

Marking the City: Interactions in Multiple Space Scales in Virtual Reality

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Fig. 1. Desktop Menu in Following VR Viewer mode while HDM-user creates a Marker with Spatial Menu and Radial Menu options.

Abstract—This article shows an overview of an immersive VR application to explore, to analyze and to mark large-scale photogrammetric 3D models. The objective is to interrogate the effectiveness of the proposed navigation process and annotation tools for spatial understanding. Due to the amount of interactions, different kinds of menus were necessary: desktop coordination menu, radial menu attached to the controller and 3D spatial menu for creating markers. Besides the menus, the navigation tasks through different perception space scales required a great number of interactions metaphors, patterns and techniques displaying the complexity of the user experience in Virtual Reality for understanding and analyzing urban digital twins. Those interactions allowed by the user interface were then analysed and classified according to a theoretical background and were experimented in preliminary tests with end users. Although designed for particular needs of the army, the tools and interactions can be adapted for city models explorations and urban planning. For future steps of the research, a usability study is going to be performed to test the performance of the interface and to have more end users feedback.

Index Terms— Immersive User Interface, Interaction pattern, Interaction technique, Digital Urban Twins.

1 INTRODUCTION

Digital twins' technologies for simulating cities are a powerful tool for planners and stakeholders. They are especially important for the development of smart cities. Studies suggest that the visualization of those 3D models in virtual reality can improve the understanding of existing and proposed urban spaces in digital twins **Error! Reference source not found.** Nevertheless, how the visualization of those models in head mounted displays (HMDs) can improve this understanding is not clear yet. Those devices allow a greater level of immersion, but this not necessarily means a deeper level of spatial

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Manuscript received xx xxx. 201x; accepted xx xxx. 201x. Date of Publication xx xxx. 201x; date of current version xx xxx. 201x. For information on obtaining reprints of this article, please send e-mail to: reprints@ieee.org.

Digital Object Identifier: xx.xxxx/TVCG.201x.xxxxxx/.

understanding. This research proposes an immersive VR application with navigation options through different space scales and annotation tools to turn 3D spatial understanding into 2D imagery. The objective is to understand if and how those features increase spatial understanding.

Studies have concluded that the visualization of virtual environments in computer screens have improved the understanding of their corresponding real-world environments [11, 12, 17, 18, 26]. While the presence in real environments aroused subjective perceptions of the users, virtual landscapes were more effective in transmit some intentions of the designers [17, 26]. Subjective evaluations of one group that experienced a digital twin in VR and other that experienced the real urban area appeared strongly coherent and highlighted the emergence of subtle quantitative but not qualitative differences, especially when added acoustic stimuli in VR [17]. In general, traditional media and physical models help the understanding of the general organization of the space, transmitting complete and integral information while the immersion in the virtual

reality environment brings more sensorial and less cognitive answers from the users, but with deeper reflections [18].

Those researches suggest that having ways to annotate and mark those impressions in the virtual environment like in traditional media may improve the spatial understanding. Ideally, should be possible to translate those annotations to more traditional media like floor plans, maps or graphs. That could improve the assimilation of dimensions in VR, besides the subjective perception created by walking around in an immersive virtual environment, or flying around and exploring the city model from different points of view that sometimes would not be possible in real life.

But for making those annotations in VR it is necessary to develop menus and interaction patterns and techniques for those tools, and although the research of 3D interfaces for virtual reality follow the process of hardware and software evolution since the beginning, the standards methods for those are not clear yet [2, 6, 8, 19, 21]. The interactions metaphors, patterns and techniques for Virtual Reality have not been consolidated like the ones for screen applications [15, 16].

The VR industry have developed some examples of menus for urban navigation for games and maps applications. Google Earth VR[14] has simple navigations patterns for visualizing 3D models and 360 degrees pictures. Spider Man: Far from Home[22] and Vertigo! [25] add to the immersive experience a different point of view and interaction patterns with buildings of the city. Fallout 4 VR [13] has a map menu option that resume location of several points of interest. Aircar VR[1] always shows a top view of the surrounds on the cockpit of the flying car. The VR driving simulator of the SUV Peugeot 3008 [10] also shows the map view of the area, simulating an on board GPS. However, those cases in general do not allow complex interactions with the 3D models that specialists and designers usually need.

This research consists in a virtual reality application for terrain exploration, mapping and training for the Austrian Army. 3D models elaborated with photogrammetric data are loaded and explored in VR through different points of view. During the experience, the users can make annotations and create markers in the 3D model. Although designed for particular needs of the army, the tools and interactions can be adapted for future city models explorations and the process of designing menus for different spaces can serve as reference for urban planning applications in virtual reality. This article interrogates the effectiveness of the proposed navigation process and annotation tools by analysing and classifying the interactions metaphors, patterns and techniques of the user interface and from user feedback from preliminary tests.

