

Improve Learning efficiency of Mixed Reality Cane Design - effective gesture based user interfaces for MR cane

Zhenchao Xia

Stony Brook University

New York, USA

Zhenchao.Xia@stonybrook.edu

ABSTRACT

The Mixed Reality (MR) Cane utilizes simple auditory and haptic feedback on an iPhone to help the visually impaired users interact with virtual objects and environments as they are walking in real-world situations. The visually impaired can use the MR cane app to learn the physical layout of unknown environments using virtual reality (VR), which encourages them to travel independently. In order to allow users to quickly and effectively learn the spatial layout of the room, on the basis of the original work, we designed a laser pointer and a gesture menu. Laser pointer is an audio-based tool for observing surrounding in a virtual environment, the purpose is to allow users to save a lot of time and energy in the process of exploring the virtual environment to build a mental map. The laser pointer takes advantage of the iPhone's back camera, enabling users to survey their surroundings by pointing in the direction of the cane. A gesture menu is an interactive method based on gesture detection, which is used to help users switch between different functions in a virtual environment, so that they can focus on the learning of spatial layout. The gesture menu utilizes the the back camera of the iPhone and the device's gyroscope to detect the ability to open/toggle menu content/execute menu options. Due to the difficulty of finding suitable blind users, I conducted a user study with 5 blind-folded users who were asked to train in different training modalities (the traditional way vs. the mixed reality cane without a laser pointer vs. the mixed reality cane with a laser pointer), find the direction of the target object and use the model to build the actual room layout as soon and accurate as possible. The results suggests that compared with other training methods, the mixed reality (MR) cane training method with a laser pointer learns the spatial structure to construct the mental map at the fastest speed and significantly improves the accuracy of the mental map. Our work can help blind or visually-impaired people efficiently learn the spatial layout of unknown environments.

CCS CONCEPTS

• **Computer-centered** → **Mixed reality**; *Auditory feedback*; Accessibility technologies; Accessibility systems and tools.

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KEYWORDS

mixed reality, face detection, augmented reality, virtual reality, audio feedback, haptic feedback, 3D environment

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1 INTRODUCTION

Mapping software, paper maps, clear room numbers all help visitors navigate to their destination in unfamiliar environments. However, due to the lack of accessibility tools, the existing navigation tools are largely unable to make visually impaired people find their destination correctly in unfamiliar environments, and they have to rely on the help of auxiliary persons. This limits the freedom of visually impaired people to explore the real environment and travel. And that restriction has become especially pronounced during the COVID pandemic. Therefore, we designed The Mixed Reality (MR) Cane. The Mixed Reality Cane [3], also called MR Cane, utilizes simple auditory and haptic feedback on an iPhone to help the visually impaired interact with virtual objects and environments as they are walking in real-world situations. The visually impaired can learn the physical layout of unknown environments using the MR cane mobile app. for example, It allows students with eye disabilities to learn the layout of the class room from their school in their backyard.

The MR Cane uses the iPhone's front camera to obtain the orientation of the user's head to obtain accurate spatial sound feedback, and the rear camera to obtain the simulated blind stick or laser pointer and the user's displacement in the real world. When a virtual blind stick interacting with virtual objects, the real-world feedback is simulated through vibration and sound feedback. The purpose of the MR Cane is to provide users with realistic tactile and spatial audio feedback, allowing users to freely explore information about the virtual environment around them, for an experience that is consistent with their exploration in the real environment. These features are very different from other existing aids for the blind, which do not guide the user's movement through sound, but provide real feedback, allowing users to learn the spatial layout by themselves.

However, we found that when users use MR Cane to learn spatial layout, they need to establish a solid mental map by confirming the positions of various objects in a complex virtual room for a long time, just like exploring in a real room. Repeatedly moving in the virtual room for a long time reduces the learning efficiency of users

and brings great challenges to their energy. The original project lacks tools to quickly check the spatial layout of the virtual room. And since our project requires the user to place the iPhone device on the selfie stick, the user needs to tap or move their finger on the phone screen to switch between the existing functions, which consumes their extra energy and distracts them from learning's attention. Therefore, on the basis of the original project, I added two new features, the laser pointer and the gesture menu, to solve these two major problems.

