Blind Sight Navigator: A New Orthosis for People with Visual Impairments

Amélie Boudreault, Bruno Bouchard, Sébastien Gaboury and Julie Bouchard
CRIAAC
University of Quebec in Chicoutimi (UQAC)
Chicoutimi, G7H 2B1, Canada
1-418-545-5011
{amelie. boudreault, bruno_bouchard, s1gabour, julie1_bouchard} @uqac.ca

ABSTRACT
People with visual impairments face challenges daily when venturing in unfamiliar environments without assistance. In this paper, we introduce a new technological orthosis, the Blind Sight Navigator (BSN), for blind people or those whose sight is deteriorating due to a medical condition, which is a new advance in the fields of assistive technology and computer science, aim to promote autonomy and to enhance the quality of life of people who suffer visual impairments. Our prototype was created in order to propose a new alternative that is non-invasive and offers potential applications to virtual reality. This article explains its functioning and how it can help people with visual impairments. Also, we present the preliminary results of an experimental phase that was conducted to assess the reliability of our prototype.

Categories and Subject Descriptors
• K.4.2 [Computers and Society]: Social Issues-Assistive technologies for persons with disabilities

General Terms
Algorithms, Reliability, Experimentation

Keywords
Visual orthosis; deep sensor; vibro-tactile interface; blind; visual impairment; assistive technology;

1. INTRODUCTION
Around 285 millions of people worldwide suffer from blindness or other visual impairments. Visual loss is the most serious sensory disability and can have a major impact on individuals' life. It should come as no surprise, then, that 48% of visually impaired have reported to feel cut off from people, or of their environment "moderately" or "completely" [1]. Existing devices designed to help people with disabilities are, most of the time, visually demanding, making them impossible to use for people with visual loss, unless they have help from a visually sighted person, which is not always the case. Therefore, researchers from different areas have created and proposed various assistive systems in order to help those individuals in having better interaction with their surroundings and thus, decreasing their impression of being cut off from the outside world. Incidentally, the literature refers to assistive technology (AT) as any piece of equipment that allows a person with a disability to enjoy full inclusion or social integration [2]. Since AT devices are becoming more discrete, their use is a great benefit for people with disabilities, including visually impaired, because they do not carry the same stigma like more conventional aids do [1].

PETRA'16, June 29–July 1, 2016, Corfu Island, Greece.

DOI: http://dx.doi.org/10.1145/2910674.2910709

2. BACKGROUND
Over the last years, new assistive systems (GPS, mobile phones) have attempted to replace the white cane which is the most used tool to this day among the visually impaired. By doing so, researchers aim to offer blind people more freedom in their displacements. However, it turns out that most GPS-based systems cannot detect important obstacles in real-time, such as crosswalks, thus making the white cane still the best way to navigate freely and in complete safety. Because of it, the white cane is considered as the standard tool for the blind who appreciate its simplicity [3]. However, when venturing outside, an important limitation of the white cane is that it cannot allow the individual to have an internal representation of the surroundings in unfamiliar environments (like a mall or an overcrowded airport terminal) because of the a very limited sensing scope it procures [4]. Thus, it is fair to say that navigation and wayfinding is still a major challenge for those with visual impairments and that the help offered from passers-by is frequently needed. This situation can cause anxiety and embarrassment, and can even prevent blind people from going to less familiar places [5]. Visually impaired are known to have good spatial orientation and memory, which enables them to navigate independently when in a familiar environment [6].

The Blind Sight Navigator (BSN) (see Figure 1) is a technological solution allowing visually impaired people to navigate freely without having to rely on a white cane, a guide dog, or a sighted person. Moreover, the BSN is one of the few assistive systems offering guidance to people in their displacements. Actually, most existing assistive systems for visually impaired are helpful in reading a newspaper or surfing on the Internet. The existing technologies in this field are usually created and designed to replace the visual faculty, just like the artificial visual system. However, the BSN offers a new possibility by being based on the faculty of touch. Given that people with visual impairments regularly develop a greater acuity with the others senses, this proposition is promising. To project a vibratory screen of the field of view in real time is a new approach that differs from other standard physical guidance. Moreover, contrary to the white cane and the guide dog, the BSN is a hands-free device. By using the white cane, blind people are forced to limit the use of one of their hands. While they are wearing the BSN, they can also use both hands in other tasks and so they are less restricted in their movements.

