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A Dynamic Haptic-Audio Traffic Environment

Charlotte Magnusson[1], Kirsten Rassmus-Gröhn[1]

[1] Certec, Division of Rehabilitation Engineering Research, Department of Design Sciences, Lund University, PO Box 118, S-221 00 Lund, Sweden
Charlotte.Magnusson@certec.lth.se
http://www.certec.lth.se

Abstract. This article reports results from a study where ten severely visually impaired users have used a virtual haptic-audio traffic environment for exploring and learning a route. The virtual environment was a model of a real traffic environment in Lund, Sweden, and included 484 static objects and 35 dynamic objects (cars and bicycles). Eight of the ten users were able to handle this large and complex environment, and the same users also succeeded in navigating the real traffic section from which the virtual environment was modeled. The users navigating the virtual world most easily were those that also were very good at navigating with a cane. Further results such as the identification of two different exploration strategies in the virtual model, different usages of this kind of model and the importance of relevant initial information are also discussed.

1 Introduction

Although there are few studies on traffic accidents involving visually impaired people, there is some indication [1], [2] that they suffer more accidents in the traffic environment compared to sighted people. People with visual impairments often feel insecure in the traffic environment, and will often avoid situations that are perceived as insecure and dangerous. This results in limited accessibility not only to the traffic environment as such, but most environments outside the home. Of course much can be done in the actual physical environment with tactile signs, sound signals, etc. But other measures, which provide information about the traffic situation and the traffic environment, can be equally important. In the study "Traffic safety, accidents and prevention among blind and visually impaired people in the city of Umeå" [1], some users requested maps containing traffic and accessibility information. Furthermore, the need for an increased understanding among sighted persons is pointed out.

The project "Haptics and Traffic – a Pre-study", investigated if and how virtual traffic environments can be made useful for blind users with the help of haptics and sound. With a virtual traffic environment, a blind user could safely investigate different traffic settings and situations. In 1999, Van Scoy et al. [3] suggested a similar project. Within our project, different ways of moving/scrolling the haptic world, preliminary zooming [4], the design of sound feedback and environmental sounds were investigated in separate user tests. As a final test, a virtual model of a limited section of a real traffic environment was built, and the way users interacted with this environment was tested. The present article reports about the design of the virtual audio-haptic environment and the outcome of the final test.

2 Test design and goal of the study

The present study was designed to investigate how blind or severely visually impaired users can navigate and understand a large, complex haptic-audio virtual environment based on one-point haptics combined with 3D sound. The study was performed in an explorative manner; user comments, ways of interacting and navigating both the virtual and real world were observed and recorded.

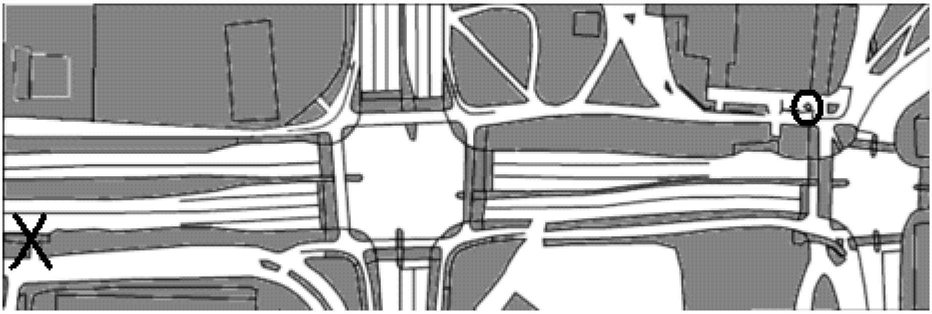

Fig. 1. Map of the environment. The map is rotated 90° (south to the left, north to the right).

The test started with a short interview, after which the user was introduced to the virtual world. The different available methods of controlling the world were explained, and a short standardized verbal overview of each world segment was given. The test was divided into three subtasks. In subtask 1, the user was asked to explore the environment in order to find a number of hidden treasures. This task was really only intended to familiarize the user with the environment and thus help would be given if the treasures were too hard to find. In subtask 2 the user was asked to describe/show a suitable route in the virtual environment from the bus stop (indicated by an X in Figure 1) to the top of the rocket by the rock music concert hall “Mejeriet” (indicated by a circle in Figure 1). To ensure that only haptic and sound feedback was tested, the computer screen was turned away from the user during these tests.

