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Modular 3D interface design for accessible VR applications.

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Modular 3D Interface Design for Accessible VR Applications

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Abstract. Designed with an accessible first design approach, the presented paper describes how exploiting humans' proprioception ability in 3D space can result in a more natural interaction experience when using a 3D graphical user interface in a virtual environment. The modularity of the designed interface empowers the user to decide where they want to place interface elements in 3D space allowing for a highly customizable experience, both in the context of the player and the virtual space. Drawing inspiration from today's tangible interfaces used, such as those in aircraft cockpits, a modular interface is presented taking advantage of our natural understanding of interacting with 3D objects and exploiting capabilities that otherwise have not been used in 2D interaction. Additionally, the designed interface supports multimodal input mechanisms which also demonstrates the opportunity for the design to cross over to augmented reality applications. A focus group study was completed to better understand the usability and constraints of the designed 3D GUI.

Keywords: Virtual Reality, Interaction, Accessibility, 3D GUI

1 Introduction

The progression of the graphical user interface (GUI) has reached a level of ubiquitous understanding, allowing users who are accustomed to desktop or mobile device interfaces to interact through familiar interface elements such as windows, icons, menus, and pointers (WIMP).

However, with the adoption of virtual reality, these design decisions have for the most part been directly translated to work in a 360-degree experience supporting, 6 degrees of freedom (DOF). Resulting in the same 2D elements being used in virtual reality (VR) with user selection primarily being a ray cast in the form of a laser. This allows designers to use existing design concepts by placing elements in a similar fashion to a traditional desktop environment would use.

If we depend just on conventional interface design choices, we are not necessarily taking advantage of the extra dimension made available. Existing interaction techniques for VR have resulted in a novel and diverse set of designs that have primarily been developed for the VR games market [1].

3D interfaces provide the opportunity to utilize our sense of proprioception as we physically surround ourselves with static interfaces in the form of 3D objects akin to that of the real world. Proprioception can also be referred to as kinesthesia and is the ability to know where your body is in space and has been referred to as our "six sense" [2]. It gives the user an idea of where their body parts are in relation to their environment and how they may be able to interact with it. Drawing closer to incorporating the human body fully can increase our understanding of the 3D digital environment presented, by using our natural understanding of the world [3].

As VR has the potential to provide more presence than a traditional interface, the idea requires more interface design evolution to become more flexible and human-oriented. An example study simulated wind; the breeze enhanced presence among users [4]. Showing that somewhat unconventional methods can enhance presence, to which, natural interaction for the user may furthermore provide fewer constraints leading to increased presence. The developed interface outlined in this paper provides a multimodal approach to interaction design and fully supports existing ray-based input controls. Thereby reducing the adoption effort required by users who may have accessibility constraints, requiring them to use ray-based interaction. Using a new medium of fully 3D panels over traditional 2D windows or forms, the system in addition to supporting novel 3D interaction also allows for the migration of ray-based interaction techniques typical for existing VR applications. Gesture-based interaction approaches have been used for input, allowing the users' hands to be tracked with or without a controller during selection and navigation. The system is modular allowing users to move the location of all UI components in 3D space to suit their preference, with the addition of contextual-based UI being explored where UI elements appear only when relevant to the task being completed.

Predicting what an interactive element will achieve is largely responsible for its placement, context, and iconography. A skeuomorph is a design concept that is used to represent objects with their real-world counterparts, primarily used in user interface design - such as associating a floppy disk with a save icon. In Ivan Sutherlands' famous essay "The Ultimate Display" he opens with "We sense an involvement with this physical world which gives us the ability to predict its properties well. For example, we can predict where objects will fall, how well-known shapes look from other angles, and how much force is required to push objects against friction." Using the real world as a guide for the GUI we can cross over our ability for pattern recognition in context using inductive thinking, with the potential to enhance memory by association with their real-world counterparts. An important aspect to consider before exploring the opportunities made available by a 3D GUI was the vehicle in which to showcase the interface itself. Usability discussions were completed in focus groups which allowed participants to share their experience using the developed interface alongside peers and provide insight into the satisfying and frustrating aspects of the interaction. Establishing a familiar metaphor was important for this reason, as recruitment targeted users' previous exposure to VR applications, where novice to intermediate users was selected to participate. The selected demographic was used, as the study's focus was to understand the usability of the designed interface and highlight issues and struggles with a 3D modular GUI without significant context to current design philosophies.

A conceptual model was therefore established to understand the problem space for a new medium of interaction. To present the interface in an application that a 3D GUI may be applicable to, the development of a 3D visualization platform for geospatial positions was developed. Allowing for visualization of various forms of 3D spatial data including point cloud scans, video playback, and geospatial data which was represented by electric vehicle (EV) chargers' latitude and longitude positions. Querying of EV charger locations was completed based on their charging type and availability. This allowed for a selection of chargers to be scanned and linked to their real-world position visualized by their point cloud scan using the Microsoft Azure Kinect. The map was selected as the primary visualization tool as a homage to the map being the "graphic representation of the milieu" [5] but primarily due to it being a familiar visualization medium for many people.

