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Virtual Reality on a SWIM: Scalable World in Miniature

Jarod Pivovar* University of Minnesota
Jasmine DeGuzman† University of Minnesota
Evan Suma Rosenberg‡ University of Minnesota

Figure 1: The original view of the WIM is set to the overall virtual environment as shown in the figure on the left. The center figure shows the user selecting a nearby tiny playset as the new view of the miniature model. The right figure shows an updated view of the WIM in which the user has successfully selected the tiny playset from the virtual space and scaled it up to make interactions more convenient.

Abstract

The World-in-Miniature (WIM) metaphor is a 3D user interface technique that allows the user to interact with an identical miniature copy of the virtual environment they are in. Users are able to manipulate an object in either the miniature copy or the life-size copy and have that change reflected in the other model. This general model lacks a method to adjust the sizing of the objects in the miniature copy or the view that it displays. As a result, precise movement on objects of a different scale becomes difficult in vast and compact spaces. We propose the Scalable World in Miniature (SWIM) which affords independent scaling and finer control across a spectrum of object sizes. By treating the WIM as an independently scalable volume of interest, users can set specific objects and subsections or the entire environment as their view in the miniature model at a scale to their liking. Only the objects displayed in the WIM can be interacted with, allowing for more natural interactions with objects of different scale factors.The proposed solution of the Scalable World in Miniature (SWIM) provides users an increased flexibility and more intuitive interactions with the WIM system.

Index Terms: Human-centered computing—Human computer interaction (HCI)—Interaction techniques; Human-centered computing—Human computer interaction (HCI)—Interaction paradigms—Virtual reality

1 Introduction

The original World-in-Miniature metaphor proposed by Stoakley et. al. [1] offers the user a more dynamic view of the virtual environment by providing a hand-held miniature copy of it. The user is able to interact with an object in either the WIM or the life-size world and have it reflected in the other model. The mapping of the objects to their counterpart in the other model thus enables the user to simultaneously interact with and manipulate both the hand-held miniature copy and the life-size virtual space.

Our proposal of the Scalable World in Miniature (SWIM) is based on the observation that it is difficult to interact with an object of a different scale located in the user's far-field. The SWIM affords the use of independent scaling and precise manipulation across a spectrum of object sizes through the utilization of an independently scalable WIM for user-designated regions as shown in Figure 1. The user chooses whether they want to focus on the virtual environment at large or a specific section and collection of objects. Additionally, users have the ability to scale this selection to their liking, independent of the scale of the rest of the virtual environment. The WIM's view changes to reflect the selection made using the volume of interest and renders only the objects within it. This allows the user to interact more naturally with objects of a different scaling such as very small objects by scaling the WIM up, or conversely with very large objects by scaling the WIM down.

2 Related Works

The SWIM expands on the capabilities for scrolling and scaling of a WIM [3] as well as making the view of the WIM more dynamic [2]. It also builds upon the idea of the Magnorama proposed by Yu et. al [5].

One of the limitations of the original WIM metaphor was that it lacked a means of scrolling and scaling. This was later extended by the Scalable Scrolling World in Miniature (SSWIM) [4] then extended by Truman et. al. This resulted in the simplifying of the required user interaction [3] to address the case of discrepancy amongst scale factors. Similarly, we decided to utilize the distance between hands as our method of scaling. In their solution, users have the option to manually scroll allowing them to observe an area of the WIM without the need of walking over to the intended location. It was from this idea that inspired the SWIM's usage case of being able to interact with an object in the user's far-field. The SWIM further extends the work on scaling and scrolling with the user's ability to scale a specific portion of the environment rather than the environment as a whole.

The idea of allowing the user to change the focus of the miniature copy stems from Trueba et. al.'s method of a Dynamic World-in-Miniature (DWIM) [2]. This iteration created an algorithm that automatically selects the region of the virtual environment that is most important to the user by requires that the environment have pre-existing subdivisions. Without these subdivisions, the WIM defaults to showing a view of the entire virtual space. With the SWIM, the user manually selects the objects they want included in the miniature copy resulting in the virtual space not requiring any pre-established regions. The SWIM affords users the flexibility to display specific objects and subsections or the virtual environment as a whole.

Yu. et. al [5] proposed the Magnorama technique to improve the remote medical teleconsultation experience in which a remote expert in Virtual Reality could collaborate on a procedure with a

*e-mail: pivov004@umn.edu
†e-mail: deguz033@umn.edu
‡e-mail: suma@umn.edu

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local user that was using Augmented Reality. The Magnorama acts as an interactive diorama which extracts a region of interest from the virtual space that the user can independently scale. The use of the Magnorama significantly enhanced its user's capabilities of precise annotations on the selected region of interest. The Magnorama creates a duplicate copy of the region of interest. The interactive duplicate therefore has no relation to the corresponding objects in the virtual space so users can only manipulate and annotate the duplicate copy. It was mentioned that future work on the topic would include actually being able to select and manipulate objects. While creating a copy of the user-designated region with the SWIM, it maintains the mapping of objects in the miniature copy to the corresponding objects in the virtual space. By doing so, the user is able to manipulate and interact with both models simultaneously.

