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Avatar Control and World Interaction in a Non-Visual 3D Gaming Environment

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Abstract

The present paper reports on the implementation and test of an audio haptic gaming environment. This environment was designed with an ears-in-hand interaction technique allowing turning of the ears in combination with an avatar separate from the haptic interaction point. The purpose of this design was to investigate how the additional rotational degrees of freedom influenced the interaction. The results of the study showed that the additional rotation was sometimes perceived as confusing, although we note that an ears-in-hand tool that can be toggled on or off could still be useful. We also report other qualitative observations which may have influence on the future design of this type of environments.

1. Introduction

For the blind and visually impaired the development of computer graphics has made much information less accessible as most information is presented graphically. The advanced 3D games of today are despite advanced audio capabilities not very accessible due to the manner in which sound is used. Sound effects may do well for enhancing the game experience for a sighted player but to support navigation for a visually impaired gamer the sonification of the virtual world needs to be either realistic or designed with care. Affordable haptic devices have the potential to make, not only the virtual realities of computer games, but any complex graphical environment more accessible than ever. The challenges of future research is how to best map visual representations to audio and haptic feedback and how to make these modalities self-sufficient so that impaired users can begin to enjoy the mainstream games available to their able-bodied peers. Blind accessible games like Terraformers, AudioQuake or the audio game Sarah and the castle of witchcraft and wizardry make excellent use of audio cues to support navigation. Audio - haptic games are still less mainstream. Studies of audio haptic game environments include a Pacman game developed to investigate combinations of sound and haptics in navigational tasks [1]. The avatar (Pacman representation) was positioned at the tip of the the stylus of the PHANTOM device and guided around a maze that was within the PHANTOM workspace. As the avatar was the interaction point, attaching the listener to the stylus position (ears-in-hand) proved useful when the player monitored the position of the ghosts using 3D-sound. The audio haptic game environment developed within the European project GRAB [2] provided a different player perspective. The game was an indoor search and adventure game where the game world also was within the workspace of the interaction device which was a two-finger haptic interface. The user located elements such as bombs, a trap of attracting force, deactivator buttons and a door key in the two-room environment by using two interaction points. Zooming, panning and constrained movement were excluded from the game design. Several panning techniques were developed for the game Haptisk skattjakt (Haptic treasure hunt) [3] where a game world larger than the workspace was explored with the PHANTOM stylus. More extensive tests on navigation and interaction in haptic environments have been performed in virtual traffic environments [4] [5], where techniques such as pushing a limiting box, pressing keyboard arrow keys to move the world in the direction of the arrow or using the button of the PHANTOM stylus to click and drag the world were investigated. All of the scroll functions proved useful and the findings of the tests suggested that different ways of scrolling and zooming can be preferred by different users when performing different tasks. A different set of controls for a game environment using the first person perspective includes the work of Johnston [6] [7]. PHANTOM movements forward and backwards were used to walk the avatar and left and right PHANTOM movements were used to rotate the avatar. A hemispherical dead zone of control in the centre allowed the avatar to stand still. When pressing the button of the Omni PHANTOM device the player could explore the surrounding space in a free explore mode. The work also included navigational aids for the visually impaired composed of a sinusoidal wave force to the stylus and a tapping sound. A zero amplitude to the force and zero volume for the sound was used to indicate the correct direction of the target object. The evaluation suggested the audio aid was most useful.

Other studies of navigational tools utilizing 3D sound and haptics have been made [8] [9] that included attractive forces, a linear fixture, a search tool of crossing planes combined with sound feedback from one object or all objects simultaneously in different combinations. The ears-in-hand metaphor was found to be a useful interaction technique in these environments where the avatar and the listener was positioned at the haptic interaction point (PHANToM proxy) and a fixed forward-facing orientation was used. As yet there have been no studies of the ears-in-hand interaction technique allowing turning of the ears in combination with an avatar separate from the haptic interaction point. This is why we decided to implement and test a gaming environment with this type of design.

2. Implementation 1, the introduction room

The game prototype implements haptic one point interaction from a first-person perspective where the control of the user representation in the virtual world, the avatar, and world interaction is separated. To really test exploration and navigation, the game world was designed to exceed the reach of the PHANToM work space. To familiarize users with the system, the initial environment is a small unfurnished environment as shown in figure 1. The avatar body is represented by the pink vertical cylinder in the middle of the room reaching from the floor to the ceiling.

