the pupil places a tangible frame around the point of interest he wants to magnify. The frame being almost flat, the other users can still see what is around and inside the frame.
- Display: the picture contained into the frame is magnified automatically. This allows the picture to be displayed in its direct context; just the same way it would when the user uses an analog lens.
- Change the display: the student can change the magnifying level using a virtual cursor embedded on the side of the frame.
- Share: the pupil can rotate its frame to rotate the view and make its content more understandable by the other students who are not standing from the same side of the table.
- Back to normal state: when the student removes the frame, the magnified picture goes back to its original aspect with its normal orientation. All the modifications of the magnifying frame settings the pupil made by manipulating the cursor will be saved by the cursor position and reused.

5 IMPLEMENTATION

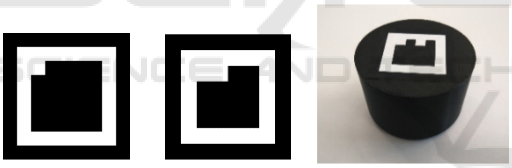

Figure 4: Fiducial markers and tangible object.

The Interactive Tabletop we use for our work is a Multitaction optical table. It uses infrared sensitive video-cameras to perform touch and object detection. Object recognition is achieved through the use of squared black and white tags pasted on the bottom of the objects (see Figure 4) which are in direct contact with the tabletop's surface. The position of such objects and fingers is then transmitted to the tabletop's software applications thanks to a communication protocol named TUIO (Kaltenbrunner, 2009).

5.1 Tangible Object

The frame was designed to answer the needs expressed by the teachers and the experts. It has been 3D printed in order to be bold and sturdy, while still being light. It was painted in red to make it more

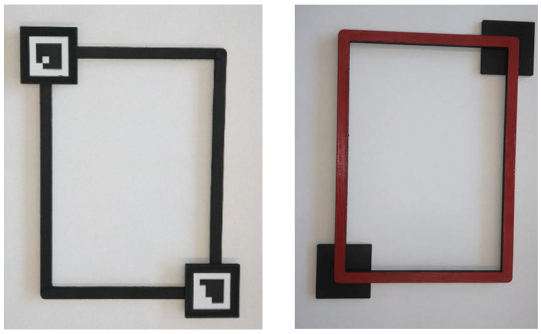

Figure 5: Tangible frame, bottom and top.

visible on the tabletop surface.

The frame is detected by the interactive tabletop using two paper made fiducial markers placed at the back of the frame on two opposite corners (see Figure 5). This allows the software to track not only the position of the frame, but also its size and its orientation, and hence allows the use of any size of frames.

While we made this frame with a 3D printer, it could easily be built with cheaper materials such as cardboard or papier-mâché while still meeting the user needs evoked in the previous part of this article.

5.2 Software

To stick with the idea of providing such an accessibility tool for different kinds of educative games, we used Unity3D (Unity Technologies, 2017) to develop our demonstration. Unity is a broadly used game engine which allows many kind of realisations such as interactive demonstrations, commercial video games or educative games.

Figure 6: Tangible frame in application.

We developed a picture exploration application featuring the frame and coded the frame interactions to be as close as possible as to the scenario proposed during the creativity sessions.

Using the TUIO data transmitted by the interactive tabletop internal software, we can track the positions of the two tags which are placed under the frame and compute the size, position and orientation of a virtual window which might fit inside the frame. Thanks to the frame using two tags and not just one, we are also able to provide a more robust tracking of its position. It allows us to handle more situations, for instance those when the frame is only partially on the tabletop, since it is likely that at least one of the two tags embedded below the frame will be on the surface. This also allows us to use the frame on the edges of the tabletop.

In this window, we display a replica of the content contained within the frame. We apply all the visual modifications required by the frame owner to this replica.

These modifications can include contrast enhancing, contour colouring, background hiding, colour shading, brightness tuning or magnification and are processed by the interactive tabletop graphical processing unit. The combination of all those modifications can be made through code or using a visual interface and is stored into a user profile. This profile is attached to a unique frame, each frame having its own unique set of fiducial markers.

The application can track and provide accessibility content to any possible number of frames within the space of the table, allowing multiple users to explore the picture simultaneously.

6 CONCLUSION AND FUTURE WORK

We co-designed and proposed tangible accessibility tools specifically aimed to respond to interactive tabletops shared interface specificities. The interviews and creativity sessions allowed us to identify several key features (weight, non-obstruction, embodiment into a single device, bright colored…) for the design of such kind of objects. The implementation of the solution allows us to easily include this tool into our game development process.

Since accessing young disabled population is difficult, more specifically in a classroom setting, we conducted all our preliminary studies and interviews with professionals of the accessibility field and teachers. As a next step, in order to validate our proposition and improve it, we plan to conduct a user study directly with the end users we target, i.e. students of different ages, both visually and sighted, in a classroom setting.

This will allow us to gather direct user feedback on our proposition and apply an iterative design methodology on our system.

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