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Designing a learning environment for visually impaired and blind persons in order to develop touch access to digital content

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ABSTRACT

Through screen-reader and Braille display, trained blind persons can nowadays manage to access to a lot of activities using computers. However, graphical interfaces and content where the spatial dimension is essential for understanding, like charts, pictures or the majority of videogames, are remaining hardly accessible. The Tactos and Intertact.net technologies are aimed to overcome these limits by providing an efficient sensory supplementation technology enabling blind users to access the spatial dimension of content through touch. Following a participatory design approach, we have worked in cooperation with blind persons to develop a learning environment for touch access to digital content with Tactos. Adoption is important when it comes to develop technologies and we report here on the research we conduct for enabling an independent learning of our system by blind persons. From our perspective, this possibility is a cornerstone for the development of a users' community.

1. INTRODUCTION

Screen reader technologies and electronic Braille cells are now providing access to many digital activities and information sources for the blind and visually impaired persons. However, these solutions have the drawback of hardly conveying spatial information like data charts and tables, drawings, graphical interfaces and web pages layouts. As more and more digital world software applications are now enabling to work and play through the Internet, for instance productivity and office software on the cloud, or multiplayer games, the accessibility of these rich applications requests for interface technologies enabling to build shared interactive spaces for all.

With the widespread of ICT non visual access to digital content for blind persons has grown tremendously, especially through screen reading software. However the experience of graphical content and its accessibility remains a problem. Several research projects have now developed innovative interface mixing tactile and sound to offer innovative ways to access the spatial organization of content [1-4]. Gathering off the shelf component and low cost tactile stimulation solutions, they overcome the accessibility limits of typical consumer electronic systems like tablet, smartphone or laptops. Such projects have the potential to change the way blind persons experience digital content compared to the linear reduction imposed by screen reading and commercially available Braille displays.

However there is a need for blind persons to develop a practice of such technologies in order to make sense of the experience of graphical content they allow in their daily life. As shown by the example of projects like TheVoice [5] or the Non Visual Desktop Access project (NVDA) [6], the wide adoption of accessibility technologies is no more bounded to the sole network of institutions or industry. To this purpose there is a need to ease the access to such technologies outside research labs and to accompany the development of community of practices [7] is important to sustain the development of new ways of accessing graphical content for the visually impaired and blind persons.

In this paper we report on the efforts we have conducted to provide tools and support the development of a community around the use of the Tactos and Intertact.net systems. After having presented the non-visual access to graphical content interfaces at stake, we detail the approach we have followed and the tools we have developed in order to gather a community around Tactos and Intertact.net in the context of a blind and visually impaired persons' local association (APICADEV). In particular, the development of learning material and enabling the possibility for blind persons to share their experience of graphical content and to teach each other independently the use of the system appears as essential. We discuss and conclude with the next steps and implications of our approach for the development of a learning environment to develop touch access to digital content.

2. MATERIAL AND METHODS

In what follows we present current research projects partly based on off the shelf device (like tablet, smartphone or laptops with integrated screen reader software) which bring the potential to broaden the access to digital content for visually impaired and blind persons. We focus especially on the Tactos and Intertact.net systems for which we have defined and implemented an approach for designing a

learning environment intended to foster the development of a users' community.

2.1 Research on touch access to digital content

Several research projects have developed interface mixing tactile and sound stimulation in order to provide a non-visual access to spatial and graphical content. By supplementing tablet, smartphones or laptop with tactile stimulation solutions as vibrators, raised paper or electronic Braille cells, these systems have a great potential to improve the experience of digital content for the visually impaired or blind persons. Indeed, compared to screen readers or commercially available Braille displays, these system allows a two dimensional exploration of content and do not constrain their user in a linear flow of information.

Brock et al. [1] have designed and implemented a system enabling blind persons to read and interact with maps by using a tablet covered with tactile paper. Double tapping on an area on the map triggers speech description and information feedback. Through this system, the users succeed in making sense of complex graphical content in order to for instance prepare a journey.

Simonnet et al. [3] propose a different approach using the audio and vibratory feedback allowed by the tablet itself in order to design an environment where blind users can explore maps. The project allows for multitouch exploration of content and trials show that users are able to remember the relation between point of interest they identified during their exploration.