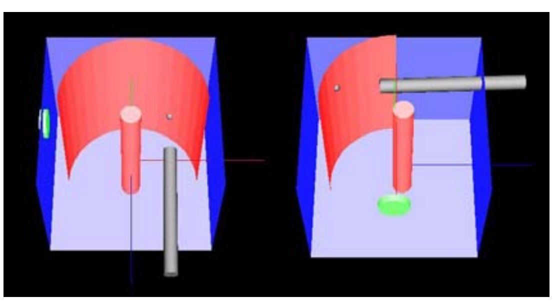

Figure 1: The introduction room from observing viewpoints (the front wall, ceiling, and occlusive parts of the stylus reach boundary are rendered transparent).

The stylus interaction point (shown as a small grey ball in figure 1) was designed to be relative to the avatar body, in an attempt to simulate a blind person's cane (the grey cyclinder in figure 1). To make it easier to separate real objects from the physical constraints limiting the PHANToM workspace, the area where the PHANToM stylus can be moved is constrained virtually. This constraint is shown by the large red half-cylinder in figure 1. Movement of the avatar body, boundary and stylus representation, was controlled by the arrow keys which frees the stylus for use in game world interaction.

The up and down keys walk the avatar forward and backward; the left and right arrow keys turn the avatar left and right. Movement and rotation of the avatar occurs in small steps, but holding down the keys will cause continuous movement. When the avatar approaches a wall (shown in blue in the figure above) it will come within range of the stylus, allowing the user to feel the approaching wall step by step. Once the avatar body is close enough to the wall, the avatar will stop or, if the wall is approached at an angle, slide forward along the wall while emitting an "ouch" sound.

When the stylus is in contact with a wall, turning towards the wall is not possible. Instead, the user is alerted of the obstacle by a "beep" sound. There are two different beep-sounds that are played depending on if the colliding wall is on the left or right of the stylus.

In addition, the room contains a single sound emitting object in the form of a ticking clock (shown by a green disk in figure 2). The listening point is placed at the tip of the stylus, enabling the player to determine the location of the sound source by moving and turning the stylus. The clock has a sound range defined by an ellipsoid, as shown by the black line in figure 2.

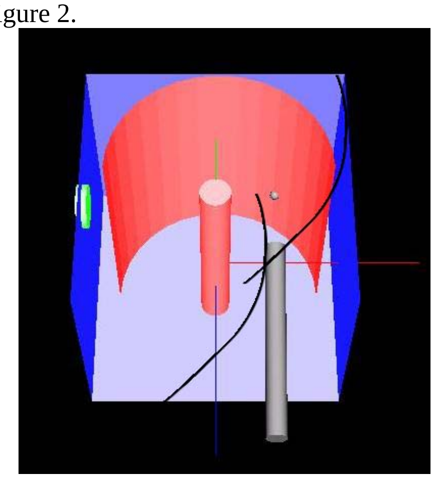

Figure 2: Sound range in introduction room.

It should be noted that it is not only how close you are to the sound that can be detected with the stylus. The entire soundscape is controlled by rotation of the stylus, meaning that if you point the stylus directly at a sound source, the sound will originate from the center speaker; turning the stylus 90 degrees left will cause the sound to come from the right speaker when using a surround system; and so on. This is an extension of the "ears in hand" metaphor shown to be effective in previous applications, since the soundscape now also can be rotated by the PHANToM movements (previously the listener was always assumed to be facing forwards in the virtual environment.

3. Implementation 2: the game environment

This environment consists of a square room furnished with a sideboard, a wall mounted shelf and a table placed alongside the walls.

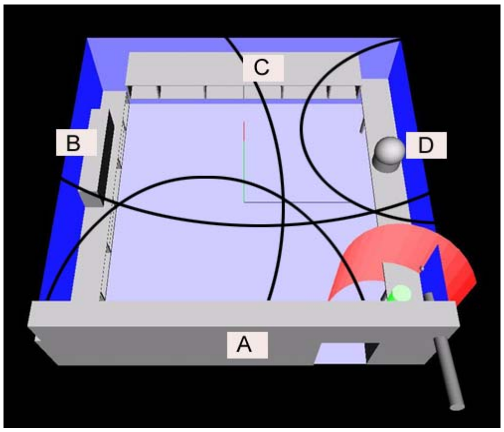

Figure 3: The game environment

Fig 3 loca-tion	Object	Description of the sound
A	Wall Clock on the south wall	The sound of the ticking wall clock is the same as in the introduction room
B	Aquarium standing on the side board up against the west wall	The sound of the aquarium is actually a sound capture from a bio lab. It features a bubbling sound for about 6 seconds and continues with the sound of running water.
C	Radio in one of the wall shelf compartments on the north wall	The radio sound is represented by Mozart's *Eine kleine Nachtmusik*
D	Table Clock standing on the table up against the east wall	Compared to the wall clock the table clock ticks more slowly and has a lower pitch.

Table 1. Sound sources

There are four sound emitting objects in the room (see table 1). In the south wall there is also a door frame. The room and the approximate range of the sound sources can be seen in figure 3.