Figure 1. Blind Sight Navigator prototype

3. SYSTEM OVERVIEW

The current version of the system consists of a cycling helmet livened up with a Microsoft Kinect sensor, a laptop embedded in a backpack, an extern battery of 5V and a vibro-tactile interface with an adjustable support. The total weight of this equipment is around 20 kilograms. The prototype analyses data collected from a depth-finding camera (the Kinect sensor). The latter is connected to a vibro-tactile interface, which the user wears as shown on Figure 1, that allows a mapping of his field of view. The depth-finding camera relays what is in the user's field of view to a computer screen (see Figure 2) where the image shown is divided in 8 X 8 small squares, each of 20mm.

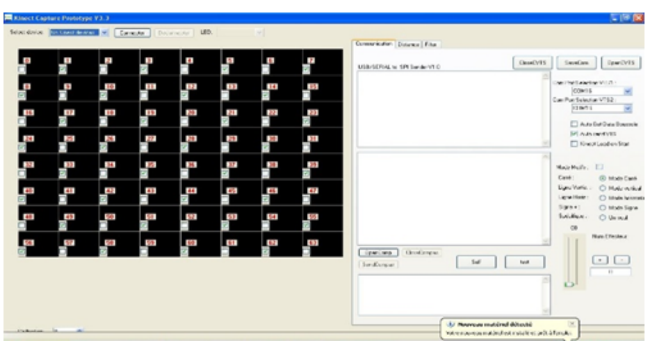

Figure 2. BSN main interface

Once the depth image is extracted and cut in equal zones, the signal is processed through an artificial intelligence algorithm and sent back to the vibro-tactile interface, as shown on Figure 3.

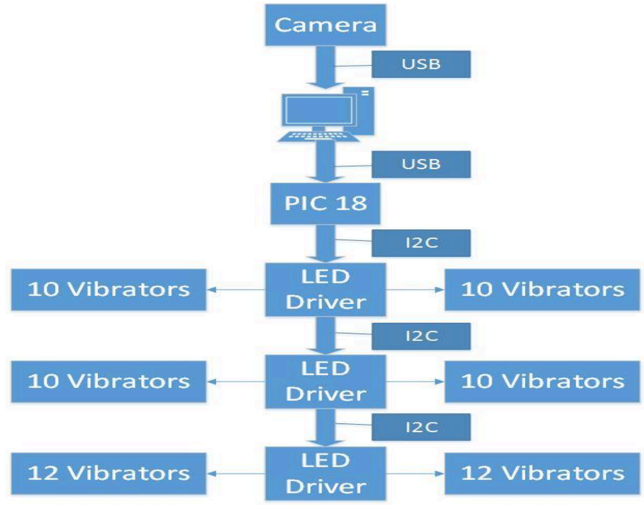

Figure 3. Blind Sight functional schema block

When the blind person walks into a room and comes across a chair, for example, it creates vibrations on his back indicating that an object or a person stands in the way. This vibratory information is processed by the Pacinian corpuscles, small skin cells located under the skin into the dermis and reacting to frequencies ranging from 30 to 1500 Hz [7]. Thus, the person can count on a vibratory representation (through the vibro-tactile interface) that recreates any obstacle detected in his field of view through the camera. For example, a chair that would be in the right corner of a room, to the opposite from where the person stands, would be represented by vibrations on the upper right corner of the vibro-tactile interface. However, if that same chair is close to the user, but still on the right, then vibrations would be perceived on the lower right corner of our interface.

The BSN is a non-invasive technology that does not necessitate optic nerve surgery, and its vibrations can compare to those produced by a mobile phone, thus preventing from any risk of injuries. Users wear the orthosis like any other piece of clothing.

4. USER EVALUATION

4.1 Study design

Goal: The goal of the study was to determine the reliability of the BSN and assess if it can actually enable individuals with visual impairments to navigate by themselves without assistance. To do so, we performed a comparative study using the white cane but with a group of sighted people for the first experimentation of the tools.

Experimental setup: The assessment was performed indoors at the University of Quebec in Chicoutimi (UQAC), in a classroom where an obstacle course had been set (see Figure 3). The latter was made of chairs, a desk, a shelf, a wheelchair and an examination bed. The room's floor was tiled which allowed a smooth and even walking surface, with no bumps. This experiment was conducted as part of a patent registration process.

Participants: The sample size for the evaluation consisted of 13 participants, 6 men and 7 women (*n=13*). All were sighted people, who volunteered to try the prototype. No specific criteria were determined other than being either a student or a staff member at the UQAC. Prior to the evaluation, the project had been approved by the ethical committee who delivered the certification, and all participants signed informed consent forms.

4.2 Methodology

The participants were only asked for one visit, lasting no more than 30 minutes, where they completed the obstacle course once with the BSN and once with a white cane. The order in which each device was used by a participant was balanced among the participants to avoid practice effect, and the time they took to finalize both trials was measured.