Safi et al. [2] have developed a vibrotactile system which enables spatial exploration of content through smartphone. With the use of proper content segmentation algorithm, the system allows the users to figure out the layout of web pages and so having an understanding of the spatial organization of the content.

Each of these systems gives rise to a specific experience of digital content to their end-users. However this experience can only become useful in visually impaired and blind persons daily life if they are able to share it and discuss its meaning with their peers and relatives. Thus we think as much important to think about how to provide a learning environment with tools supporting the development of a users' community. For this purpose, we have developed an approach on the framework of the Tactos and Intertact.net systems.

2.2 The Tactos and intertact systems

We have developed the "Tactos" and the "Intertact" system, which allows the exploration of the computer screen and interaction through the Internet [8]. Tactos is a compound of a touch interaction module and the associated driver software. Intertact.net is a web server that distributes interactive and multiuser applications through the Internet to Tactos users.

The user's finger movements on a touchscreen are controlling the position of a receptor field in the digital environment. When the receptor field crosses the colored pixels of a shape on the screen, a tactile stimulation is triggered. This stimulation is produced by the activation of a pair of electronic Braille cells consisting of a matrix of 16 pins (two piezoelectric cells of 8 pins) that the user touch with the index finger of her/his free hand [8].

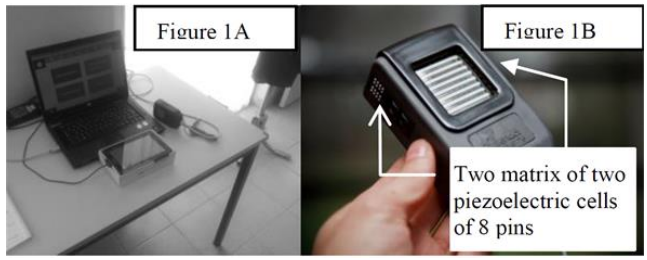

Figure 1. A: The Tactos system. Here, for a left-handed person, the tactile interaction module is to the right of the touch pad. B: The Tactile Interaction Module with matrix of two Braille cells

Thus the users can perceive the shapes and the layout of objects on the screen through the attention they pay to the tactile stimulation and the movements of their fingers on the screen as well. The mastery of this device requires a systematic learning that we have already presented [9]. Straight lines and basic geometrical shapes, like squares or triangles, are recognizable in few hours of training. With the user engagement in learning, more complex content like maps or webpages layout become meaningful.

The evaluation of these devices was conducted jointly by experimental studies on pattern recognition [10], interpersonal interactions [11-12] and the longitudinal tracking of several young users [13]. The interest of the Tactos system as a support for teaching geometry to young blind students from a special education school has also been demonstrated [14]. One of the key features provided by Tactos lie in the ability for students to check the results of the spatial operations they perform (ie. tracing a circle tangent) without the assistance of a sighted person.

As we mentioned earlier, the current widespread of Information and Communication Technologies (ICT) lead us to consider the use and relevance of Tactos in broader application fields in order to support blind persons in their daily life. We have especially identified the access to information (layout of objects and windows on the desk), discovery the spatial organization of information (as the layout of a web page, direct access to input fields), maps reading for wayfinding and social interaction as areas of special concern [15]. Adoption is important when it comes to develop technologies and we describe the research we conduct for enabling an independent learning of our systems by the blind and visually impaired persons.

2.3 An approach for designing a learning environment

The need for a learning environment as a way to develop a Tactos users' community has been identified as essential on the framework of the ITOIP (Tactile Interaction for Information, Orientation and Presence) research project. We followed a participatory approach [16-17] for the improvement and adaptation of the Tactos and Intertact.net system to the context of the blind persons we met in a local association (APICADEV). The project has especially focused on the need for accessing digital content, wayfinding and online social interactions.

Along the 18 months of the project, we have worked in tight cooperation with four blind persons who have participated in developing the Tactos and Intertact.net systems: Laura, Elizabeth, Cedric and Marie.