2 THEORY

Humans do not perceive the entire space equally; there are regions around us with different perception characteristics. The personal space is out to about 1.5m from the body and is the space where we usually manipulate objects. Action space is from 1.5m to 30m from a person's body. In this space is where social interaction usually happens, where it is possible to recognize other's faces and to talk. Vista space is all the space that we can see more than 30m away from our bodies, in these area objects are seen, but their characteristics and motion are considerably less salient for the human eye [11, 12].

Immersive VR systems allow interactions to happen all around the user's body with six degrees of freedom [15]. Nevertheless, those interactions should consider the perception space scales. Most of them should be in the personal space, the main content zone should be from 50cm to 1.3m and in the front of the user, in the case of a user sitting on a chair [2]. If the user can walk around in the room while in VR – the case of our application – than this area can be bigger and the sides and back of the user could be used for displacing some interface. While the action space is not optimal for placing objects manipulation is an area where graphical information will be noticed [2]. Information in vista space can deceive the user, like in the case of *trompe-l'oeil* [15], but in the case of immersive VR experiences in models with a

big area - like urban models – this can be very important for spatial understanding.

In graphical user interfaces, metaphors can help the user to understand how the interaction works, for example using an image of a recycle bin for deleting files from the system. The most suitable metaphors for 3D menu interfaces for spatial interactions are not clear yet. Kwon et al. have listed the current ones: desktop, room, card, art gallery, cube and box [16].

Those metaphors are the way the information is presented to the user, for interacting with the information interaction patterns and techniques are necessary. According to Jerald [15], an interaction pattern is a generalized high-level interaction concept (pointing, selecting, walking...), while an interaction technique is more specific and technology dependent (pie menu, voodoo doll, panel...).

3 METHODS

The application was made in Unity - version 2018.2.10f [24] using SteamVR plugin for Unity - v1.2.3 [23] and the VRTK - version 2 [4] toolkit for virtual reality. Working with Steam VR and VRTK allowed creating a user interface for different HMD models, in this case for HTC-Vive and Oculus Rift. The application was designed for two users: one user with a HMD in immersive mode standing in a demo room and a supervisor user that can watch the HMD-user in the desktop screen.



Fig. 2. Screenshot of Desktop Menu in Fit Plan to Screen Option.

3.1 User experience

In the desktop menu is possible to see the scene from four different cameras: Follow User in VR, Follow user in Plan, Fit Plan to Screen and VR User's Camera. There are also zoom and scroll options to better control the point of view (Fig. 2). At this point of the research, few interactions between the supervisor user and the HDM-user are possible through the desktop interface, but we assumed that they would be in the same room for communicating during the experience.

The interactions and tools for the HDM-user were organized in different kinds of menu and user interfaces. The first clear division is that the left controller is exclusive for teleport navigation in real scale immersion, while the right controller is used for selection (Fig. 3). On the right controller, there is a multi-level radial menu. With this menu, the user can change from different visualization methods and use tools for measuring or marking her path in through the model. The first level of the menu had the basic options of the application: Visualization modes, Point of view, Tools, Take Screenshot and Save. The first three options included subdivisions.

Visualization Modes consists in different rendering shades that reveal different information: Visibility – creates a red mask on every part of the model that can be seen by the HMD-user where she is standing (Fig. 4). Inclination – creates a red mask in parts of the 3D

model with high degree of sloping (Fig. 3). Fog – simulate fog in the environment.

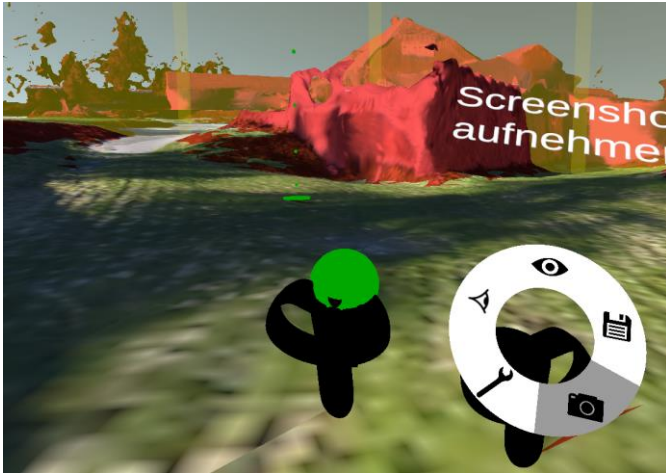


Fig. 3. Teleport navigation on left controller, Inclination mask (in red) and Fixed Distance (in yellow) activated in Real Scale VR mode.