4. User tests

Four visually impaired participants (aged 18, 18, 20 and 27), with previous experience with the PHANToM device, took part in the tests. The test environment can be seen in figure 4.

Figure 4. Test setup.

The test started with a session in the introduction room followed by a test in the full environment. The aim of the first session was to familiarize participants with the controls, the haptics, the sounds of the collision detection and ears in hand by performing a set of tasks:

- Task 1. The test person was asked to walk straight ahead. This resulted in the avatar hitting the front wall, causing the "Ouch" sound to be played. The next instruction was to back up as much as possible, resulting in another "Ouch" sound as the avatar hit the back wall.
- Task 2. At the start of the task, the avatar was positioned with its back against the south wall. The sound of the clock was turned on and the participant was asked to locate the clock. If the participant experienced the beep sounds that indicated restriction of rotational movement while the stylus was in contact with a wall, this was explained by the test leader.
- Task 3. When standing in front of the clock the participant was asked to turn the back to the clock, to turn so that the clock was on the left hand side, to turn so that it was on the

right hand side and then to face it directly. Lastly the participant was asked to make a 360 degree turn i.e. to face the clock again.

- Task 4. The avatar was positioned in the middle of the room, facing the clock. The participant was then asked to locate the four corners of the room, one by one.

After this the participants tried the game environment. The avatar was initially positioned in the southeast corner of the room (by the door). The participant was informed of now being in a different room containing four sound emitting objects and was asked to find them and point them out with the stylus.

5. Test results

In general the users were able to complete the tests quite well. The results of the tests are summarized in table 2 showing task completion (Yes/No) and time for completion in minutes. All users completed the first task of walking back and forth. All users were also able to successfully locate the clock (task 2) although one of the users needed the hint "it may not be on the floor" before finding it. The tasks involving rotating (task 3) and finding corners (task 4) caused some problems.

Task	User 1	User 2	User 3	User 4
1	Y:-	Y:-	Y:-	Y:-
2	Y:0.52	Y:4.20	Y*:2.32	Y:1.10
3.1	Y:0.25	Y*:2.31	Y:1.21	-
3.2	Y*:0.30	Y:0.27	Y:0.22	N:0.41
3.3	Y:0.27	Y:1.00	Y:0.27	N:1.46
3.4	Y:0.31	Y:2.35	Y:0.35	-
3.5	-	Y:0.57	Y:0.49	Y:1.45
4.1	Y:0.56	Y:1.03	Y:0.34	Y:4.20
4.2	Y:0.43	Y:1.26	Y:0.08	Y:0.44
4.3	Y:0.26	Y:1.24	N:0.15	N:1.20
4.4	Y:0.16	-	N:0.01	Y:1.50
Total time	17	32	27	31

Table 2. Task completion summary. Asterisk (*) shows that the task was completed during a second attempt.

Some observations, based on interviews with the participants:

⇒ In general the users tended to keep the PHANToM quite still while walking. The general strategy appeared to be to concentrate on one type of interaction at a time.

⇒ It was interesting to note that the avatar was often referred to as "he" but at the same time the users tended to say "I" when they were touching things with the PHANToM. Also the avatar generated emotional type responses – two users thought he was complaining too much when he hit the wall, whilst two felt sorry for him.

⇒ The fact that the PHANToM stylus could rotate the soundscape complicated matters on several occasions – if you were standing with the clock to the left and then turned the stylus towards it the sound would be heard in the middle.

⇒ It is a problem you can't touch the walls while rotating (this is to prevent falling through the walls).

⇒ It is hard to judge your speed of movement – although the sounds may help.

In the game environment, all four users found the wall clock, the table clock and the aquarium. Only user 4 found the radio. The times used for this test were 22, 26, 34 and 26 minutes. Some observations, again based on interviews with the participants:

⇒ In general the users were able to quite easily find the clocks and the aquarium.

⇒ Also here the users tended to keep the PHANToM quite still while walking. The general strategy appeared to be to concentrate on one type of interaction at a time.

⇒ The fact that you cannot walk sideways makes it harder to scan the room systematically

The radio was very hard to find due to the fact that the sound source did not vary much enough as you moved the stylus. The music was dynamical, and the changes that could have been induced by the motion drowned in the variations in the music itself.

6. Discussion

The current study tested the "ears in hand" for the case where the rotation of the stylus also rotated the soundscape, and where the user had an avatar separated from the PHANToM proxy. In our previous studies [5, 8, 9] we had always used the PHANToM proxy as the avatar, with a fixed facing forwards listener orientation. We wanted to investigate if the introduction of a rotational degree of freedom could be useful. Observations during the test made quite clear that this was not generally the case – instead the rotational degree of freedom introduced problems. One problem was that users could easily rotate the stylus slightly without noticing it. Another problem was that not all users realized the influence of rotation. With stylus rotation of the soundscape there are really two orientations to keep track of – the orientation of the avatar and the orientation of the stylus. Both during this test (and the pilot tests that preceeded it) it became clear that it is probably better to adopt the previously used fixed facing forwards rotation of the listener for the ears in hand design.