Subtask 3 consisted of going out into the real world and walking the route described in subtask 2. The user was led to the bus stop, informed in which direction north lay, and then had to find the way on his/her own. During the test the test leader walked just behind the user, not to indicate the way, but close enough to be able to intervene in case of danger. The entire test took between 2 and 2.5 hours to complete.

3 Virtual model

The virtual model contained 484 objects, making it considerably larger than models in other reported studies [4], [5], [6], [7]. We used the ReachIn API for the haptic interaction and the static world objects were designed in 3DStudioMax and then imported into our program as VRML. Dynamic objects such as cars and bicycles were programmed directly in the ReachIn API. Due to problems with OpenAL (used by ReachIn) we used Direct3DSound for the implementation of the three dimensional sounds. Headphones were used for sound feedback.

Fig. 2. Six screen shots from the 3D model produced with 3DStudioMax. Lower right image: bus stop – starting point of subtask 2. Top left image: rocket – goal. Colors or image textures were not elaborated due to the fact that the world was to be experienced using haptics and sound.

All virtual world objects had surfaces with friction. Vegetation had a somewhat rougher surface compared to other objects, but to save processing power, more elaborate surfaces (such as bumpmap surfaces) were not used. The world was contained within walls as if it were in a box to stop the user from accidentally sliding off. These walls were slippery (without friction) to distinguish them from the world objects. Both walls and world objects were given sound labels that could be activated by touching them with the PHANToM stylus and pressing the PHANToM button. This action would also position the avatar (the user representation in the virtual world) at the position currently pointed to by the PHANToM stylus. The avatar was always positioned facing forwards just as the user was sitting facing forwards in front of the PHANToM. Also, a limiting box was created around a subpart of the model, since the model was too large to fit into the PHANToM workspace with a reasonable zooming size. Pressing the sides of this box could be used as a way of scrolling/moving the world model [4]. To clearly distinguish the containing walls from world objects, the sides of this box emitted a short sound upon being hit.

The dynamic objects within the world were cars and bicycles. They moved along pre-defined paths, but would stop at traffic lights. Collision detection was also implemented between the dynamic objects to keep them from running into each other. These objects had a collision zone at the front (red in Figure 3), and if the user hit this part of the object, the car or bike would stop momentarily and emit a collision sound.

Attached to each car was an engine sound consisting of “brown” noise. When the car hit the user, the sound of a bump followed by screeching tires was emitted. The bicycles were silent as they moved, but would emit a bicycle bell ring when hit. It should be noted that with a one-point interaction there is no need to use more elaborate dynamic objects than the simple boxes of this test application. The illusion produced by a simple box hitting the finger works just as well as a more complex shape.

Fig. 3. A screen shot from the haptic virtual world. Cars are seen as green boxes with red fronts, while blue boxes with red fronts signify bicycles. As the focus was on the traffic environment, houses and trees were only schematically modeled. The semi-transparent boxes by the traffic lights show the state of the traffic light and allow the test leader to keep track of it. The static 3D model for the haptic virtual world is the same as in Figure 2.

The traffic lights in the virtual world controlled the flow of cars and bicycles, but they also emitted realistic ticking sounds when pedestrians were allowed to cross just as real world traffic lights do. As in reality, this sound was located in the box on the traffic light pole.

The world model could be scrolled/moved by using the keyboard arrow keys or by pushing the sides of the limiting box. The environment also allowed zooming.

Due to limited processing power, the world had to be divided into five segments. The test leader switched between these segments at requests from the user. The limited processing power also had the unfortunate side effect of influencing the way in which scrolling could be implemented, and we had to resort to fairly short scrolling steps.

4 Results

The users were observed during the tests, and the way they interacted both with the real and the virtual world was noted. Eight out of ten users managed to successfully complete all three subtasks. A few users were given help during the tests. The help given is described as follows: User 7 described the way correctly in subtask 2 without help, but then she managed to slip past the goal object several times, and she received instructions on how to find it. Users 6 and 7 performed subtask 3 together. At one point they were about to walk a different way compared to the one they had indicated on the computer (both had described the same way during subtask 2). They were then told, "Now you are not walking the way you showed on the computer," and they immediately corrected themselves. User 8 was stopped from walking out in front of the cars right at the beginning of subtask 3, but then performed the rest of this task successfully.

It was seen that the users who were observed to find the virtual world most easy to navigate (users 2, 3, 5 and 9) were also the ones who appeared to be best at navigating with a cane. None of these users utilized vision for navigation.