User training: Each participant was blindfolded prior to the test and briefed in order to familiarize with the prototype. Then, a research assistant standing in front of the participant held a pole on which a beach ball was attached. He asked the participant to try to catch it by relying on the internal representation provided by the vibratory information perceived on his back, through the interface. This important pre-trial step allowed each participant to figure out how the system worked.

Device testing: Once the briefing was complete, half of the participants were asked to start the experimentation with the BSN. The other half of them was asked to enter the obstacle course with the white cane. This division among the participants permitted to balance the execution, so there was no possibility of bias about the practice effect. The time was not taken into account thus each person was free to take the required time to complete both trials. Finally, when both trials were completed, the participant was asked to fill a questionnaire on his experience with the prototype and suggest eventual improvements using the comments section.

Figure 3. The obstacle course

5. RESULTS AND DISCUSSION

The experimentation phase provides results that can be statically analyzed and compared. The goal of this experimentation was to evaluate the reliability of the BSN and assess if it can assist people with visual impairments to navigate by themselves without assistance. During the part of the "user training", which was based on movement anticipation with the beach ball, the majority (61,5%) of the subjects confirmed that they felt in security while trying the BSN. Even if the participants were able to complete the second part of the experimentation, named the "device testing" part, faster with the cane ($t= -3,099$; $p <0,05$), all of them (100%) reported feeling confident when wearing the BSN prototype in the circuit. In support to this, one of the participant affirmed that "*this concept is interesting*" and that he "*felt comfortable and in security*" throughout the experimental phase.

The collected data showed no difference in performances according to the gender of participants. Moreover, it was a good opportunity to receive feedback on more qualitative aspects, such as the weight of the BSN and the intensity of the perceived vibrations. Among the comments collected, one participant noted that *"vibrations detecting the floor ought to be reduced in order to improve the contrast with those that detect objects"*. That is a very good point, considering that there will always be a surface to walk on, whether it is a floor, a street or a sidewalk to name a few, that will be detected. Thus, the prototype should be calibrated more precisely so that a walking surface does not generate constant vibrations and is not mistaken with an actual obstacle, such as a bench for example. Another participant insisted on the fact that *"there should be another interface elsewhere on the body […], perhaps at feet level, because the haptic feedback is not strong enough"*. This comment suggests that the user found he was missing important information regarding the circuit and what could be expected in the obstacle course, hinting that more sensors should be added in a future version.

Furthermore, the positioning of the camera turned out to be a bias to some participants when completing the circuit. Indeed, the fact that the camera was situated in front of the helmet prevented them to detect all the obstacles on their way. All the participants who were taller than 1,72 meters completed the circuit more slowly than those who were smaller. The observed difference can be explained by the fact that their field of view was restricted due to the high positioning of the camera. For example, in the qualitative survey, a participant claimed to have experienced some difficulties because of that. He suggested to move down the camera's position to the waistline. Therefore, a readjustment of the camera would allow taller individuals an optimal use of the BSN. More precisely, moving down the camera in the middle of the body could accommodate those who felt embarrassed by this technical problem. In sum, the research team was satisfied with the experiment and its results since all users successfully completed the obstacle course using the BSN. This indicates that using the device will undeniably benefit to people with visual impairments.

Moreover, because recruiting individuals who are considered vulnerable due to a specific medical condition, including blind people, may be hard to achieve in a short lapse of time, it was more realistic and easier for the research team to complete the present study with people who don't have any problems with their sight. Hence, the idea of doing the experimentation phase quickly was an opportunity to have feedbacks, but since ethics standards still had to be respected we believed that it would be easier to try the prototype the first time around with full sighted individuals, leaving an assessment with visually impaired for an ulterior phase. On the other hand, opting to do the experiment with sighted people may have introduced a bias in the results. Indeed, the navigation patterns of blind people versus those of sighted people are presumably different, so the results could have well been affected by this. In fact, one can assume that blind people should have been more efficient in using the BSN because they compensate their visual loss by using sensory information produced by other senses, like audition and touch [8]. In addition, it is fair to presume that they should be able to complete a given obstacle course in a shorter period of time than the current sighted participants when completing the part with the white cane because of their daily use of this tool. Observing the specific navigation patterns is one of the main reason why our research team is looking forward to the next phase in this project, when participants are effectively visually impaired. This will allow us to avoid a bias and to perfect our orthosis in order to make it the most effective as it can be for our target population.