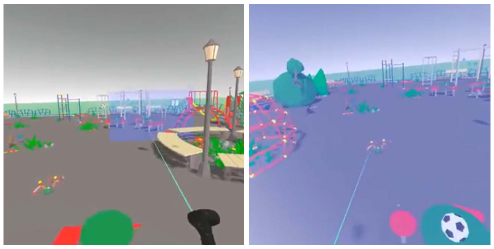

Figure 2: Our interaction technique displays a preview of the portion of the world space that will be used as the focus of the WIM with a cubic selection window. The left figure depicts the user only wanting a small subsection of the world space displayed in the WIM. The right figure demonstrates how the user is also able to select the entire world space for the focus of the WIM as the light blue volume of interest completely covers the environment.

3 Methodology

3.1 Implementation

With the goal of having a dynamic view, it has to be able to change to what the user wants displayed. Since the system has to be able to change its focus point, it needs to be able to do more than simply mimicking the movement of a larger object and its corresponding smaller copy to create the WIM effect. In order to copy the position of the smaller object to the larger one, a vector of the distance from the center of the WIM is taken every frame and scaled according to the scale factor. This is done using polynomial scaling so that the user can select very small scales and very large scales. Scaling is done relatively each frame and supports one degree of freedom (1DOF). This allows for better ease of implementation since the local scale gets reconfigured whenever the object parent changes. The larger object is then changed to the position in the world space that represents the focus of the WIM resulting in an absolute update due to the updated position not being relative to the previous frame. This process can also be reversed to instead copy the position of the larger objects in world space to the smaller objects of the WIM.

Whenever the user is not holding an object, the smaller object copies its transform properties from the larger object using the methods just described. Only when the user is holding the object does the reverse happen. The smaller objects are only grabbable when they are either already grabbed, or that portion of the object is within the boundaries of the WIM. Only a cubic portion at the center of the WIM is visible. If an object is not grabbed and is outside the WIM cubic volume, the portion that lies outside the boundary is made invisible by a shader therefore making it not interactable.

The exact method of scaling and repositioning can be changed easily to any desired method. The presented work implements scaling with simple pointing to determine the new WIM focus location, and it uses the distance between the hands to simultaneously determine the new scale of the WIM, similar to the work done in [3]. After it is initially loaded, the WIM sits just a little in front of the user. In order to change the center of focus of the WIM, the user must hold down the secondary button on either controller. This results in a ray shooting out the front of the controller and displays a preview of what portion of the world space the WIM will focus on as seen in Figure 2. While pointing at the desired location in the world space, the user is able to simultaneously change the scale of the WIM focus by changing the distance between the controllers. Once the desired scale is chosen, simply release the button again and the WIM will change its focus.

3.2 Design Process

We initially began designing this solution as part of a project for CSCI 5619: Virtual Reality and 3D Interaction at the University of Minnesota. The original assignment was an exercise on implementing more advanced selection and manipulation techniques such as Spindle, the Fishing Reel variant of the pointing technique, and the Go-Go grasping technique. This assignment was later used as the base for the final project in which students were tasked with exploring some topic in 3D user interface software in more depth than in lecture. The project was split into three benchmarks that were due throughout the semester: a proposal stage, an implementation stage and a final presentation and demonstration. After completing the project, we were inspired to expand the idea and submit it as part of the 13th annual 3DUI contest.

In order for the files to be stored in a central location, code was uploaded to a GitHub repository and documentation was stored in a Google Drive folder. The presented work was created on a machine running Windows 10 using Unity 2021 and although it was tested on the Oculus Quest, it is designed for any general VR system.

4 Conclusion

The World in Miniature (WIM) metaphor affords users a finer precision over the virtual space by allowing them to make changes in the miniature copy and see it reflected in the corresponding life-size objects in the virtual environment. We implemented and extended the capabilities of precise selection to incorporate the ideas of a dynamic view of the WIM for a Scalable World-in-Miniature (SWIM). By treating the WIM as an independently scalable volume of interest, the user is able to change the view of the WIM and set the scale of the objects within it independent of the rest of the virtual environment. Future iterations of this proposed technique involve enhancing the user interactions for more natural movement. One such example is allowing the user to pick up the WIM after a view has been chosen and grabbing the edges of the WIM to change the current scale factor. Through this expansion, the SWIM affords users increased flexibility and more intuitive interactions across a spectrum of object sizes with the WIM system.

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