

VR-based interface enabling ad-hoc individualization of information layer presentation

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Abstract. Graphical user interfaces created for scientific prototypes are often designed to support only a specific and well-defined use case. They often use two-dimensional overlay buttons and panels in the view of the operator to cover needed functionalities. For potentially unpredictable and more complex tasks, such interfaces often fall short of the ability to scale properly with the larger amount of information that needs to be processed by the user. Simply transferring this approach to more complex use-cases likely introduces visual clutter and leads to an unnecessarily complicated interface navigation that reduces accessibility and potentially overwhelms users. In this paper, we present a possible solution to this problem. In our proposed concept, information layers can be accessed and displayed by placing an augmentation glass in front of the virtual camera. Depending on the placement of the glass, the viewing area can cover only parts of the view or the entire scene. This also makes it possible to use multiple glasses side by side. Furthermore, augmentation glasses can be placed into the virtual environment for collaborative work. With this, our approach is flexible and can be adapted very fast to changing demands.

Keywords: virtual reality, CAVE, head-mounted display, virtual environment, interaction, visualization

1 Introduction

Environments, requirements, and ways to solve a task are often unpredictable and therefore cannot always be planned. Still, user interfaces (UI) created for scientific prototypes are often designed to only support a specific and well-defined use case of a very complex endeavor [1-4]. They often use a handful of classical graphical user interface (GUI) elements like buttons and panels, e.g., at the top of the field of view, to cover needed functionalities. For potentially unpredictable and more complex tasks, such interfaces are often unable to scale properly with the larger amount of information that needs to be processed by the user. Simply combining classical 2D elements and concepts would likely introduce visual clutter and lead to an unnecessarily complicated

interface navigation that reduces accessibility and potentially overwhelms users. Therefore, new methods are needed that allow users to set up their interface flexibly and appropriate to the situation at hand.

With recent developments in head-mounted display (HMD) technology, virtual reality (VR) and mixed reality applications become more relevant enabling, e.g., on-site mission planning for space and emergency services. It also has the advantage of utilizing the human capability of spatial processing, especially in combination with enriching real-world data with additional sensor data. Furthermore, VR can give the user a feeling of being on-site. This can help to understand the current environment and situation. Unfortunately, the classical way of accessing, managing, and displaying UI elements and information layers are still widely used although not very suitable for HMDs. New concepts for accessing, managing, and displaying information in VR and AR are needed.

In this work, we first give an overview on the state of the art, followed by a presentation of our concept including a general introduction to augmentation glasses, their application and possible use cases and finally a discussion of our approach.

2 State of the Art

UI design is closely linked to the characteristics of the display and its input devices. Originally, classic interaction in 2D using monitors, mouse and keyboard is based on classical GUI elements like drop-down menus or buttons which can be used efficiently for enabling and disabling the display of information and to interact with the application. Additionally, docking widgets facilitate the management of information layers and enable the user to fit the GUI to the current needs. Even in complex scenarios such as mission planning and execution for planetary exploration, these classical 2D widgets are widely being used e.g., by ESA [5,6], displaying all the information on a wall of monitors [7] allowing multiple specialists to analyze the data at the same time.

Instead of using a wall of monitors, it is also possible to use a Cave Automatic Virtual Environment (CAVE) placing the monitors or projection surfaces in a cube, circle, or half circle to, e.g., see a virtual representation of the environment of a robot [8]. Planthaber et al. [2,4] were able to use different input devices such as a controller, an eye tracker or even an exoskeleton [9] in their CAVE. The ability to choose the appropriate or preferred input device provides the operator with a better and more intuitive way to interact with and monitor the robot's environment. But even in their teleoperation scenario utilizing a CAVE, additional information visualization and interaction options, like setting waypoints, are managed by classical 2D widgets on different screens. This approach was appropriate for their teleoperation task, but for complex tasks like a rover exploration mission, this does not scale properly with the amount of data.

