VR Interactive Prototype: The Future Wardrobe. Explore VR interaction design for the sense of presence enhancement through an immersive VR installation

Jing Lyu
jl6328@rit.edu

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VR Interactive Prototype: The Future Wardrobe

Explore VR interaction design for the sense of presence enhancement through an immersive VR installation

Jing Lyu

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Fine Arts in Visual Communication Design

Rochester Institute of Technology
School of Design
College of Arts and Design
Visual Communication Design
Rochester, NY
December 10, 2018
Committee Members

Chief Advisor
Mike Strobert
School of Design, College of Art and Design

Associate Advisor
Daniel DeLuna
School of Design, College of Art and Design

Associate Advisor
Shaun Foster
School of Design, College of Art and Design
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1.0 Abstract

Virtual Reality (VR) is a new platform that provides the public with an immersive experience in a virtual space. With the development and promotion of VR hardware devices, virtual reality technology is applied in various industries such as the advertising of products, traveling, game, art, therapy, education and many others. Unlike media such as videos and pictures, VR applications allow users to interact with content instead of only watching. Beyond the novelty of the technology, for a meaningful immersive experience, VR interaction design and visual design must work together to place the user in a natural and comfortable state. The immersive VR interaction design is the key to improve the sense of presence in VR.

However, most VR applications are still using traditional two-dimensional interactions. The most common is that information is displayed on a two-dimensional plane or a three-dimension space only has few interactions available. It is hard for users to keep having the presence through those traditional interactive ways. This project is a VR interactive prototype exploring VR interaction design to enhance the sense of presence through the showcase of the future wardrobe. It creates an immersive experience of integrating the futuristic user interface design, responsive gesture-based interactions, and VR environment design.

Keywords

Virtual Reality Technology; VR UI Design; Immersive Environment Design; Gestural Interaction Design; User Experience;
2.0 Introduction

2.1 Background

Intriguing VR experience creates a presence for users. It should not only visually immerse users in the VR scene, but also let users behaviorally feel that they are the protagonists of the virtual world. Different from two-dimensional user interfaces with limited range, VR users are involved in the borderless information display in a 360-degree virtual space. VR interaction design is to help users get information from the virtual scene. Therefore, to intensify users’ sense of presence in VR, it is necessary to consider the useful way information is presented in the 3D space, and also consider whether users’ behavior is suitable for this environment. The traditional two-dimensional interaction design isolates users from having the presence in the VR environment because it has no depth of space.
2.2 Problem Statement

*It is hard for people to have a presence experience when they are interacting with traditional two-dimensional interactivity in virtual reality.*

As televisions, computers, and smartphones use screens to display information, people are familiar with getting information on the screen in front of them. However, in a VR environment, users are impatient with reading a lot of images and texts on a flat plane, because the image resolution of VR devices at this stage is not very high-definition for legibility. Moreover, when users pay attention to the interfaces in front of them, they are more likely to find out what information is on the interface instead of exploring the scene (Schell Games 2016). Applying the two-dimensional screen in the VR scene will lessen users’ motivation to explore the scene, and reduce the spatial immersion of virtual reality.

Two-dimensional interactions are monotonous. The design of two-dimensional interactions is more focused on allowing users to get content using simple behaviors quickly. However, when users are in the VR scene, they have already visually obtained information and a sense of three-dimensional space. VR user experience design needs to pay attention to what it feels when users interact with spatial information. Besides, two-dimensional interactions are not intuitive. VR users in the virtual scene, intuitively want to touch everything, this curiosity brings concentration that is one of the factors to obtain immersion (Lidwell, Holden and Butler 2003). However, the two-dimensional interactive stacking interfaces hinder the curiosity. Traditional interactions are not adaptable to the scene and keeping users isolated from the VR environment.