The HMD-user can change between Points of View, changing the relation of scale between the user's body and the loaded 3D model (Table Top View, Immersive Real Scale VR and Flying mode). Table Top View – Reduces the size of the 3D model and all annotations and markers to the size of a table and adds a puppet to indicate the last position of the user in the Immersive Real Scale VR mode. In this option, the 3D model stays in the action space of the HMD-user. The Immersive Real Scale mode adds the user in the 3D model environment, both in real scale. The Flying Navigation Mode simulates aerial views of the model in real scale (Figure 5). In the last two options, the 3D model is in the vista space of the HMD-user.

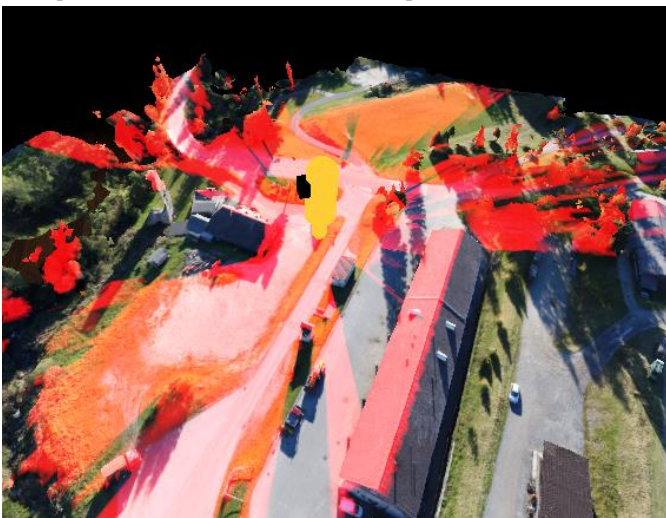


Fig. 4. Visibility Option in Table Top view mode.

The HMD-user can also use Tools options to create annotations in the 3D model: Measurements - for take real scale measurements. Record Path - draw her path through the model. Fixed Distance – create a 50 meters diameter sphere around the user. Markers – create markers that follow the joint military symbology of the North Atlantic Treaty Organization (NATO) (Fig. 1). The last tool is the Eraser for deleting existent annotations. The HMD-user can also take screenshots and save those measurements, paths and markers for loading them again later.

Each level of the radial menu had a maximum of six options, which was convenient for the user to change from one option to the other using the joystick or trackpad of the controller keeping the selection interactions in the personal space of the user. However, for the

Markers there were four different first options and each of these options with more than ten symbols, having more than 50 symbols that in some case should be combined to create a unique marker. This amount of options was not easy to visualize and select in the radial menu. The solution was to keep the four main categories for the markers in the radial menu and spatialize the options of the symbols in a spatial menu (Fig. 1).

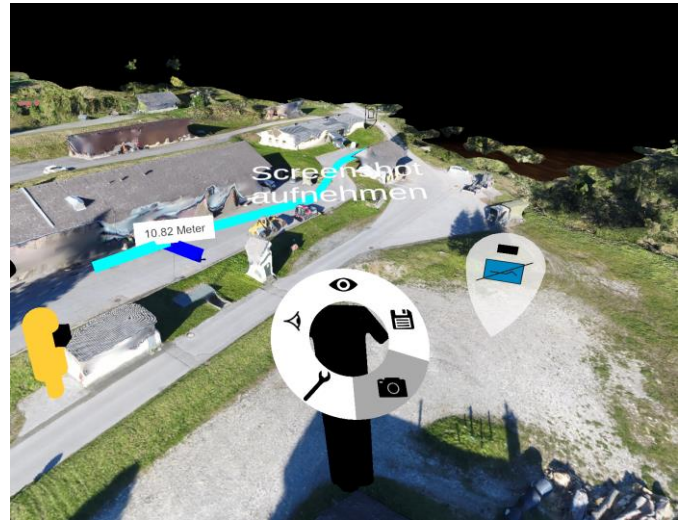


Fig. 5. Radial Menu for HMD-user in Table Top view mode. In the model is possible to see the miniature puppet for moving the viewpoint of the user, measurements and paths annotations and a marker.

3.2 Analyzing interactions

For the spatial menu for the markers, we opted for the Card Metaphor for the symbol selection [16] and the pin on a map metaphor for the marker element (Fig. 1). The symbols were organized around the marker in a way to create a selection room inside the 3D model. This menu shows a case of multiple perception space scale interaction, which the personal space of the radial menu and the action space for the spatial menu for creating the markers are inserted in the vista space of the model [11, 12].

Table 1. Interactions patterns and techniques of the project according to Jason Jerald's classification [15].

