Experiencing and Navigating Virtual Reality without Sight (The all-seeING ears)

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Abstract

Navigating a public space or building can be challenging without sight. To facilitate understanding for the hazards visually impaired people face, the authors created a virtual reality environment modelled after the Ruhr-University's ID building. The task in the simulation is simply to find your way through the building to a certain desired office. The virtual reality vision is darkened, so that all participants are effectively blinded. The participants can utilize various audio-based aids, like an AI agent to follow, a collision warning system, a semantic laser pointer and the haptic virtual white cane.

Index Terms: Virtual Reality—Sound Navigation—Assistant Devices—Unity Engine;

1 Introduction

Virtual Reality (VR) is often considered a visualization technique and as such obviously addresses the sense of vision. However VR offers several more opportunities besides pure visualization such as the presence of virtual acoustics that address the sense of hearing. Thereby vision can be omitted, helping seeing people to experience the difficulties of visually impaired. In contrast, approaches and tools for visually impaired to experience virtual reality can be developed more easily and in finer detail and could later be transferred to real-world use-cases.

1.1 Related Work

The development of sound navigation and orientation aids for blind or visually impaired people was formerly addressed with augmented reality systems. In most of the cases the idea of an optical camera view was pursued to substitute the original sense of human vision. Based on the image capture, automatic object recognition is invoked and transcribed to a suitable audio reproduction. More specifically, the system in [2] is semi-automatic in that the user points to a direction of interest and on-button-down queries semantic feedback of the environment by text-to-speech synthesis. In the same context, the study in [1] investigates and confirms the fundamental utility of automatic object localization, recognition and audio transcription by a survey on 54 blind people. Additionally the idea of binaural sound reproduction for directional indication of objects was deployed. Then, a device has been reported in [4] with additional Global Navigation Satellite Positioning input to localize the user in augmented reality. This macro-sense of positioning was merged with a cartographic database and a camera-based micro-sense in order to deliver context-aware audio feedback, both verbal and using binaural auditory trajectory rendering. Recently, another concept of an augmented-reality system with binaural indication of obstacles has been described, where the former camera view has been substituted with a radar sense for robustness against environmental lighting conditions [5]. A fundamental study of the psycho-physical sense of spatial hearing of the blind has been delivered in [3] to support the understanding of the auditory sense and cognition addressed by the practical systems.

1.2 Goals and Limitations

The main goal here is to create a realistic scene containing a representation of several stories of one of the universities buildings with real navigation paths, such as the way from a certain office to the faculty's administration office. Blind people will find a lot of hazards and difficulties in navigating the real building, as elements like switches for automated doors or pillars are placed inconsistently throughout the building. The authors aim is to replicate and further worsen the scenario to create a test bed for tools that may help blind people to successfully navigate and beyond that experience virtual reality in more detail. The project is an interdisciplinary effort between a mixed reality group in mechanical engineering and an acoustic signal processing group in electrical engineering and information technology of the same university.

2 Requirements

On the one hand, the user needs to gather information about his surrounding objects, such as the position of surround walls and possible hazards in the vicinity. On the other hand, the user needs assistance in navigating from a starting point A to a destination B. The mentioned goals for lending aid in navigation of Virtual Reality scenes without sight are addressed with three main functionalities, which were planned from the beginning of the project. Those functionalities are a virtual collision detection and warning system comparable to Radar- or Ultrasonic-based car parking assistants, a virtual white cane based on haptic feedback and also a navigation agent, which finds the best route between the current and the desired location and avoids hazards on the way. The agent sends out an acoustic signal for the user to locate, follow and keep track within a specified range.

3 Implementation

The authors implemented the all-seeING ears project with the Unity engine. The scenario is based on the two upper floors of *one of the university's buildings* and modelled in Unity. The actual visual quality of the surrounding does not matter in this particular use case, as the virtual light in the scene will be turned off, effectively blinding every participant and letting them move trough total darkness. For demonstration and development purposes the light can, however, be turned on (cp. Fig. 1 and Fig. 2) to show the avatars of the user and the navigation agent, for instance, to enable *in situ* diagnosis of the program logic around problematic hazards. Through the course of the implementation process and weekly meetings, the authors faced evermore challenges when navigating the familiar building without sight in VR and, based on the occurring problems, sought to improve the support functions. Hazards like cardboard boxes, pallets or barrels are randomly placed in the way in each new run in the level,

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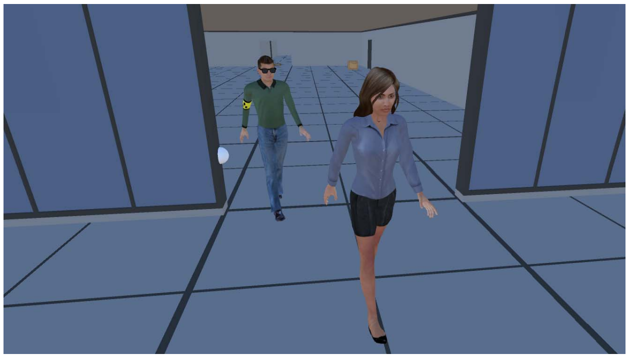

Figure 1: Screenshot with the light turned on, showing the blind player (left person), the navigation agent to follow (right person) and a collision warning (sphere on the left door frame).