This project is a VR interactive prototype exploring how VR interaction design help users increase the sense of presence in virtual reality environment. It is mainly designed from three aspects of the VR interactions. The futuristic user interface is designed to display information, which aims to enhance the spatial immersion for users by combining the user interface with the VR scene. In the VR interaction design, responsive gesture-based interactions are used to increase the sense of intuition and entertainment by reducing interaction steps. In the building of the virtual scene, create a comfortable space without motion sickness for users according to the principles of VR space design. Finally, to build a VR demo, this project was prototyped in Unity3D by collaborating with a developer.
3.0 Context

The objective of this VR prototype is to enhance the experience of presence in the VR environment by increasing the interactions between users and the scene in a comfortable three-dimensional space. Three approaches are applied in this prototype.

3.1 Building A Non-real World Scenario

This project takes The Future Wardrobe as the content, which simulates the use flow of a smart closet. The user plays a future human being, who has an intelligent wardrobe. The smart closet can project virtual models of the clothes. Users can interact with the virtual clothes and track different outfits’ location inside the closet, allowing the user to pick up these chosen outfits directly to avoid messing the closet (Figure. 1). Because the user's identity in this demo is a future person, the scene design mainly creates an atmosphere and context for a future vision. Thus this project is to study the VR interaction design in the scene that is not a simulated real world.

The non-simulated real world VR scene means that the environment is not familiar in the real world. This unusual scene design is mostly in the field of product advertising. Some product companies or brands prefer to use VR showroom to showcase their future products concepts, such as Tesla Showroom In Virtual Reality, Mercedes-Benz 360° EQ VR Experience. The scenes created in these VR applications are usually scientific fictional and futuristic. In these applications, users cannot immediately recognize new products or concepts, so they need to explore the environment and get more information. In this case, to build the presence for users, it is not enough to create the affordances or feedbacks for items in the scene. It also requires impressive information display and the interactions that are suitable for the worldview expressed by the virtual scene.
3.2 Responsive Gesture-based Interactions

Users should fully be immersed in the first-person interactions and behaviors of a future world. Therefore, in the interaction design, the user is given some “superpower” to create a sense of the future. For example, when the user needs to pick up an item from a distance, he can use the “superpower” to let the object flyover. Responsive gesture-based interactions are designed as the primary interactions of this project. It sets the limited range of movement for the user’s hand to determine the interactive actions (LeapMotion 2015). The interactive gestures replace the traditional selection behaviors: the button and the controller’s ray casting, allowing users to swing their arms to communicate rather than only fingers. This approach does not only enrich the behavior and also increases the fun of interaction.

3.3 Futuristic User Interface Design

The user interface design in a VR environment essentially simplifies the logic and the hierarchical relationship of interfaces to reduce the interactive steps (不二飛 2017). Moreover, the information interfaces should be distributed across the scene, which ensures users a complex and complete interactive scene to create full presence. The story background of this project is the future world so that the UI design needs a way more sci-fi style.

In order to build futuristic scene-like interactions, the types of UI are divided into diegetic UI and on-body UI. The diegetic UI is more to show the information associated with this project’s story (University of London n.d.). These contents are distributed and hidden on different objects in this scene. And only show information when users have “requested” or “needs” it. This method can avoid users getting lost in much simultaneous information. On-body UI means that some functional UI is placed on the user’s body or limb and moves with the user.
4.0 Solutions For VR Interaction Design

4.1 VR User Experience Design

VR user experience design (UX) is a communication bridge between users and the product. It builds the users’ behaviors for understanding the product’s functions and features. UX can behaviorally create the sense of presence for users in VR space. This project starts with designing the use case of the wardrobe that users need to interact with, and how users use the future wardrobe by the input device.

4.1.1 Use Case of The Future Wardrobe

This use case of the wardrobe shows that there are three main steps in using this wardrobe (Figure 2). Users can interact with the virtual menu of the closet after wearing the virtual augmented-reality glasses. Users can choose the clothes they want to try on in the virtual menu. Then using the closet’s tracking function to locate the selected outfit in the closet. The last step is that users can open the closet door and take out the dress and check the dressed look through the mirror.