Table 1. Qualitative comparison between the BSN and the white cane

	BSN	White cane
Average time to complete the course	2 minutes 50 seconds	1 minute 22 seconds
Successful anticipation of movement	✓	N/A
Sense of confidence	✓	✓
Feeling of security	✓	✓

6. CONCLUSION AND FUTURE WORK

The prototype has shown interesting and promising results. Though preliminary, the results we present are promising and confirm the potential of the device. Indeed, the experimental phase allowed our team to have people try the prototype in order to compare its reliability with that of the white cane. The BSN constitutes an interesting alternative for the targeted population. This product is innovative and could be a good opportunity for the blind people to be more independent in navigation and wayfinding. For sure, evaluating the BSN during an experimental phase with sighted participants gave us the chance to have qualitative and quantitative feedbacks to improve the device. Likewise, the fact that the experimentation has been done quickly allowed our team to take note of the improvements that could be done to have an optimal improvement of the BSN and that, rather quickly. In fact, settings such as the intensity of the vibrations and the camera's position are aspects that can be easily modified and these amendments could make a huge difference in the efficiency of the prototype. Future versions should also be tailored to fit people from different sizes so an optimal field of view is guaranteed independently of a person's height.

Also, the significant difference between the cane and the BSN might be explained by the fact that using the BSN requires a prior learning. Indeed, being more familiar with its functioning could actually favor better results. An adaptation to the port of the device could be an easy and effective way to obtain a navigating speed similar to the cane's. The research team noted an important aspect, which will definitely have to be taken into account for future experiments: participants who wore thicker pieces of clothing did not perceive the vibrations as clearly as those who were wearing t-shirts. This indicates that vibrations produced by the BSN should be strong enough so that the person feels them regardless of the clothes he/she is wearing.

When alterations will be made on the prototype, it will be interesting to realize a new experimental phase with participants who are actually visually impaired, with a more complex circuit to complete so that it provides a more realistic context. By doing so, our research team would gather more accurate data regarding the navigation pattern of individuals with visual loss, allowing a fine tuning on the orthosis. Since the current prototype is rather bulky, the final product is going to have to be redesigned in order to be less cumbersome for people who will use the BSN on a daily basis. Therefore, users will get more freedom in their movements and a greater independence which is what we aim to achieve with this project.

In light of the results obtained and the many comments from the participants, it is possible to think that the BSN is a good tool to improve the autonomy of people with visual impairments.

On a final note, it could be relevant to mention that the system used to create the BSN offers various possibilities in other fields of interest. For example, it may be interesting to develop applications based on it in the area of virtual reality, such as interfaces, or as an interaction mode.

7. ACKNOWLEDGMENTS

We would like to thank the National Sciences and Engineering Research Council of Canada (NSERC), the Quebec Research Fund on Nature and Technologies and Bell Canada, for their involvement in this project.

Special thanks go to the following authors having also greatly contributed to this paper: Valère Plantevin, François Dallaire and Kim Charest, all from the UQAC.

8. REFERENCES

[1] Hakobyan, L., Lumsden, J., O'Sullivan, D., and Bartlett, H. 2013. Mobile Assistive Technologies for the Visually Impaired. Survey of Ophtalmology. 58, 2013, 513-528.

[2] Foley, A., and Ferri, B.A. 2012. Technology for People, not Disabilities: Ensuring Access and Inclusion. Journal of Research in Special Educational Needs. (2012), 192-200.

[3] Martinez, M., Constantinescu, A., Schauerte, B., Koester, D., and Stiefelhagen, R. 2014. In, Computers Helping People with Special Needs. (pp. 128-135). Springer International Publishing.

[4] Ong, S.K., Zhang, J., and Nee, A.Y.C. 2013. Assistive Obstacle Detection and Navigation Devices for Vision-Impaired Users. Disability and Rehabilitation Assistive Technology. 8, 5 (2013), 409-416.

[5] Jain, D. 2014. Pilot Evaluation of a Path-Guided Indoor Navigation System for Visually Impaired in a Public Museum. In *Proceedings of the 16th international ACM SIGACCESS conference on Computers & accessibility*, 273-274.

[6] Brock, M., and Kristensson, P.O. 2013. Supporting Blind Navigation using Depth Sensing and Sonification. In *Proceedings of the 2013 ACM Conference on Pervasive and Ubiquitous Computing Adjunct Publication* (Zurich, Switzerland, September 8-12, 2013). ACM.

[7] Gescheider, G., and Wright, J.H. 2013. Roughness Perception in Tactile Channels: Evidence for an Opponent Process in the Sense of Touch. Somatory and Motor Research. 30, 3 (2013), 120-132.

Papagno, C., Cecchetto, C., Pisoni, A., and Bolognini, N. 2016. Deaf, blind or deaf-blind: Is touch enhanced? Experimental Brain Research. 234, 2 (2015), 627-636.