The laser pointer obtains the movement of the device in the real world through the rear camera of the iPhone, deploys the laser pointer at the corresponding position in the virtual world, and shoots a long laser at the end according to the movement trajectory in reality, when it touches. When reaching the surface of the virtual object in the virtual room, the user will be informed of the physical and spatial information of the pointed object in real time through the verbal message. The Gesture menu, through the data of the iPhone's rear camera and gyroscope, obtains the posture change of the device. When the pitch of the device is higher than 30 degrees and lower than 90 degrees, the gesture menu will remain open. And when the gesture menu is turned on, it automatically switches from the current option to the next option every two seconds. When the gesture menu is closed, the system will execute the current options when the gesture menu was closed. The user does not need to physically interact with the device.

Compared to virtual cane (used to interact with virtual objects for real feedback), laser pointers allow users to quickly obtain general information about the environment and verify the accuracy of the established spatial layout. Through the use of these tools, users can independently explore in the simulated real space, safely learn the spatial layout of the destination, and achieve the purpose of free travel.

2 RELATED WORK

2.1 Audio Navigation Tools

There are many effective navigation methods in virtual reality.[2] We can guide the user's movement by arranging beacons on the ground of the virtual room, and through the feedback of the specialized sounds of these beacons, and then explore the spatial layout of the entire virtual room. However, this method requires users to have the ability to analyze three-dimensional sound, and requires a certain amount of time to analyze. We can also play an alert sound at the location of the virtual object by using a radar-like method. But this way contains too much information and may make users miss important information. Therefore, in this project we use a laser pointer to quickly obtain the spatial information of surrounding objects. By holding the direction of the laser pointer, the user can easily obtain the position of the virtual object. And the physical information of a single object is obtained through voice broadcast. [1]

3 METHODOLOGY

According to the movement data of the device in the real world through the rear camera of the iPhone, the laser pointer tool will make the same displacement in the virtual world. And the laser pointer tool will emit an intense beam of the ray cast larger than

the room's length. When it hits the surface of the virtual object in the virtual room (the laser can't pass through the virtual object), the user will get the physical and spatial information of the pointed object in real-time through the verbal message. Since the length of the laser is not fixed, users can explore all virtual objects in the room without considering the limitation of the length. However, due to the special use of the laser pointer tool, users won't get the feedback of simulating the sound of different objects colliding with each other in the real world. Based on the data collected by the iPhone's rear camera and gyroscope, we can obtain the posture changes of the device. The gestures menu will remain open state when the device's pitch is between 30 degrees and 90 degrees, any other postures will make the gestures menu remain closed state. And when the gesture is open, it will automatically switch from the current option to the next option every two seconds, and broadcast the content of the current option. When the gesture menu is closed, the system will execute the current options when the gesture menu is closed. Users do not need to physically touch the device mounted on a longer selfie stick to switch functions within the project.

4 EXPERIMENT

In order to study that the gesture menu can effectively improve the user's efficiency in using the app and that the laser pointer can help users quickly obtain the spatial layout information in the virtual room, I randomly selected five people without disabilities, and each tester will receive the same instructions about gesture menu and laser pointer tool. They will explore the complex virtual room and learn the spatial layout of the virtual room with a limited time of ten minutes by using a laser pointer and a gesture menu while wearing an eye mask. After confirming with the instructor that the study is complete, the tester will complete the reconstruction of the mental map with paper and pencil. Confirm the effectiveness of the laser pointer tool by comparing the spatial layout of the user's mental map and the actual map. And through subsequent user interviews, the positive effects of the laser pointer tool and gesture menu were identified.

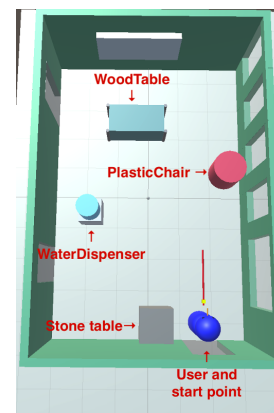


Figure 1: Experiment virtual room

5 RESULTS AND DISCUSSIONS



Figure 2: Mental Map Reconstruction

In Figure 2, it has four sets of user-built mental maps compared to real map. Black is the user’s mental map, and red is the actual spatial location map. From these comparison graph, it indicates that the mental map established after the user wears an eye patch to simulate a blind person using a laser pointer tool to explore the virtual room, although there is a gap in the distance, the spatial positional relationship is basically consistent.