2 Modular Interface Concepts

The definition of modular by the Oxford dictionary states, "employing or involving a module or modules as the basis of design or construction." In programming design practices, modular code is to divide the functionality of the system into separate modules that are independent of one another. The concept also stretches into UI design where interface elements are created for a variety of environments. An example of this is during website development, where interface elements are isolated with their own set of constraints, allowing them to be independent and dynamically adjust based on the user's device. This approach to a responsive layout allows for support across various platforms; mobile, desktop, tablet, and even VR. In contrast, defining constraints for 3D UI in immersive environments have been explored [3] but have also yet to be fully integrated into real-world applications. UI Elements without any constraint are problematic as the increased design space leaves many design choices at the discretion of the developer. The key areas in the presented 3D interface include the following and will be discussed further.

- Free-floating allows for adjustment in 6-DOF for users with specific viewing angle requirements and allows for anchored placement in 3D space.
- Contextual, allowing elements to only be displayed when relevant to the location in the environment resulting in;
- Predictable task-focused interactions, using skeuomorphs and colors around 3D interface trims in designated context zones

Key to the naming conventions definition, it aims to provide the "basis of design or construction." The presented 3D interface allows users to move the UI to a location in 3D space, that isn't dictated by the application being presented. Rather than employing rigorous design methodologies to focus on the layout of interactable element positions such as the location of buttons and sliders, we can instead empower the user to place interactive elements best suited to their needs.

By interacting with VR interface elements repeatedly, the user can learn the spatial location of objects and understand the interaction mechanism employed by them [6]. As a user completes their desired task, they can adjust the placement of immediate controls in location to suit their preference. This allows users who may have accessibility constraints to adjust the UI to a location that is suitable for their interaction.

Fig. 1. Render of the developed 3D interface panels, allowing for manipulation of the 3D map visualization by querying a geospatial dataset

The concept of consistently visible UI controls stems from traditional fixed UI elements. An example is the toolbar on most WIMP interfaces where the close, expand, and minimize buttons are always available to the user. The developed interface has included this fixed UI concept through an iterative development process ensuring users can show and hide 3D panels in a single action.

Panels containing UI elements such as buttons can be moved in 3D space with no gravity influencing them, resulting in panels being *free-floating*. The user interacting to move the placement of panels uses natural gestures such as grabbing and releasing. These panels can be fixed to the user’s virtual body for movement around the environment but also when not fixed to the user’s movement (controlled via button press) they are instead anchored in place in relation to the desired task being carried out in the environment. A paper exploring new directions and perspectives of 3D GUI [6] notes that “standard 3D UI techniques can and should be based on object attachment” when regarding interfaces floating in space. In addition, the author describes this as an exception, not a rule when relating real-world interaction to virtual interaction. The designed interface presented in this paper includes panels that are free floating based on the user’s exposure to existing interfaces in the real world that may have free-floating connotations. Primarily being, the computer tablet. Although the paper's release was in 2008, many users would not have been familiar with the concept of the digital tablet as the original iPad was released in 2010, two years after the initial paper's release.

The panel is a key component to the design of the modular interface, allowing for relocation in free-floating space and anchored to user movement or left static in a location desired by the user. This is consistent across all panel and UI elements, keeping interaction between elements predictable. Using panel color and shape to direct the user to these interfaces with predictable interaction areas. This was created by adding trim around all panels in a color that can be selected by the user. In figure 2 the trim is white around the grey panel, with various transparency properties on the back panel to provide contrast to the surrounding environment.

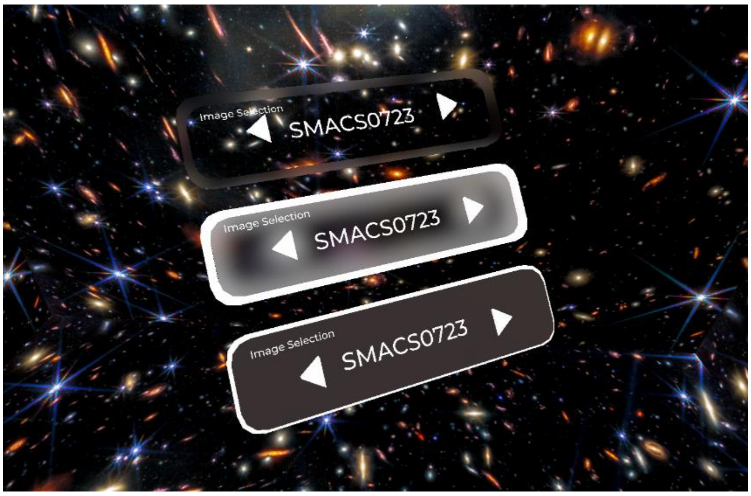

Fig. 2. 3D UI Panels allowing for side navigation using buttons, demonstrating three different contrast approaches in a noisy background environment.