![Figure 2. Use case of The Future Wardrobe](image-url)
4.1.2 Input Device: HTC VIVE

This prototype uses HTC VIVE as the input device. HTC VIVE has a head-mounted device that displays a 360-degree virtual environment. Space-based tracking technology allows users to walk within a physical space of up to 15’ × 15’. Wireless controllers provide users with tactile feedback and diverse interactive ways, which are extensions of the users’ hands. I set different functions for buttons of the controllers enabling users to interact with the virtual wardrobe menu(Figure 3.).

Users mainly use three buttons on the controller. The trigger button is the switch of gestural interactions that define which movement is the interactive action, as users move the controller all the time in VR environment. To interact with the wardrobe menu, users need to hold the trigger button and make gestures. Users can hold the side button to pick up items and press the pad button to show the outfit’s location inside the closet.

*Figure 3. Functions of HTC VIVE Controllers*
4.1.3 Responsive Gesture-based Interactions Design

In the use of this future wardrobe, users’ behaviors have six sets of actions: open and close the wardrobe menu, selection, pick up items, put on and take off clothes, switch to another outfit, unfold and close the wrist menu. These actions are designed as gestural interactions. To avoid gestures are too abstract to understand for users. The gesture design of this project uses some metaphors of the physical world, which means extended by the habitual behaviors of people in the real world, and induces users to play gestural interactions intuitively.

**Gesture 1: Open and close the wardrobe menu**

As the closet menu is hidden in the scene, users need to hold the trigger button and pull down to open the closet first level menu. Conversely, closing the closet main menu requires to move the controller from bottom to top (Figure 4.). These gestures are evolved from the traditional interaction: drop-down list menu. Drop-down menus are widely used in web and mobile platforms, which help users learn this gesture.

![Figure 4. Gesture 1: open and close the wardrobe menu](image)

**Gesture 2: Selection**

After opening the first level menu of the wardrobe, users need to choose a type of clothes and enter the second level menu. Users can stare at an outfit model making it bigger than others by eyes tracking, and then drag it close to users. To go back to the main menu, they need to push the outfit model away (Figure 5.). These gestures are used to simulate people’s habits of life. When people want to see an item clearly, they often intuitively shorten their distance from that item. Similarly, if users want something away from them, they usually do the push.
Gesture 3: Pick up items

In the second level menu, users need to pick up the clothes model directly with the controller by holding the side button. This gesture simulates a people’s behavioral habit that when people want to take something, they intuitively reach out and touch the thing (Figure 6.). This gesture replaces a choice behavior in two-dimensional interactions: pressing a button or using ray casting to select an item in VR scene.

Gesture 4: Put on and take off clothes

When users want to try on a suit, they need to pick up the suit model. Pick up is an intuitive gesture that uses the controller to mimics tangibility of real-world interaction. To wear the suit, users can keep it on the controller by holding the side button, and then put the controller on their real body. After they release the side button, they will see a character appear next to them, and the character wears the selected suit. This gesture is to simulate the most straightforward people’s dressing action like wearing a hat. To take off the clothes, users only need to pick up the outfit from their body, and then throw it out. The clothes model will automatically return to the original position in the second level menu.
**Gesture 5: Switch to another outfit**

In the second menu, to check the next outfit, users can move the controller from the left to right or right to the left (Figure 7.). This gesture is also extended from the two-dimensional interaction. When interacting on the screen in the physical world, people are accustomed to swiping interfaces by moving the finger.

![Figure 7. Gesture 5: shift to another outfit](image)

**Gesture 6: Unfold and close the wrist menu**

The wrist menu is a history of the clothes that have been tried on. The purpose of hiding history menu is on users’ wrist is to save interactive steps and ensure users to check the menu at any time. If design the history menu in the way of traditional interaction, users will go through several steps to check the history content, which is repetitive and tedious in a VR environment. To expand the wrist menu, users need to twist their wrist and palm up, and users can take out the clothes from the wrist menu and try on again (Figure 8.). The design of this gesture comes from the children’s behavioral observations. When they show a candy in their hands, they habitually spread hands to others.
4.1.4 Gaze Detection