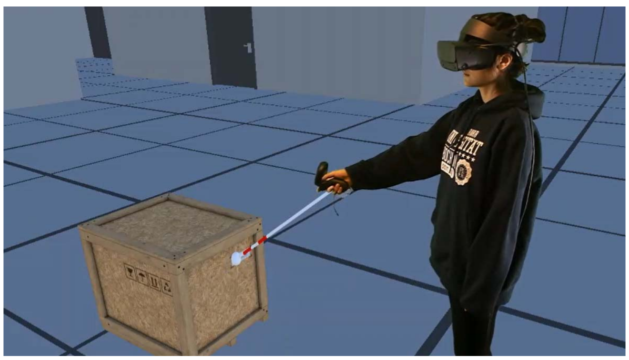

Figure 2: Screenshot with the light turned on, showing the player in front of a green screen using the virtual white cane to detect and avoid an obstacle.

making the otherwise straight corridors more demanding to navigate. Doors are opened/closed randomly with each new run of the system, with fixed configuration though, thus restricting otherwise possible paths. The iterations resulted in far more than the planned features while two different categories could be figured out.

Aids that are or might be soon available in real-world systems: A white cane of 2m length to give ”haptic information” for one’s surroundings. The VR controller’s force feedback is used to create the haptic feedback. A local collision warning system that automatically detect hazardous obstacles in the environment, for instance, using camera or radar views, estimating the distance and translating it into a repelling warn sound.

Aids that are currently hard to implement in the real world: The navigation agent (i.e., based on global cartographic knowledge) as a virtual abstraction of a guide person or guide dog, where this agent emits a continuous acoustic signal to follow. The Pointing (and clicking) at an object returns the type of the object and the distance to the object utilizing synthesized speech through a text-to-speech engine. A context-sensitive warning speech message based on the user’s and the agent’s positions, notifying the user whenever hazardous obstacles occur in the users path. For instance, when the current height level of the agent changes, up- or downwards, by using stairs or when the agents path leads around sharp building corners.

The application features a full data-logging function that tracks all relevant events in the application like movement speed changes, collisions, use of support functions etc. with their timestamp. This enables a virtual ”replay” for analysis and development.

4 Preliminary Test Procedure

For a first informal evaluation of the effectiveness of the assistant functions of the system, the following procedures have been applied with six participants (i.e., the authors plus students). The task for the participants was to walk a recommended way from one room to another room at a different floor level as fast as possible. In doing so, they must conceptually avoid any collisions with walls or any other obstacles. In a first ”learning” run the participants were seeing, i.e., virtual lights turned on, to familiarize the participants with their virtual assistant devices and to obtain a first reference time for later comparison to the time needed in the ”blind” run. In the blind run, the participants were allowed to use all assistant devices and functions and the navigation agent was always active.

After gathering additional feedback from both, experts in the field and the participants, the authors will seek to improve the assistance functions and do a test run with actual blind persons, obviously skipping the ”lights-on” part of the learning-run.

5 Conclusion

The authors successfully recreated a part of their workplace in virtual reality and exaggerated hazards to blind and visually impaired people to let seeing people experience how the ”run in the gauntlet” of even a short walk to another office of the same public building can be. A third category of assistant functions is obvious, but not trivial to implement even in VR. Based on the created assistance functions, the discussion quickly led to the simple question ”why not let another human help?”. Therefore the next step in the development of the all-seeING ears project is to implement a VR multiplayer scenario in which another human person takes the place of the navigation agent. This person should also inform the blind player about the players surroundings and give hints or warnings about potential hazards.

In the current implementation, those tasks fall to automated assistant functions. In future studies, the authors would like to test combinations of automated and human assistance. The authors provide a small demonstration of the current sound-based navigation agents to experience this special feature without specialized VR hardware. The WebGL application runs in every modern browser on desktop PCs. The use of stereo headphones is advised, as precise localization of the audio signal is key to successful navigation.

Web-based demo for the audio-based navigation and collision warning system:
`http://projects.lde.rub.de/allseeingears/`

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