The key to natural interaction is the use of gestures and physical movement to move panels, to support accessibility, it is intended that the interface can be customized via a configuration file that has values of key elements pre-placed in the environment allowing them to interact with the interface. For example, if a user is unable to stand and lie down, they may not be able to reach for the interface components at first, instead, another user or a configuration file can be used to allow the user to interact with the elements from their position. Further exploration into the availability of interaction techniques is discussed in Section 4.

The redesign of the traditional 2D slider into its 3D counterpart was centered around ensuring it doesn’t require a complex interaction, being a variation of small and large movements in a single action. Instead, the slider allows for scrolling via small movements at a fixed distance, not requiring movement across the entirety of the slider. Prioritizing shoulder and elbow movement over wrist movement. Due to the spring physics associated with the anchor point in the center, the slider's anchor always returns to the center position upon release. Scroll speed scales as it is moved further from the origin. This design is like that of the middle mouse click auto-scroll on existing 2D scroll-bar elements.

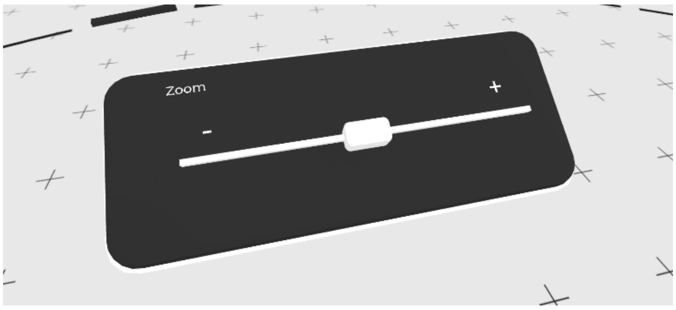

Fig. 3. Reimagined 3D slider using physic spring joints to return anchor to the center point after an interaction.

2.1 Required Constraints

With the addition of the third dimension being added to interface design, there becomes more opportunity for additional confusion in establishing a mental model of the system for end users, due to the context space in which the interface may be presented. With more freedom of space, there becomes an increased availability for the placement of GUI components. Existing 3D applications such as CAD software on 2D interfaces are designed for professionals and as such, provide a plethora of options in tabs and sub-menus. With the extra dimensionality of visualization VR provides, there is an opportunity for an excess of choice, consequently, an intelligent reduction of choice needs to be integrated into its design. It is therefore important to consider constraining the system to allow interface elements to display only when necessary.

The panels developed are a key area to which add constraints to. The button and slider elements that are traditionally found in forms or menu systems can be located via panels in the designed interface. These panels act as grabbable containers allowing the interface elements to be arranged inside an area that can be moved in 3D space to suit the user's preference. The borders of these panels are consistent in color and style to highlight their interactivity, a consistent interaction color theme was established to convey to the user that elements in this color can be interacted with. Such as a white button, white panel border, and white slider anchor.

2.2 Contextual Interface

Contextual UI location allows for interactable features to only appear when in proximity to the task at hand. Much like the real world, computer users can physically walk to a monitor to select its controls. If the monitor is fixed into world space in a virtual world, the question must be asked, is it appropriate for the monitor to be fixed? The two contexts described below, show how local user space and world space can be used effectively to provide UI context to the task being carried out.

Player Context

Consistent user interface elements are concepts that can be found in the WIMP design structure. A common feature of window controls allows for minimize, maximize, and float controls of windows or form containers. These are always available to the user and are persistent throughout the navigation of an application. In a virtual reality environment, the player's space can also be divided into fixed player UI and environment UI. The developed system shown in figure 4 shows specific UI elements that can be locked to the player's position while navigating each zone. Controls available to them may be consistent throughout environment contexts, such as loading a settings menu, resetting player position, or closing the application. The specifics of what events the UI elements complete are at the discretion of the developer, however the separation between environment-specific controls and player controls is the context in which they are displayed.

For example, closing the application would likely be best suited as *player context* UI as it is always linked to the player regardless of *environmental context*. Entering an environment focused on video playback in figure 4 annotated as “zone 2”, can allow for a play button to be locked and added to the player's context while navigating in this zone, but not necessarily. The player may choose to keep UI in a fixed location in world space close to the interface’s *environment context*, which is the virtual screen in this example.

Environment Context

Based on the player's location in the virtual environment, it may be appropriate to hide all UI and only display relevant UI elements based on the task in the environment. For example, if the user is interacting with the 3D map in figure 4 “zone 1", then the controls for this map should be located near the map itself, as the user would be unable to see details of the map if controlling at a distance. The context here is the environment which is map control. In the other example described above, video playback, the screen is the environment context and the UI elements that are in the proximity of this will be displayed.