Based on current technology, the gaze detection means that track the angle of the head to determine where the user is looking, not the real track of eyeball. Gaze-based interaction is intuitive for users, and it is appropriate for the situation that users do not need to move fast and content of gentle rhythms (P. 2018). This prototype has only one scene and does not require lots of users’ actions. It is active to use the gaze tracking to assist users when they make selection. When users want to choose a long-distance outfit, they can look at the outfit model making it larger than other models, and then it has been selected. Gaze controlled selection is more natural than waving arms around to focus a pointer.
4.2 Futuristic VR User Interface Design

VR user interface design (UI) is mainly the way to design information display in the VR environment. Since the VR space is three-dimensional, the information display of VR should be considered for spatial distribution. The diegetic UI primarily are related to the story of this prototype, which includes information of the closet, clothes, the future human being and clothing menu of the closet. The purpose of the diegetic UI is to increase the realism and credibility of this future world. There are also functional UI, which are hints and feedbacks for users to help them interact with gestural interactions, such as on-body UI and tutorial UI.

4.2.1 Diegetic UI

Information about Wardrobe, Clothes and The User

The information is designed to improve the story atmosphere that increases the realism of the virtual world. The clothes data includes purchase date, brand and so on (Figure 9.). Each piece of clothing has this kind of information, but it only shows on the outfit model in front of the user (Figure 10.). The info about closet contains capacity, battery state, temperature, ventilation and so forth (Figure 11.). These user interfaces are scattered in different parts of the smart wardrobe. For example, the capacity data is placed on the left door of the closet (Figure 12.), and it is displayed when users look at the left door. The user’s information includes name, height, weight, dress style, etc. (Figure 13.) There is a UI animation showing on the Head-up Display (HUD), which is played when the user wears the AR glasses of the wardrobe in the VR scene.

Figure 9. Info UI for clothes
Figure 10. Info UI only shows with gaze detection

Figure 11. Info UI of the wardrobe
**Figure 12.** Info UI is placed on different parts of the closet

**Figure 13.** UI animation of the user
Wardrobe Menu

The wardrobe menu has two levels. The first level menu shows the category of clothes. The second level menu displays outfits of a type such as running suit, kendo suit, and training suit containing by the Exercise menu. All clothes are built by 3D models instead of using images. 3D models are more visually appealing and provide more ways to interact with like the user can rotate the outfit model to check details. To display the wardrobe menu, all clothes models of the first level menu surround the user (Figure 14.). The clothes models in the second level menu are arranged horizontally on the opposite side of the user (Figure 15.).

Figure 14. The Radius of the closet first menu is 1.8m.
4.2.2 On-body UI

The UI placed on the user’s body includes the functional UI of rotating clothes menu, the history menu of showing outfits that tried on, and the tutorial UI. In the first-level wardrobe menu, the user can turn the circle UI on his waist to control the rotation of clothes models around the user (Figure 16.). This circle UI is to facilitate the user to check the outfit models and avoid the motion sickness caused by the user turning around to see models.

The history menu is hidden on the user’s wrist, which displays vertically the clothes models that the user has tried on (Figure 17.). The wrist UI is designed to help the user open the history menu. After the user turns the wrist to the angle of 180-degrees, the wrist UI will turn blue to remind the user that the angle of rotation is sufficient.
Tutorial UI primarily teaches the user how to use gesture interactions, each step has a prompt, and follow the user’s sight to move. Besides text prompts, the start point and end point are also designed to guide the user to do gestures (Figure 18.), allowing the user to interact with the tutorial to improve the success rate of gestural interactions.
4.2.3 Visual Feedbacks

The gestural interaction of this project is to let users wave their arms in the air. Some feedbacks like trail and colors are designed to help users determine if the gesture is worked. The trail is used to track the movement path of the controller. It shows the moving direction and distance. Yellow is the original color for the starting point of a gesture. When the controller moves to a valid gesture distance, the trail color changes to blue. After users release the trigger button, the interactive gesture is effective (Figure 19.).