Two APICADEV members, Laura and Elizabeth were especially involved in our research project (the names have been changed for anonymity purpose). They discovered Tactos with the research project. They have taken part to all the phase of the participatory workshops. Laura has been blind since she was in her teenage, while Elizabeth progressively lost her sight. They are practicing regularly travelled routes, such as the route from their respective homes to the APICADEV headquarters. Laura is using a white cane whereas Elizabeth is accompanied by a trained guide dog. Cedric is a Tactos expert who learned the system at school on the occasion of a former research project [14]. He joined 5 times the participatory workshop after nine months the project was running and we were working on the system deployment in the field. As he lived at more than 150 km from the research lab, he has been able to be present three times at our office but at the end of the refinement phase the Tactos and Intertact.net system where sufficiently robust to allow at a distance participation over the Internet with the use of a teleconferencing system in parallel. Marie was an APICADEV member who have joined us 4 times as she heard about the project from Laura and wanted to learn the system.

All of them have access and use the Internet with a screen reader software. Laura and Cedric have a good knowledge of the Braille writing system and use it on a daily basis. Elizabeth was less familiar with the Braille and prefers audio content reading. Marie was not Braille literate as her sight no more allows her to read printed characters since one year at the time of the project.

Through the deployment of a participatory design approach the stake is to develop content and application which usable and relevant for end users. To this extent methodological adaptations are needed for engaging blind persons in a participatory design approach [18-20].

End users participation is also an opportunity to invite the participant to act as door opener and invite other persons to try and use the system. This appears as an efficient way to progressively build a users' community. Thus providing tools for end-users to share with peers their experience of accessing digital content through touch, and to help them to teach and spread this practice is what we are developing with the ITOIP project.

3. RESULTS

We present the implementation and the results of the participatory workshops we have conducted and the two tools we developed on this occasion with the aim to enable blind persons to learn and develop a practice of Tactos: an interactive tutorial and a cooperative tutoring setup.

3.1 Tactos workshops

The room where our Tactos participatory workshops took place is four persons open space with a big central table for prototype tests. Each design session took on average 3 hours. It usually starts by the agenda of the afternoon as the lead designer presents the new application prototypes or their latest updates to the blind persons who took part to the workshop.

These workshops were intended on one hand to collect feedback and open the design to end-users, on the other hand they were seen as a way to initiate a community around the practice of using Tactos to explore graphical content. These participatory design workshops were organized in three phases during the project:

- Discovery: The first six months, the blind persons were invited to come twice a week in order to learn the Tactos system and take part to the design of digital content prototypes. At the end of this period the more promising content were selected with the participants in order to improve them. The content selected was concerned with three types of application: interactive geographical map, graphical drawings exploration and games.
- Refinement: The next six month were dedicated to the iterative development of the selected applications. We met with end users once in two weeks over the period to refine the applications.
- Deployment: The last period was dedicated to export the use of Tactos and Intertact.net outside the University to the APICADEV office.

One or two applications were tried out during each session. The users with the help of the lead designer explore each application. The participants are let free to explore the prototype on their own at first. Then they are invited to report on their difficulties and experience with the application. During these discussions they mention encountered usability problems and express their opinion about the usefulness and the relevance of the proposed functions for their daily life. At the end of the session, the lead designer writes a synthetic note. These notes record a set of improvements to be implemented for the next design sessions as well as the ideas for new applications discussed with users and the team. This assisted adaptation process helps us from week to week to adjust applications' usability and functions. It also allows us to grasp their usefulness from the users' point of view.

3.2 Interactive tutorial

The experience of graphical content with Tactos involves giving meaning to the shapes explored through the tactile interface by the subjects.

Most of the available content is concerned with 2 dimensional shapes however the background of blind persons in basic drawings is very limited. For instance a triangle sat on the top of square did not evoke at all a house to the blind persons who have worked with us. Later, with the use of Tactos one of their interests was on making meaning of complex drawing from their exploration with Tactos. For instance, a complex content is to develop an idea of the shape of an airplane by locating the wings and the cockpit. To this purpose the adjunct of speech synthesis with active area triggering the name of the part currently explored is especially useful.

Thus in order to define an adapted tutorial our participants has made several suggestions:

- Horizontal and vertical lines are easy to recognize with Tactos and should be the two first steps of the interactive tutorial.
- Making sense of the explored graphical content is essential for the user to find an interest in Tactos, even if complex shape takes time to master. The blind persons who took part to our workshops have chosen capital letters as the main content for the tutorial. They explain their choice because of Latin alphabet letters are shapes most of the blind persons already learned or know

basically, for instance in order to sign document themselves.