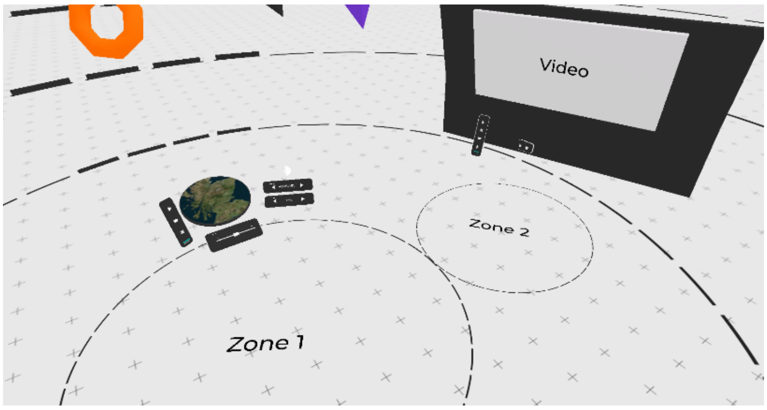

Fig. 4. Environment context UI zones, demonstrating UI elements only visible to the task

2.3 Natural Interaction Matrix

This section explores the requirements for a VR application, and how planning interaction mechanisms can support engagement with the task being completed. Evolving technologies and newer interaction techniques will likely result in the matrix changing for the requirements of an application over time however it serves as a baseline to understand the input techniques made available to complete an action.

In questioning naturalism in 3D interfaces [7], two high-level mechanisms for 3D interaction design are discussed. A design technique with *interaction fidelity* and another with a focus on enhancing usability and performance by using “*magic techniques*.” The two techniques contrast in strategy, where interaction fidelity focuses on how natural the interaction is in relation to a real-world environment, and “magic techniques” focuses on task completion in an unnatural environment.

Such as using the teleporting locomotion strategy due to lack of physical play space which would otherwise be a high-fidelity interaction. Each actionable task in virtual space will need to be broken down to fully understand the potential options made available and select the best-suited technique for the interaction. The paper [7] notes 3 universal UI tasks that can be viewed as high-level requirements for a 3D application, travel, selection, and manipulation.

Travel is movement in the virtual space, where both high interaction fidelity - physically walking in a tracked environment - and “magic” mechanisms - such as teleporting are options available to the user. In visualizing big data challenges [8], a set of requirements were provided that describe features a VR visualization platform should achieve in the context of 3D visualization of multidimensional datasets. This was used as a guide for the development of the conceptual model for an application with a 3D GUI focus presented in this paper. The matrix shown in table 1 categorizes these requirements into three interaction tasks, travel, selection, and manipulation. These are categorized further by a potential choice for their interaction mechanism, high fidelity, or a “magic technique”. Based on the requirement type, developers decided what category of interaction it falls under. The matrix is to encourage the exploration of High-fidelity and Magic interaction approaches in 3D UI development.

Table 1. Natural interaction matrix for defining universal 3D task interaction mechanisms.

Requirement	Scaling	Navigation	Subspace Selection	Object Selection	Object Move
Travel		x			
Selection			x	x	
Manipulation	x				x
Mechanism	Magic	High-Fidelity	Magic	High-Fidelity	High-Fidelity

3 Multimodal Input

In the following sections, multimodal input and selection approaches are discussed. Providing a multimodal approach to user input has been shown to allow more users to interact with the system more effectively [9]. The availability of various input mediums is an important accessibility design consideration and is a critical component of the modular system.

Input modality is discussed in the web accessibility guidelines for "pointers" [10] where timed and complex gestures may be inaccessible for some users. Although not to be avoided in its entirety, the functional recommendation is to offer alternative methods of inputs to enable users with motor impairments to interact with the interface still. The input control mechanism for the discussed 3D modular interface is supported by ray-based interaction. In addition to this popular method of input, by using gestures recorded with hand tracking - with or without controllers - we can support the user in deciding their preferred input medium.

As the user can freely move in 6 DOF, they are away from surfaces that can support fine motor skills for accurate selection of objects at range. Mouse and keyboard interaction approaches limit natural interaction grasp because of this and why for natural interaction approaches, hand tracking is a lucrative opportunity for improved immersion and intuition.

In comparison to 2D input approaches which are traditionally 4-DOF, 6-DOF interaction approaches have the caveat of requiring more physical movement which can be restrictive to some users. 2D input mediums have been shown to be two orders of magnitude more precise and have less latency [11] [12]. Although attempts have been made to alleviate this, more study is required to see what other algorithmic approaches can be used.

It is for this reason that supporting numerous input mediums should be considered when developing a 3D GUI. Every panel in the designed interface has elements of buttons and or sliders.

3.1 Hand tracking with Controllers

Ray-based UI interaction systems can support controller input with the use of a laser pointer. In augmented reality, the same concept of laser pointers is used as a metaphor for interacting with an augmented environment [13]. For 3D interfaces that can rely on gestures followed by the selection of interface elements, there is an opportunity for the support of controller and hand-tracking input. Supporting both allow for user preference to be exploited and the potential to use the same interface system as new input mediums are supported. At Meta reality labs, research into using electromyography (EMG) where electrical motor nerve signals are translated into actionable input for a virtual interface [14]. With new different input mediums, the interfaces currently developed in VR based on the WIMP concept may have to be redefined to support such an input. Whereas the opportunity with a modular 3D GUI, a multimodal input mechanism can be established from the start, including an accessible first design philosophy.