Task	Interaction Pattern	Interaction Technique	User Interface
Choose options in VR	Indirect Control - widgets and panels	Pie Menu	Radial Menu in Right Controller
Creating Marks	Hand Selection	Non-realistic Hands	Spatial Menu
Measuring	Pointing	Head pointing	Head point and click in controller
	Walking	Real walking	HMD sensors
	Automated	Teleportation	Click in left controller
Navigation/Viewpoint control	Indirect Control	Pie Menu	Options in Radial Menu in right controller
		Panel	2D Desktop menu
	World in Miniature	Moving into one's own avatar	Table Top view mode
		Voodoo doll	

For improving spatial understanding, the navigation patterns needed a big number of transitions between in the three different perception spaces for the HMD-use [11, 12]. The HMD-User sees the 3D model in the personal space (out to about 1.5m) in the Table Top mode, in the action space (from 1.5m to 30m) and vista space (more than 30m) in the Immersive Real Scale VR and in the Flying mode. Any time of the experience, the user can change from perception space scale using the radial menu options. The user interface also required different interaction patterns and techniques. In the table in Table 1, those interactions were listed according to the classification of Jerald [15]. In the table is possible to see that navigating and controlling the viewpoint through different perception scales demanded a great number of interaction patterns and techniques, while selecting and manipulating actions although are in a great number of option required less interactive patterns and techniques.

4 PRELIMINARY RESULTS

For using 3D spatial menus is important to consider the physical conditions for the VR experience. In this research case, the integration of radial menus with spatial menus was successful mainly because the HMD-user will be standing and moving around an empty room. If the user is seated or in a room with furniture large-scale menus in the action space interaction pattern would not be a good solution.

We worked simultaneously with a HTC-Vive and an Oculus Rift during the design process of the menus and that clarified that although SteamVR [23] make it possible to program interactions for both of devices the button equivalency between them creates completely different user experiences. So virtual buttons are better options for controlling the user experience when the application is not bounded to one device model.

In our preview trials, the multi-level radial menu was successful so far with specialists and trained users, for quick demonstrations with new users, having to perform various clicks to get into an option is not intuitive. This must be consider in case of application for participatory planning or design when the main audience is not composed of specialists.

The relation between the scale of the user's body and the 3D model has great impact in the quality of the experience of the menus. For example, it is possible to create markers in the Table Top view mode, but for that we had to adapt the size of the marker and spatial buttons and the menu can still suffer occlusion from the 3D model. This must be improved in future steps of the research, or the option of creating markers in this view mode may be excluded, depending on the usability study.

The research showed that for professional and specialized purposes virtual reality application should consider a 2D desktop interface; this was one of the specific request of the users after the preliminary tests. Only one person usually does not take planning decisions and the process can benefit from multiple users interactions and coordination panel. When it comes to exploring and understanding space measuring and marking actions, this should be considered.

The classification of the interaction patterns and techniques (Table 1) showed that although the application has many tools for annotation and manipulation in VR those interactions required less patterns and techniques to implement. While navigation and control of the point of view of the users required multiple interactions patterns and techniques showing that for exploring and understanding urban spaces the interactions that deal with the perception scales are more complex to implement. Our preliminary results suggest that for projects, which that is not much time or resources for development, is better to keep one point of view and develop manipulation and annotation tools than investing in changing the perception space scale.

The preliminary tests with end users have also shown that the option of colouring in red faces that have very steep is very important for understanding of the landscape geometry (Fig. 3). While the option for colouring what is visible by the HMD-user is very important for the coordinating user with the 2D desktop menu (Fig. 4). The users requested more integration between the coordination tasks in the 2D

desktop menu and the tasks performed in immersive VR, to allow a future remote coordination.

5 CONCLUSION

The recent development of devices to visualize augmented and virtual realities in game industry allowed the experimentation with those devices for urban planning with digital twins, but spatial understanding requires more than immersion. The preliminary results of this research illustrate that alternating between perception spaces scales is important for understanding the space and that requires multiples interaction patterns and techniques.

For future steps of the research, we will perform usability tests with final users and check the performance and adequacy of the proposed user interface. For future researches, we are looking for ways of applying measurements and markers tools for urban design and planning specific topics. Looking for guidelines of virtual reality interfaces for urban exploratory applications and maybe checking if those guidelines could be transferred for augmented reality in the real city landscape.

ACKNOWLEDGMENTS

The author would like to thank the Institute of Military Earth Sciences of the Austrian Army (Institut für Militärisches Geowesen – IMG) for the support in this project. VRVis is funded by BMVIT, BMDW, Styria, SFG and Vienna Business Agency in the scope of COMET - Competence Centers for Excellent Technologies (854174) which is managed by FFG.

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