With the development of head mounted displays (HMDs) as consumer electronics mainly for gaming purposes, new use cases and approaches have been enabled. Classical UI design paradigms from 2D environments are often transferred to the immersive 3D environment provided by this new hardware. However, these design principles created specifically for constrained 2D environments limit the range of new possibilities

provided by 3D. The virtual 3D environment enables new ways of interaction that can be used to solve this problem.

Many HMD and CAVE-based virtual reality applications, such as mission operations centers for rover operations [2,4,8] or underwater exploration [3], use UI design paradigms from classical 2D environments. Following the same approach for more complex tasks with an increased range of functions likely results in an overloaded UI making the application more difficult to use. For example, [1] and [3] are using floating 2D panels which are fixed to the field of view. They display information like a mini map, the camera view of the robot, and the robot coordinates [3] or make it possible to use a measurement tool [1]. However, this comes at the cost of covering a significant part of the main application which displays the virtual environment. Adding more functionality to the interface while retaining the same design approach would quickly overload the interface and compromise large portions of the view.

Today, even more complex implementations of a VR interface for the commercial construction sector [10,11] still use static panels with information and UI elements to interact with the environment. As an example, [10] implemented a classic nested menu using 2D panels to control the display of routes and related information in the environment for a virtual training scenario. The virtual reality scientific collaboration tool for space exploration activities developed by García et al. [12] follows a similar design path. Various tasks like showing the rover path, selecting datasets, or creating landmarks are managed in a more structured way by using a floating menu. Even though this approach is less obtrusive by hiding unneeded information from the view, the amount and manner of presentation of information in 2D panels is static and not adaptable to changing scenarios or custom needs.

More recent concepts are being developed for mixed-reality devices that augment the real world with additional virtual data. NASA makes use of this technology in [13] to create an immersive mixed reality tool to visualize the surface of Mars. It is also possible to collaboratively inspect the environment and inform vehicle operation.

Mixed Reality applications are also being developed in the field of digital medical assistance. A review study by Kim et al. [14] discusses many practical applications for training surgeons, surgical planning, and surgery supported by VR and AR. Here, it is especially important to keep the field of view as clear as possible while augmenting it with additional information like x-ray images.

In the future, approaches will have to be developed that enable far more complex applications on the one hand, and on the other hand make even more effective use of mixed-reality approaches to enable simple, intuitive adaptation to changing, often unpredictable situations or to serve one's own preferences [15].

3 Concept Description

In the following, we present our new approach, which was designed with the aim of simplifying the interaction effort required to use the GUI and enabling efficient, ad-hoc presentation of information layers.

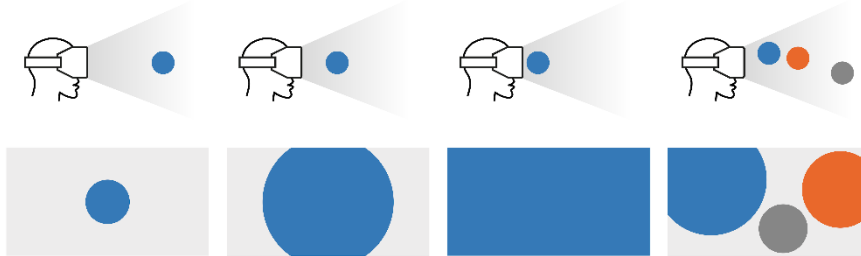


Fig. 1. Depending on the placement of the glass, the viewing area can cover only parts of the view (left, middle left) or the entire scene (middle right). This also makes it possible to use multiple glasses side by side (right).

3.1 General idea of augmentation glasses

The basic idea of our design approach is to have a set of monocle-like augmentation glasses, which can be placed in front of the virtual camera or directly into the virtual scene. These augmentation glasses can display arbitrary information layers augmenting the underlying three-dimensional virtual scene with data or even depict a completely different “version” of the scene. In a construction scenario for example, this could be the representation of how the area should look like in the future.