Not all VR headsets require controllers as they have inside-out hand tracking capability which at a minimum allows for navigation around the headsets OS via gestures – such as pointing. Specifically, in 2022 the Meta Quest 2 headset allows for navigation on the browser and loading of applications without the use of a controller. This has its advantages such as user convenience for a more passive experience such as video playback, however not all VR applications support hand tracking. By doing so developers are limiting those with hand-tracking headsets to experiencing their product. As the future could contain more and more hand-tracking supported headsets, it was therefore deemed important to develop support for hand-tracking and controller-based input.

The Valve Index controllers can be seen in the figure 5 with input mappings highlighted. These controllers use infrared on the index fingers to track the user's finger at a distance without touching any of the controller itself. The grip around the controller support tracking other fingers with the thumb having more infrared sensors available on each button at the top of the controller. This provides finger-tracking capability while also being able to support feedback via haptics.

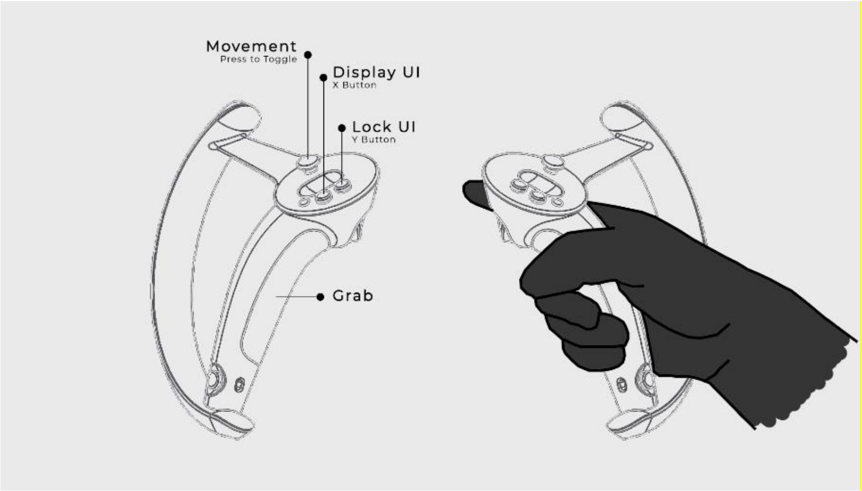

Fig. 5. Exclusive finger tracking approach supported with Valve Index controllers, allowing for locomotion using the joystick and two buttons for displaying and hiding the 3D UI

The environment is manipulated exclusively with hand tracking for this reason but selection/input with ray-based mechanisms can be used via toggle. The buttons on the controller do however provide additional functionality such as virtual space movement. Room-scale tracking is enabled by default; however, it is not always convenient, and designing for every room layout is not feasible. The joysticks are therefore used for locomotion techniques supporting teleporting and standing movement by clicking down the joystick. This keeps both mediums of movement selected by one control mechanism. In addition, this supports the same controls for each hand, allowing users to navigate using their preferred hand and further supporting temporary accessibility issues, such as users having a broken dominant hand.

The UI displayed around the user at any given time can be hidden and redisplayed at their own preference via a toggle on the controller's button. The UI can also be locked to the user's position as they navigate around the map. In Section 2.2, contextual UI is discussed where this feature opens a lot of opportunities for hidden control mechanisms in the virtual space.

3.2 Eye tracking

With the adoption of variable rate shading and foveated rendering based on eye tracking, there presents an even larger opportunity than physical interaction design, to intelligently introduce a new input medium into virtual reality interfaces. Rather than selecting a UI component using physical hand tracking, the gaze-based selection is an alternative ray-based interaction technique, that can be used as an additional input mechanism [15] demonstrated in Figure 6. Where the user can select a UI element for interaction and confirm their selection with a button press or with a countdown while gazing at a specific element for a specified duration based on a ray directed by the user's eye gaze. By designing an interface that supports both gesture and ray-based interaction we can exploit eye tracking as it becomes more available in VR headsets, such as the Quest Pro and HTC Vive Pro.

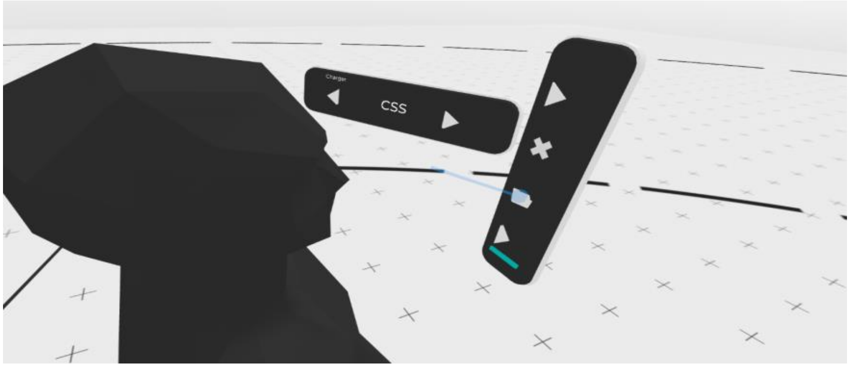

Fig. 6. Ray casting approach of selection can also be used with the 3D UI by using visual cues to show where the virtual "cursor" is being displayed.