![Figure 19. When the gesture worked, the yellow changed to blue.](image)

4.3 VR Environment Design

According to the design principle of VR environment, it is hard for users to recognize the shape of an object 10 meters away and is different to see the details of an item 1 meter away (Applebee 2016). The scene design and items placement of this prototype need to follow the principle, which means the items that users will interact with the need to be organized within 1 meter. Besides, the distance between items and users should be reasonable that aims to prevent users walk a lot.

There are some technical limitations of the input device: HTC VIVE. For example, if users walk out of the traceable range, controllers' position will be tracked inaccurately; the headset has many connecting wires that are inconvenient for walking.

The distance between the first level menu of the wardrobe and the user is 1.8 meters. As the 3D clothes models are made in real proportion, the user is easy to feel oppressed when all clothes models are too close to him. The distance of 1.8 meters allows the user to look the outfit models comfortably. The clothing model in the second menu is 0.4 meters away from the user, which is to facilitate the user to reach out and pick up.

The scene is designed to create a futuristic bedroom. The most effective way for users to feel the future style is to have them immersed in the space environment. The arched dome applied for the bedroom to build a structure of the spacecraft. For the objects' design, the irregular shape is
designed on objects and a large number of flat lights to enhance an atmosphere of the futuristic scene (Figure 20.).

Figure 20. The scene of this VR prototype
5.0 Implementation of VR Prototype Development

5.1 3D Modeling

The VR scene and items of this project are all 3D models. In order to have a final optimizing prototype in the program, the total number of all models meshes is controlled below 20,000. All environment models were built in Autodesk Maya (Figure 21.), and the textures were drawn in Substance Painter. Finally, designing the lighting and particle effects enhance the scene atmosphere in Unity 3D. It is different from scene building. The clothes models and character models were built in Marvelous Designer.

*Figure 21. The scene of this VR prototype*
5.2 VR Prototype Development In Unity 3D

The VR prototype was built in Unity 3D through collaborating with a developer. It is a process of balancing the ideal design and implementation. The developer and I have encountered many challenges and problems. Due to technical or VR device limitations, I have to modify the design to achieve a good result continually.

5.2.1 Challenges For Gestural Interactions Development

This prototype requires users to wave their arms for responsive gestural interactions. In order to avoid letting users get the fatigue of “Gorilla arm” (Goodwins 2008), the moving range of gestures should not be too broad. After many tests, the movement range of comfortable gestures can be determined by these four factors: the effective distance of the controller movement is 0.25 meter; the starting point of the gesture cannot cross the user interface or items; the allowable offset angle of the gesture movement is 30 degrees; the user is taken as the center coordinate of the gesture, and direction of gesture is judged from the x, y, and z-axes to distinguish different gestural interactions.

How to guide users to interact with this prototype is also a challenge. Gestural interactions are challenging for people who never have experience with virtual reality. The tutorial is designed in the user flow of the prototype to make it easy for users to learn gesture interactions. When users finish a gesture tutorial, they can get the result instantly, instead of letting them learn in an individual tutorial room, and then recall what they studied.

5.1.2 Technical Issues

There are three problems related to technical limitations. Firstly, it is weird to reflect the user’s entire 3D body with a mirror in VR. As current VR devices can only track the headset and hands controllers, the character model projected by the mirror only have to let the head, and two hands follow the user, and the arms and body are stiff. In the prototype, after the user tries on a virtual clothes model, feedback of dressed the clothes should be provided for the user. In the original design, the user can see the dressed look from the mirror on the closet. However, thanks to the technical problem, the way of checking the dressed clothes from the mirror is removed, and a character model is placed next to the user to show the clothes in the final version.

Secondly, in the stage of build prototype program in Unity 3D, the lighting effect could not be rendered out. Scene lighting was darker than the previewing in edit mode. After the investigation, it was found that because I use the emission material for lighting instead of regular lights to enhance the futuristic atmosphere, the emissive lighting needs different render setting. This problem was
addressed by changing the render type of emissive material from Real-time to Baked.