Another issue is the design of the workspace (the "reach" of the avatar). It is clear that the surfaces used were too similar and users confused the workspace limits with objects. Also the fact that the workspace contained corners added to this problem. This can probably be remedied by adding textures either to objects or to the limitation of the workspace or possibly by changing the workspace limitation surface to more of an elastic membrane type. And of course by using a more ellipsoid shape to avoid sharp corners.

At the same time the limited workspace can help to show sighted persons some of the problems facing blind or visually impaired persons in their everyday life. One further issue that is to some extent illustrated by the above test results is the fact that a person may perform quite well in an environment also if that person never builds up a cognitive map of the actual layout of the environment. This may be said to relate to navigation by waypoints/routes versus map navigation – and it is well known that it is quite possible to navigate quite well also without an overview mental map of the environment. Still, the test results on this point should be used with caution – just because a person does not remember the layout of the environment after the actual test does not necessarily imply that he or she did not have some notion of it while being in the environment (we saw the same effect in [4] where persons often navigated the environment well, but when they were asked to draw a map afterwards they found this very hard to do).

If we look at the way the test persons used the stylus the general trend was that for walking they would keep it fairly still in front of the avatar while moving the avatar using the keyboard. Also during avatar rotation the PHANToM stylus was in general held quite still. So, in most cases our users preferred to focus on one type of interaction at a time, i.e either they would scan using the PHANToM or they would move the avatar using the keyboard. It is possible that this is something that may change with experience – after all it takes some time to train persons with visual impairments in the use of the white cane.

For the avatar navigation, it was suggested that one should also be able to walk sideways. While it is known that this may make navigation easier (e.g [12]), the current design was for a gaming application where this type of difficulty may actually be part of the challenge of the game. So far we have decided to keep the number of controls to a minimum, but to add sideways movements is clearly an option.

The presented environment illustrates the importance of active exploration. It also illustrates the importance of the close link between gestures and feedback. This is shown both by the difficulty of judging the speed of the avatar movements and the difficulty of finding the radio.

The difficulty of judging the speed of the avatar makes it clear that more feedback is needed for these actions. Auditory cues such as footsteps are suggested, and one could also add some kind of ribbed or checkered texture to allow the user to get movement information through the haptic sense.

The difficulty in finding the radio illustrates what happens when variations in the feedback received is not linked closely enough to variations in the gestures. Since the music played by the radio was quite dynamic, it was hard to really identify the volume changes caused by movement of the stylus. Also, the sound of the radio was heard over quite a large area, and the amount of volume change caused by moving the stylus was not large enough. Furthermore the music piece used was less well suited for spatial hearing – it had the kind of sound that can be a bit hard to locate precisely in space (in the previous navigational study [8] we used a not very dynamic rock'n'roll piece with a rather "heavy" fuzzy guitar since this type of music was seen in pilot tests to make it easy to hear the spatial location).

7. Conclusion

This test shows that this type of environment where avatar control and world interaction is separated can be used also by blind persons. That blind persons are able to handle this type of separated design has also been shown in a recent study where the goal was to help blind sailors to get access to nautical maps [11], which lends further support to our claim.

The rotational degree of freedom introduced made it very difficult to envision the surroundings if the player was identifying himself with the avatar since the soundscape turned with the stylus. If the avatar was facing a sound source and the user pointed the stylus forward, the sound would emanate from the center and front speakers. If the stylus was then turned 90 degrees left, the sound would emanate from the right speakers even though the sound source was in front of the avatar. There can be situations when the direction of the sound is confusing even if the stylus is held pointing forward (facing the same direction as the avatar). For instance, when the sound source is located between the stylus and the avatar on a straight line in front of the avatar the sound will emanate from the rear speakers although the sound source is in front of the avatar. In the prototype the problem was not prominent since all sound emitting objects were placed along the walls.

However, the ears-in hand interaction technique was also seen to be useful when the player focuses on locating a sound source within reach while ignoring the avatar body (although the rotational degree of freedom still is a problem). The ears-in-hand sound would then guide the player towards the target. This leads us to believe the ears-in-hand interaction technique, used as a tool that can be toggled on and off at will, may be valuable also for this type of design where the avatar is separated from the haptic interaction point/proxy. It provides similar properties as attractive forces pulling the stylus towards objects of interest; yet it is superior in the aspect of being able to convey the directions of several sound sources at the same time.

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