3.3 Voice Input

Buttons on panels can be selected using voice input using the Azure Voice SDK. Each button has a required value to be said such as "left charger status." Each panel is named appropriately allowing any user who can view the panel to know its primary identifier. Every button that can be interacted with via voice commands requires a primary key to be said to activate the correct event. Alternatively, a hierarchy can be established if a button is the only one displayed on a panel. For example, the panel tag title followed by the button. Due to the significant amount of UI displayed, this was only implemented on a set few buttons for experimentation. An example of the keyword followed by a command is as follows broken down into the primary key and command associated with a button. “Charger panel, next.”

Beyond the selection of buttons, such a mechanism can be used to expand menus into further groups without alternative interaction. Such a mechanism can enhance the usability and performance of the task being completed by the user by being presented with only relevant information to the task being carried out. This allows preparation for the next task while still immersed in one.

Emerging user interaction design principles could also have a place in a virtual environment. Sonic interaction design (SID) can play a key role in supporting the quality of an interactive experience. Paper [16] describes how multimodal listening approaches such as “listening in, up, out, through and around” a play space can help form shape perception.

Although not directly implemented in this conceptual model, it does provide a notion for further expansion by exploiting audio cues for 3D objects beyond selection feedback.

4 Research Design & Methodology

The preliminary focus group study provided qualitative data about how 6 users reacted to a 3D GUI, allowing the ability to query a database and update visual cues on a 3D topographical map. The aim of the study is to identify potential accessibility constraints and explore the use cases for producing high and low usability satisfaction.

Participants were invited for an initial interview to confirm they are the target demographic for this study which was targeted at users aged 18 to 55 and classified their experience between intermediate use of virtual reality and inexperienced. The participating users were aged 24-29.

4.1 Participant Interview

Preliminary interviews were carried out to establish a baseline user base of novice to intermediate VR users, with users between 1 and 3 on the Likert scale displayed in table 2. User consent was required at this stage and was followed by an opportunity for participants to highlight any history of locomotion sickness in the context of VR.

Table 2. Initial interview questions to target users VR exposure

Initial Interview Questions				
Do you have experience with motion sickness from VR or other?				
Are you at present comfortable to proceed?				
Scale from 1 to 5, where would you place your VR experience?				
1	2	3	4	5
Once or Never	Rarely	Occasionally	Frequently	Very Frequently

4.2 Process

The in-person study was completed where participants were in the same room around a screen which allowed the current user's VR headset perspective to be displayed, this was to encourage discussion about experienced interactions with the system. Firstly, a tutorial demonstration was provided by the chair to the entire group, allowing them to view the external screen and ask questions about what they are seeing. This provided an overview of the interface to give some context and expectations on interactions.

Once an overview of the experience was presented by the chair of the focus group, the first user was placed into VR, this was selected based on their experience in VR. Those who are novices with little to no experience – Likert scale 1 – were asked to go first and users were then selected incrementing in VR exposure until everyone had completed the task.

The study demographic only had novice to intermediate experience with VR. Requiring headset adjustment and fine control over the IPD for each user which took 2-5 minutes per user. Participants only started the experience once their headset was comfortable and they could see text in the environment clearly. Users were asked the following.

1. Walk around the space and select a locomotion technique of their choice (if the default joystick wasn’t comfortable, they could opt for teleport)
2. Interact with the 3D UI Panels that interface with the map and move the map to latitude-longitude locations queried.
3. Interact with the point cloud playback and view the cloud alongside the video counterpart.

During the interaction, the user in the experience was asked to share their unfiltered thoughts about their interactions. Other members of the focus group could spectate from the perspective of the VR user and participate in the conversation as well due to displaying on an external screen. After 10 minutes or so the next user would be placed into the same experience. Once half of the users have completed their experience further questions were added to the group discussed in Section 4.3.

4.3 Assessment Criteria

Notes were carried out during each participant interaction in the focus group session. Questions were asked to support in identifying areas of interaction satisfaction partnered with the observation notes taken. **Thematic analysis** was used and will be outlined in the following section which allows for themes and patterns to be identified that can be further explored with further questioning. Key questions for discussion were asked throughout and open to anyone to respond, not just the user in the experience at the time. Two key research questions are focused on and are supported by three follow-up questions.

Research Objective 1: What aspects did you see as high usability satisfaction?
Research Objective 2: What aspects did you see as low usability satisfaction?