The last issue is that after the UI animation is added, the demo was overexposed and the texture of the material was disordered. After two days of troubleshooting, the reason for this strange phenomenon is that the size of the PNG sequence of the UI animation was too large, resulting in insufficient memory for the computer graphics card. The solution is to reduce the size of the UI PNG sequence frame from $2048 \times 2048$ to $1024 \times 1024$. 
6.0 Results and Improvement

6.1 Exhibit The VR prototype

This VR prototype is an exploration of VR interaction design. Try to create a futuristic virtual world with futuristic user interface design, responsive gesture-based interaction design and immersive 3D virtual environment, let users feel the presence in VR environment. This project uses HTC VIVE as a VR input device, which offers a physical space for walking and two wireless controllers for more interactive ways. The first version of this prototype was exhibited at the Imagine RIT festival (Rochester Institute of Technology 2018). After observing many visitors’ tests, the issue of making successful gestures needs to be improved (Figure 22.).

The low success rate of drawing gestures makes users feel frustrated. There two reasons result in this issue. Most visitors cannot follow the tutorial to move the controller in an accurate distance or direction of an interactive gesture. In the first version, the tutorial is consisting icon and texts to describe how to make gestures, but it is still hard to imagine. Therefore, in the final version, the tutorial UI was modified to allow users to participate in the interaction. Each gesture tutorial has two points that are the yellow start point and the blue endpoint, guiding users to learn the gestural interactions while making these gestures (Figure 24.).

Figure 22. Exhibition at Imagine RIT 2018
(Chen 2018)
In addition, people usually make gestures by pulling arc lines instead of straight lines. Most users are used to turning the shoulder joint not the elbow joint. When users draw a gesture, the controller’s movement usually mixes two axes, such as the y-axis and the x-axis, or the y-axis and the z-axis. In the final version, I increased the degree of the axis offset of gestures from 15° to 30° (Figure 24.), ensuring the high success rate of gestural interactions.

The revised final version of the VR demo was exhibited at the event of RIT MAGIC Spell Studios Building Opening Day (McGrain 2018). The final version of the tutorial is more effective than the first version, and the success rate of interactive gestures has also improved.
6.2 Final Result

The final design of The Future Wardrobe link (Website and Video):
https://jinglyu-design.com/vr-prototype-the-future-wardrobe

Figure 23. More content of this VR prototype on this website.
7.0 Conclusions

The Future Wardrobe VR prototype is an experimental project exploring the VR interaction design to improve the sense of presence. By creating a virtual world of the futuristic environment, users are immersed in acting as future human beings and interacting with a wardrobe. This project integrates the futuristic user interface design, gesture-based interaction design, and virtual reality environment. These three approaches help users access information quickly and interestingly from virtual space. It is designed to avoid the use of two-dimensional interactions, allowing users to have the feeling of presence in exploring the virtual scene.

After observing the two exhibits of this VR prototype, I found that whether users can use this prototype successfully and smoothly depends on how much VR experience they have. Users who do not understand VR technology need to learn how to get information in the VR environment. As the popularity of VR devices is not as extensive as televisions, computers, and mobile phones, users are accustomed to the information being concentrated in a screen and then pushed to them. In a virtual space with no boundaries, users become cautious, and their interactive actions are reserved or even rarely turning the head to explore the surroundings. The gestural interactions and futuristic user interface require users to adapt to the sense of loss brought by the virtual space, as well as the lack of proprioception, and then to practice the coordinating of the controllers and eyes to interact freely. This adaptation process is laborious for VR novices to learn in the short playtime of the exhibition. Most visitors are trying to make useful gestures, and only a few people who already have VR experience have completed the process.

Based on my conclusions, the futuristic gesture-based interaction is not the mature mode for the current public. However, after the VR technology is popularized and more advanced VR equipment, the gestural interaction will not only track the position of the hand but will allow the user to use fingers to make more intuitive interactions flexibly. In the design to enhance the users’ sense of presence, not only the development of intuitive VR interaction design and realistic vision, the interactive design of sound, touch, emotion recognition is also the future direction (Labs 2017).
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