To implement the augmentation glasses, we render a virtual sphere which can be placed with respect to the virtual camera. Depending on the distance to the virtual camera, the augmentation glass can cover anything between only a small portion of the screen and up to the full screen (see **Fig. 1**). The augmentation glass can also be positioned along the other two axes of the camera coordinate system which allows for placing it anywhere in the field of view. This also makes it possible to use multiple augmentation glasses side by side, enabling the user to individualize the display as needed.

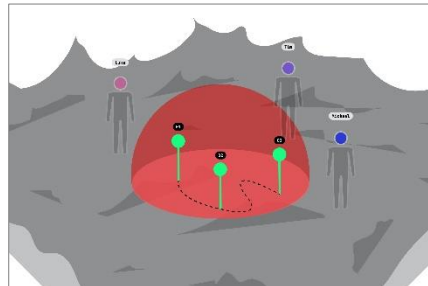


Fig. 2. Augmentation sphere (red) placed in the scene for collaborative inspection of a planned robot route (dotted line) with 3 way-points (green).

Furthermore, our concept of using such augmentation glasses allows to place the sphere directly into the virtual environment (see **Fig. 2**). This can facilitate collaborative work where multiple people can walk around in the virtual world looking at parts of the scene rendered with additional information through the augmentation sphere.

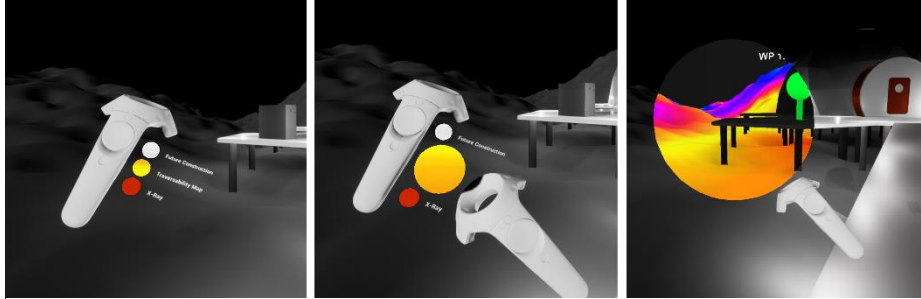


Fig. 3. Left: The stack of augmentation glasses is depicted. Middle: One glass is selected by using the right controller. Right: The user draws a glass from the stack and can use it as needed.

3.2 Accessing information layers

In addition to displaying layers of information, accessing, and managing information from these layers requires additional new concepts for retrieving, especially when there are many different layers to choose from.

In our virtual environment of a construction scenario on a lunar base, we implemented a stack of augmentation glasses located at the left-hand controller of the HTC Vive head-mounted display (see **Fig. 3** on the left). When the right-hand controller comes close to one of the augmentation glasses in the stack, the augmentation glass preview pops out, slightly increases in size and a small description is depicted (see **Fig. 3** in the middle). Pressing a button, the augmentation glass can be dragged to a location as needed (see **Fig. 3** on the right). This allows for a variety of uses: The augmentation glass can be used temporarily like a magnifier and then put back, it can be attached to the user's virtual camera where it stays at a fixed position relative to the eye, or it can be placed anywhere in the scene for collaborative use in case of multiple users. The implemented solution for accessing the information layers and customizing the view was chosen with the aim of making the process of finding, selecting, and handling augmentation glasses quick and intuitive. It also enables the user to set up the interface ad hoc and as needed.

3.3 Use cases

As mentioned before, our prototype was developed in the context of a lunar exploration and human-robot collaboration scenario. When working with robots, it is particularly important to understand what the robot is currently doing. This is especially relevant for detecting and identifying errors when multiple error sources are possible.

In an exploration scenario, it is important to display information of the environment and the robot. This can be, e.g., the raw laser scan data, the robot map as a color-coded heightmap, images taken from the orbit, and the traversability map to see where the robot can go, and which areas may not be accessible to the robot. Mission control also needs to create new target waypoints, where the robot should explore next. Scientists, on the other hand, need to be able to annotate interesting locations such as geological

rock formations or craters on-the-fly, which can later be used for mission planning. One might also be interested in the current task plan of the robot. This is especially interesting in the case of an error, but also when multiple robots or even humans must work together.