Question 1: How was the experience overall?
Question 2: Where do you see the application of such an experience?
Question 3: What do you think of using a 3D Interface?

4.4 Results

A total of 6 adults participated with initial interviews indicating their exposure to VR was 1-3 on a Likert scale of VR experience, with 4 users being inexperienced at 1 on the scale, and 2 being at scale 3. This defined a baseline demographic of novice VR users. No candidates were disqualified at the initial stage due to experience with motion sickness. One participant reported they do get travel sick, but due to their exposure to VR in the past were comfortable to proceed as previous VR motion sickness exposure was due to a sharp drop in HMD framerate.

Users who stated 1 on in the initial stage said they have only used VR for demonstrations at short intervals at shopping centers or at a friend’s house. Users who put their experience as a 3 on the Likert scale shared that they have previously owned headsets, however, it has been “a few years since using it.” Key themes were consistently brought up by all users, these included, controls haptic feedback, multimodal input, task-specific usability, and UI functionality.

Haptics

One of the points of discussion was how users know that they have interacted with a game world object. Responses here ranged from desiring more vibration feedback to having unique sound prompts for every type of action completed. A frequent comment was that users didn’t know when their finger had entered the actionable UI element such as a button. They suggested visual effects that could be added to let the user know that the button was ready to be interacted with. Due to the 3D depth requirement to trigger a button, this comment came up more than once. One comment discussed how haptic feedback wasn’t fully recognized due to the sound that was played back, they said they heard the button press, and that indicated selection to them without vibrational haptics, which went unnoticed upon reflection.

Multimodal Input

Users had the capability to select their desired locomotion technique, either teleporting or using the joystick for a more natural walking experience. Two users brought up that they instead felt comfortable physically walking in the place space and found that using the joystick to navigate was to move larger distances to interact with the floating interactable around the environment. Another user did mention that a larger play space would have been preferred but also commented that if they were familiar with their physical surroundings, they would feel more comfortable. Ideas discussed regarding this included demonstrating the pass-through VR mode that allows the VR headsets camera to be displayed to allow the user time to become more familiar with the physical environment. The joysticks however were not favored by one user who hasn’t spent much time in VR apart from one previous demonstration, this made them “feel sick” and preferred to use the teleportation mode.

Two users once entered the environment instinctively looked for a laser pointer to interact with the UI, even after watching other participants interact. They shared that this was something they are used to in VR and haven’t interacted with UI in this way before. One user stated they preferred to use their finger to interact with the slider using physics colliders rather than grabbing the slider's anchor handle.

Virtual Environment

One user shared that they are never in a cockpit-like environment with so many controls floating around them so learning how the elements interact with their hands was a learning curve. In addition, it wasn’t always clear what elements are interactable with their virtual hands, once informed that everything in the environment is interactable participants ventured away from the menu to explore the floating 3D models in the distance. Visualization of the point cloud scan of the geospatial location selected proved to be an exciting point of discussion. One user mentioned that they haven’t experienced anything like this before and had ideas for virtual meeting rooms to be presented like this, allowing for a fully collaborative 3D experience. Further to this discussion comments on collaborating in this environment were discussed as a benefit for sharing 3D data, with use cases being discussed in the tourism sector for viewing hotels and in the real estate sector for viewing the property.

Video playback was also a discussion once a geospatial location was selected, a user mentioned it felt unnatural to look at the video and said it was something they would have to get used to seeing a video “floating” in space. Furthermore, one user adjusted their headset and went back into the experience, and instinctively tried to grab the interface without the controllers being placed on them.

UI Functionality

The users were tasked to interact with the menus and panels surrounding the 3D map which allowed for zooming and navigating around the world. One user shared a creative comment, that moving the UI system between locked and unlocked positions “felt like a Star Wars cockpit more than a menu” another user praised its interaction as feeling more “natural” than a conventional UI. Users unanimously enjoyed being able to hide and show the UI based on what they were doing in the environment, allowing them to walk without the intrusion of the objects being displayed in the environment, allowing for less distraction when completing tasks. However, one user mentioned that there could be an annoyance if the UI panels are obfuscating a task being carried out at the time. In such a scenario the UI panels would be required to be displayed while also interacting with the 3D map movement.

Pertaining to extending functionality, some users felt there was a lot of freedom to move and place the UI in different locations but would have additionally liked to scale the UI elements presented allowing for complete customization of the interface elements. In addition, two users stated that they always customize the UI for applications they have and saw the benefit of real-time manipulation of the UI's location, allowing for specific UI priorities to be "kept close" to the user at relevant tasks.

High usability satisfaction highlights

One user who was rated 1 on the scale admitted to not using their less dominant hand – left – for anything other than movement. They preferred to use their dominant hand for interacting with UI elements and having the freedom to select the hand they use for movement as both controllers supported movement was a benefit.