In addition to the above observations, the program logged the way the user interacted with the program. These log files show interesting patterns in that they reflect some of the explorative behaviors of the users. Together with the number of objects touched in between two clicks, as well as the total number of clicks performed during the test, the data reflected two different types of exploration behavior observed during the tests. Some users clicked for sound information more or less continuously and did comparatively little haptic exploration in between clicks, while others explored haptically for longer periods and clicked for sound information less often. This was interpreted to signify that the users who clicked less often relied mainly on the haptic information and clicked to obtain sound information on the basis of what they could feel haptically. The users that clicked to obtain sound information almost all the time instead gave the impression of using sound rather than haptics as their primary input.

The short scrolling steps did not work very well with the "scrolling by pushing" function where the user presses the sides of the limiting box to scroll. If a user kept on pressing the walls to scroll a longer way, the user lost track of his or her position. Therefore the users were biased towards using the arrow keys on the keyboard. When using the arrow keys it worked well to keep pressing the same key, as the user could put the PHANToM stylus close to a reference object and follow the world along.

5 Discussion

The results of this test show that most of the users were able to understand and navigate in this fairly complex virtual model. It was interesting, although possibly expected, to note that the users who were particularly good at navigating with a cane also were good at exploring and navigating the virtual world using the PHANToM. This may seem trivial, but becomes quite interesting if it can also be shown to work the other way around, i.e., if practicing in a virtual world using the PHANToM can be shown to improve navigational skills in the real world. The PHANToM is unlike a cane, but possibly strategies as well as the ability to create a mental model of an environment using limited sensory input could be improved through training. Of course, information about environmental properties could also be learned. Such possible training effects need to be the subject of further studies.

The amount of work needed to produce the present type of model is somewhat prohibitive for the immediate production of large numbers of user specific environments, i.e. the route to school for a certain student. When and if the generation of 3D models of the real world can be performed in a more efficient manner, the user responses show that there is a demand for these kinds of environments. Their responses also show a demand for more schematic, map-like environments. Such environments have already been suggested by different authors [3], [5], and the results of this test support this suggestion.

A further utilization of such a model already apparent in the present test was as a means of communication between a sighted and a blind user. This is a way for the accessibility of different designs to be visualized/articulated and discussed.

The present study contained both haptics and sound. It was interesting to note that different users utilized the sensory modalities differently. Some users appeared to rely mainly on the audio feedback, and would click for sound information very often. Such users would have benefited from a continous change of the avatar position – i.e., the position of the user's ears in the environment changing as the PHANToM position changes (with the computer capacity available, this was not possible to implement). Other users employed haptic exploration more often, and used the sound labels more as confirmation. For such a user it is actually beneficial to be able to put the avatar in a specific position and then to explore haptically around that position (this was also explicitly stated by user 9 in reply to the suggestion that the sound should change continously). Thus, it is important to consider both users relying primarily on sound and those relying primarily on haptics when designing these types of virtual environments.

There were a couple of problems that arose from the limited processing power of the test computer – the need to split the model into 5 separate segments was one, and the limitation of the scrolling steps was another. With a single virtual model and with a longer moving distance, we expect more users to make use of the "scrolling by pushing" function, which was the preferred one for navigation in the pre-study [4]. The problems experienced due to the limited processing power highlights the need for some kind of space partitioning structure [8], [9] for larger world models.

Finally the test results confirm the observations made in [5] that the expectations of the user heavily influence the results. Several users had problems with the fact that the route from the bus stop at Malmövägen was unusual. They kept looking for pavement or a pedestrian crossing for a long time before they realized that they had to go down the stairs at the back and follow Järnåkravägen instead.

6 Conclusion

A majority (80%) of the test users were able to handle the present large complex haptic-audio virtual environment. The users appearing to navigate the virtual world most easily were the same users who were very good at navigating with a cane. From this we infer that some similarities appear to exist between cane navigation and PHANToM navigation, and it is suggested that this effect could be used in the other direction (i.e., for training). A further use of this type of model is as a visualization/articulation tool for discussing accessibility. Two different explorational modes were identified, one apparently relying more on sound and one relying more on haptics. Interfaces of this type need to cater to both these explorational strategies.

The study shows a demand both for the detailed 3D models investigated as well as more schematic, map-like environments. It also indicates a need for more automatized ways of creating such environments. The test confirms the importance of initially providing the user with relevant environmental information. During the test the test leader provided this initial information verbally, but this could easily be included as recorded verbal descriptions. Finally, the processing problems encountered during the design of the virtual world, indicate that some kind of space partitioning structure (such as an octree) may be needed to exclude irrelevant objects from the haptic loop.

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