	Position1	Position2	Position3	Position4
User1	278	330	22	355
User2	275	325	5	335
User3	300	330	10	355
User4	275	320	4	345
Average	282	326.25	10.25	347.5
Real data	268	315	11	342

	Position1	Position2	Position3	Position4
User1	Stone Table	Water Dispenser	Wood Table	Plastic Chair
User2	Stone Table	Water Dispenser	Plastic Chair	Wood Table
User3	Stone Table	Water Dispenser	Wood Table	Plastic Chair
User4	Stone Table	Water Dispenser	Plastic Chair	Wood Table
Real data	Stone Table	Water Dispenser	Plastic Chair	Wood Table

Figure 3: Spatial Relationship Evaluation

The table in the top of the Figure 3 indicates that the precise relative positional relationship of each virtual object relative to the user in the mental map established by the user is compared with the actual spatial map. The table below shows the virtual objects represented by different positions on the mental map created by the user. These two tables show that the user can accurately establish a mental map about the spatial layout of virtual objects by using the laser pointer tool, but it is difficult to record the names of virtual objects.

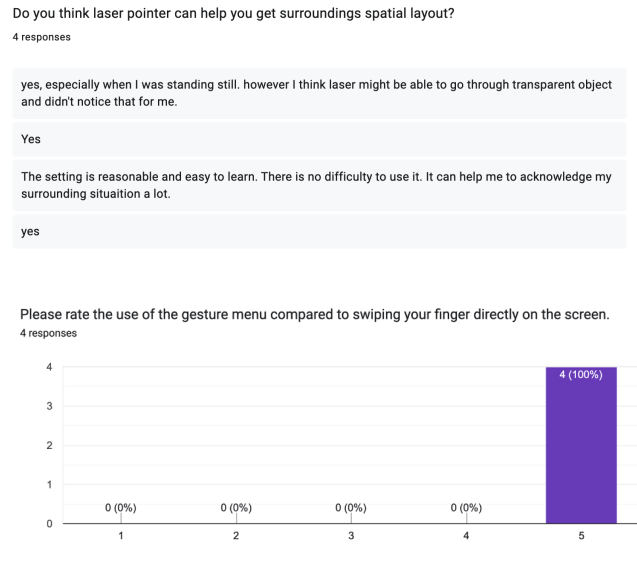


Figure 4: User feedback on laser pointer and gesture menu

Surveys from users indicates that users strongly agree that using the laser pointer tool can effectively help them obtain information about their surrounding’s spatial layout, and strongly agree that using gesture menus is far more effective than physically touching the device screen to interact.

6 CONCLUSION AND FUTURE WORK

In this work, we introduce the laser pointer tool, an audio-based tool to help users quickly obtain spatial information in virtual environments. It controls the movement of the laser pointer tool in the virtual environment through the information collected by the rear camera of the iPhone, and obtains the physical information and spatial information of different virtual objects by interacting with the surface of the virtual object to help users quickly build a mental map. . We also introduced the gesture menu based on gesture detection and switching the built-in functions of the software, which has become a new interaction method that replaces the original physical contact with the screen of the device. Through experiments on these two new features, we found that users can use the laser pointer tool to build an accurate mental map in a short time, and the gesture map makes the connection between the user and the app more closely. However, our research still has many flaws. Due to the limitation of participating users, we did not use blind people in the experiment, but simulated blind people by making ordinary people wear blindfolds. Because blind people have learned many exploration skills that ordinary people do not have, such as shoreline strategy, two point touch strategy, etc., the performance of ordinary people in the experiment may be quite different from that of blind people, which makes the experiment not very convincing. In the future, we will try to recruit different visually impaired research participants to enrich the design of our project. We hope that blind users can travel freely in the future.

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