Another high usability feature that was discussed was how close the UI was to them after the initial setup, they found it helpful to have the controls move around with them as they explored the environment with the addition of the locking and unlocking feature. One of the more experienced users shared that they wanted to move the UI as soon as they were placed into the environment to locations that they prefer, and further discussion exposed that having UI not relevant to the current task at hand would be cumbersome.

Users thought highly of the UI being displayed only at relevant locations where tasks were completed showing a clear indication of what task the UI elements were associated with. The contextual UI in this scenario allowed users to explore without requiring them to manually disable the UI based on where they were in the world "the map UI disappears when I can't see the map which makes sense."

Low usability satisfaction highlights

One user stated while using the joystick locomotion technique that looking at their feet made them feel "wobbly" this was discussed where a virtual set of legs may benefit them. Novice users shared that they were concerned with how long it took them to set up their IPD and adjust the headset which was large, and one comment suggested wireless headsets may provide less of a cumbersome experience. They shared that they were confused as to why distant objects were blurry.

Some users were concerned with the haptics vibrational frequency being set too low. It wasn't consciously noticed that it was being used, although it was admitted that they could hear the sound which may have distracted them from the vibration.

Although UI elements could be moved, one user desired to scale and snap the elements to ensure they are always straight. The current implementation allows full rotational freedom resulting in some UI panels not being "straight or parallel."

One user with a 3 on the experience scale shared they prefer to have the traditional first-person joystick rotation movement over snapping rotation to 45 degrees. This was described as a “smoother” transition for turning on the spot.

4.5 Discussion

The focus group study targeted users with little to intermediate exposure to VR applications, with the goal of supporting an unbiased view from existing VR interface design aiming to encourage discussion on novel ideas the interface presents. It provided insight into usability concerns when interacting with an exclusive 3D interface environment. Findings concluded high usability satisfaction when interacting using natural interaction approaches, such as the manipulation of the interface in 3D space via hand gestures. Low usability satisfaction was primarily focused on the haptic feedback of the interface, where depth perception using hand tracking was a concern for multiple users as they were unsure if the UI element had been interacted with.

User safety is of the highest concern when working with any population Initially users were asked if they had experienced motion sickness from travel or VR in the past [17]. The study was designed to focus on users’ movement being minimal in the real world and virtual world as motion sickness is primarily experienced by those who passively travel [18] ensuring they are as comfortable as possible while interacting with the presented interface. All users felt comfortable proceeding with the focus group as the one user who has experienced motion sickness in the past had intermediate exposure to virtual reality experiences. Users were also offered to sit down if it would make them more comfortable as the experience is also possible to do this way, but users wanted to physically walk between interfaces which drove discussion around how UI is presented in different areas of the environment. Topics such as object occlusion between interaction areas were raised because of this.

Participants expressed that they enjoyed being in the environment and interacting with the various objects and interface it presented. Users were encouraged to discuss between them in an informal manner what they enjoyed and what made them uncomfortable to interact with, this generated a significant amount of relevant conversation exposing ideas on how the presented interface could be used in various applications along with their usability considerations. The 3D map of the world provided an element of familiarity to users, standing as a metaphor that all participants reported being exposed to in the past in a more traditional way via smartphone and desktop applications. Interacting with the map in a fully 3D immersive environment was reported to be an enjoyable and memorable experience due to the familiarity and comparison users could provide.

The study format was focused on the user discussion with the headset being rotated between each user leaving time for discussion while one user was interacting with the various panels containing buttons and sliders. This allowed for the formulation of thematic discussion, leading from one idea area to the next and exploring the usability considerations in various contexts.

4.6 Conclusion

This qualitative study explored the use of a modular 3D interface presented in an interactive VR setting. An important aspect to consider before exploring the opportunities made available by a 3D GUI was the vehicle in which to showcase the interface itself to participants with appropriate feedback. The developed application provided a conceptual model using a 3D topographical map, linked to geospatial locations allowing for navigation and view selected locations through a point cloud scan. The modular panels provided a novel interaction mechanism that leverages the strengths humans use in their day-to-day interactions and empowers the user to adjust real-time interface elements to suit their exact needs and preferences.

Overall, the focus group discussion provided key areas of future work, where notably low usability satisfaction was perceived with appropriate haptic feedback being a primary concern. The participant's sentiment overall however was positive during the experience, with many ideas being generated for how such an interface could be used in a practical application.

Limitations of the study included time allocation per user, where some users took longer to adjust to the virtual environment than others. Some users naturally immersed themselves in the VR environment and were comfortable interacting with the various elements it provided with minimal direction. Whereas other users needed more guidance through the applications flow, and to understand that the entire environment is interactable with their virtual hands.

With the rapid adoption of VR headsets and their sensor capabilities - such as eye-tracking, this growing area of study appears to lack a multimodal development approach beyond using typical ray-based interaction. It is therefore important to iterate 3D GUI design concepts with users to expose usability constraints with various input mediums. The implications of the presented study will provide a framework for future VR focus groups, allowing for developed 3D GUI components allowing for faster iteration of high and low usability satisfaction.

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