Construction site management, whether in space or on earth, can be imagined having a special display showing planned sites, buildings, or objects. This can also be easily complemented with, e.g., progress reports or a list of needed materials and assets at the specific site to be used for mission planning and task assignment.

Another very promising use case for our approach is the field of search and rescue. Here, operation centers need an overview of locations already visited, sensory information about hazards in an area such as contamination levels, the stability of buildings, fire, flooding etc.

With a very good tracking of the human on site and a virtual representation of the environment, our concept can also be implemented and used for augmented or mixed reality applications making all the features possible not only for mission control but also for humans on the moon base, the construction site or emergency services.

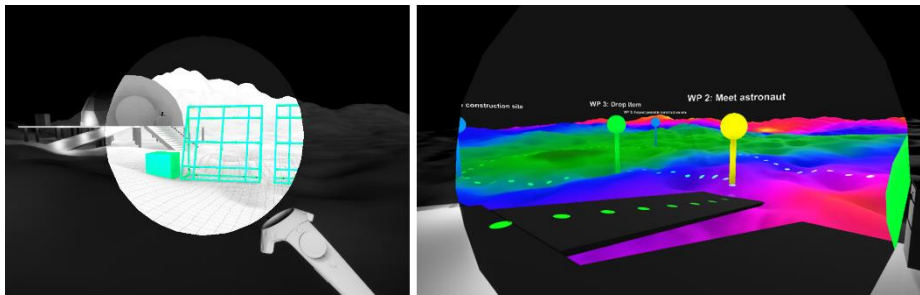


Fig. 4. Left: Example visualization of a construction view implemented using a render target. Right: An overlay with a traversability map, robot waypoints (pins) and route (dotted line) are depicted.

3.4 Implementation details

For our concept, all the different information layers need to be in the same reference frame making it possible to overlay or exchange the views. Some features like displaying the scene as a color-coded height map or enriching it with volumetric sensor information like gas concentrations or flood levels, can be implemented using shaders. Other features, like displaying and managing a construction site or placing new buildings and objects into the scene, need a separate virtual representation. This can be implemented using render targets (render to texture). For that, we use additional virtual cameras which render other representations of the environment, e.g., one which has additional models for planned infrastructure (see **Fig. 4**), into a render target texture (RTT). Then, the RTT will be displayed in the corresponding augmentation glass. We implemented our prototype using the Unreal Engine [16].

4 Conclusion

The concept of the augmentation glasses was developed with the goal of enabling efficient, ad-hoc individualization of information layer presentation. The augmentation glasses can be attached to the virtual camera or can be used temporarily by dragging and dropping it as needed. Depending on the placement, the augmentation glass can cover only parts of the view or even the entire scene making it possible to use multiple glasses side by side. Furthermore, augmentation glasses can be placed into the virtual environment for collaborative work. By using augmentation glasses to access and handle information layers, enabling and disabling layers only requires a single interaction that does not introduce a full change of view and does not require interacting with menu structures. Instead, it is natural and intuitive, resembling real-world interactions. However, this general concept is highly dependent on a good referencing of all the information layers and a good localization of the human.

While we believe that this concept could provide ways to simplify the workflow and provide more flexibility and individualization for users, the question on how to mix different information layers like robot maps paired with objects of future constructions has not been addressed yet. One way could be to implement an information combination feature where users can overlap different augmentation glasses with each other. When glasses overlap, their information needs to merge, and a new layer would be created.

Our approach was specifically designed for the handling of visual data. However, even numerical data, e.g., from joints of the robot, could be displayed on a placeable object that behaves similarly to the augmentation glasses and is drawable from a stack in the same way. Further, for our current interaction approach the user's hands must be free. However, using speech or eye tracking to control the accessing and handling of information layers could be a solution. For VR, we currently need an interaction device like a controller, while for AR, the control could be implemented by using gestures.

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