- The letters have been ordered according to the difficulty they present through Tactos: number of segments and line orientation. From the feedback of the participants, we ordered the tutorial content the following way: L, T, F, E, N, Z, V, X.
- The importance of providing a guidance system to Tactos newcomers in order to help them to find the shape to explore on the screen. Speech synthesis was chosen for this purpose so it does not interfere with tactile sensation. The voice guide the user by telling her or him whether the shape is on her/his left or right, and also nearer or farther from her/him. The last point is interesting as the idea of top and bottom of the capacitive screen was judged as not intuitive at all by our participants.

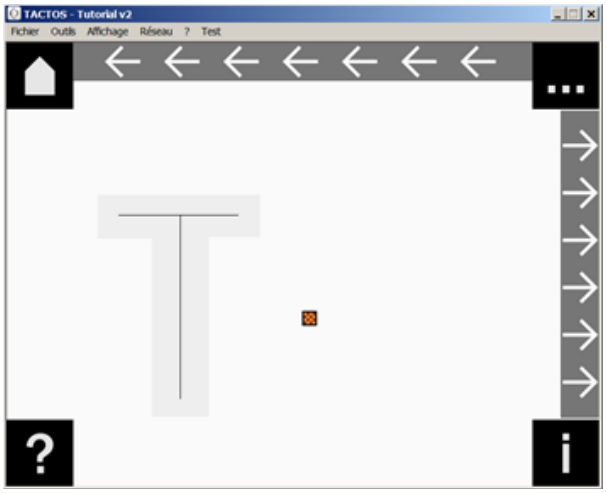

Figure 2. A screenshot from the interactive tutorial on the exploration of the letter "T"

The interactive tutorial was then deployed as a room available from the landing screen on Intertact.net. The application was used on the Tactos workstation installed at the APICADEV.

3.3 Cooperative tutoring between blind persons

In order to enable a blind person to teach the use of Tactos and Intertact.net to another blind person, we achieved a specific device that we present in this section.

The teacher supports the learner in her/his exploration of the screen while receiving the same tactile signals. Indeed, the touch interaction module used includes two tactile arrays, one for the learner and the other for the teacher in the current situation.

The teacher places his hand underneath the module on the first tactile array and the learner places his hand on top of the module on the second tactile array. The two tactile arrays trigger exactly the same signals. The learner explores the image on the screen while listening to the advice of the teacher who receives exactly the same tactile information than him. This way they feel they "touch" the same thing at the same time. A situation which overcomes physical constraints since two persons can never touch simultaneously the same point.

Figure 3. Learning session: while a blind learner (in pink) explores virtual forms, she can be guided by her blind teacher (in white) that shares the same tactile signals

The first uses of this device are particularly encouraging. Two new Tactos users have so far followed a series of more than 4 sessions on the occasion of the deployment phase. Their already enthusiastic feedback and their requests for improvements show the benefits of this cooperative tutoring system in order to teach the use of Tactos and trigger interest for the system. The current session were using mostly the interactive tutorial and simple shapes. The next step is to use this setup in order to teach the use of several existing Intertact.net application using complex shapes and layout, especially a multiplayer online game (Battelship) and Tactos Map [4].

4. CONCLUSION

Many support systems turn out to be invalidating if they increase the awareness of disability by making the user dependent on learning from a non-disabled person. The situation of an independent learning of our tools in the community of blind people seems to us crucial. In this paper, we have presented the approach we developed in order to design a learning environment for touch access to digital content. By organizing participatory workshops with blind persons and developing tools to support independent learning of our technology, an interactive tutorial and a cooperative tutoring setup, we enable our participant to spread their practice of Tactos with peers.

On one hand, it signifies the maturity of an aid project that does not have the former drawbacks. On the other hand, we are confident that this learning process will allow the development of users' communities that can then autonomously improve the system.

A perspective for future work could be to support the distribution and making of a more important number of tactile interaction module MIT. This would be essential to develop a bigger Tactos and Intertact.net users group. Leaving apart the cost of the research associated with their design, the expense for buying the electronic component of these systems opens the possibility for these systems to be reproduced on the framework of local association or with the help of technology literate people. The current DIY and maker movement [21-22] show such development is today realistic. To this extent the question of sharing the design documents and associated software with the public, for instance through Open source hardware [23] and software [24], is an entire project in itself.

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