Volume Visualization on a WIM: Design Considerations and Planned Evaluations

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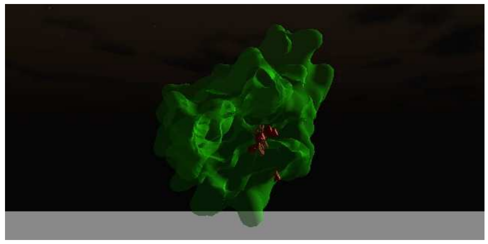

Figure 1: Volumetric visualization of a molecule with user defined waypoints.

Abstract

We present on-going work on designing a world-in-miniature (WIM) interface for interaction with volumetric data sets in immersive virtual environments. In the proposed system the WIM consists of a small representation of the volume directly in front of the user, who also sees a large-scale first-person view of the environment. The user can draw paths in the WIM using hand gestures to generate flight paths through the larger volume, and the WIM also serves to provide context showing the position of the user in the volume. We have developed an initial proof-of-concept desktop prototype using a commercial game engine and open-air hand-tracking device. Our initial work involves the navigation of complicated internal molecular surfaces. We plan on evaluating this system by comparing its effectiveness across desktop, consumer-grade immersive, and high-end immersive systems.

Index Terms: H.5.1 [Information Interfaces and Representation(HCI)]: Multimedia Information Systems —Artificial, augmented, and virtual realities; I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Virtual Reality

1 Introduction

Immersive display systems are a useful tool for the visualization of volumetric data [3, 8]. However, maintaining an understanding of position and orientation in virtual environments is challenging [4], even when not taking into account the full range of viewing transformations available to the user within a volume. Volumetric data, such as molecules or internal organs, can be dense, complicated structures. For the user in an immersive virtual environment, navigation of these features can cause disorientation.

The goal of this work is to provide researchers a natural and intuitive way to explore volumetric data using a world-in-miniature (WIM) [9, 10] to enable navigation of the volume and provide focus and context for visualization [2]. The basic idea of focus and context is to show the user selected regions in greater detail (focus), while preserving the global view at a reduced detail (context). A world-in-miniature (WIM) technique embodies the idea of focus and context, thus enabling data exploration of complicated volumetric data sets using a third-person perspective (3PP) miniature-model view (context) to generate flight paths and display user location combined with a user controlled first-person perspective (1PP) along the flight path (focus).

Navigation in virtual environments is defined by the tasks of travel and wayfinding [1]. Travel relates to the user locomotion (controlling the point of view) while wayfinding refers to the cognitive aspects of navigation (such as path planning and spatial orientation). Volumetric datasets are typically dense and cluttered, and wayfinding becomes a larger concern than in sparse environments. Our proposed concept of using WIMs for volume exploration enables relevant tasks to be performed naturally, while maintaining a good understanding of the overall structure of the volume.

Previous work used miniatures to display contextual information during volumetric interaction. Kopper et al. [5] employed miniatures of volumetric datasets as wayfinding aids for multiscale navigation. As users traverse through multiple levels of scale, local and global context information is provided by rendering miniatures of the local and global scales in the same orientation as the user, and with a representation of the user position within the miniatures. Our proposed concept for volumetric exploration expands this work by, besides providing contextual information, enabling the user to plan a travel path and by scaling and panning the miniature.

We present our current implementation of an initial desktop prototype developed with the Unity3D game engine, using the Leap Motion, a short range hand and finger tracker, for interaction with the WIM. We discuss design issues and plans for future development and testing with immersive virtual reality (VR) systems such as a head-mounted display, a zSpace, and a CAVE^{TMTM}. We are especially interested in the eventual evaluation of such a system in the context of recent work outlining the need for evaluation in immersive visualization [6].

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2 Proposed Technique

As presented in [10], the WIM metaphor supports display interactions that may aid visualization, such as "spatially locating and orienting the user" and "path planning." However, we are currently unaware of immersive scientific visualization systems that use the WIM metaphor to aid navigation. We propose developing an immersive three-dimensional display system that provides users both a WIM and large-scale view of volumetric data, supporting focus and context.

User interaction of the WIM will be natural hand-based gestures, enabling transformations of the WIM for a bird's eye view of the entire volumetric data set. Using natural hand gestures, the user can define waypoints through the data for a directed fly-through. Our aim is that use of the WIM will aid users in spatial understanding of the data to support navigation.

3 Current Implementation

The current prototype is developed with the Unity3D game engine, using the Leap-Motion. The navigation model currently is optimized for manipulating a WIM, and translating that information to the larger model. The user's hands are tracked with a Leap Motion Controller, and a virtual representation of the user's hands are displayed in the VE. The tracked user's index finger combined with a key-press defines waypoints within the WIM, that are then mapped to the full scale model.

We introduce a user-controlled data collection toggle to give more control to the user, both in terms of model manipulation and model input data. Using Unity3D's Hermite Spline Controller package we enabled users to define "Spline nodes," connected with a spline interpolator, creating a fluid path for the user's fly through based on the user specified waypoints. The waypoints are then connected with a Hermite spline, defining a flight path through the data. A molecule model and user-placed waypoints can be seen in Figure 1. Rotation, transparency, and scale of the model are currently performed through the keyboard.

The user location is then placed along the interpolated spline path created from the scaled and translated data and begins traversing the path. The user view-direction is decoupled from location, enabling full view of the data. Future implementation will enable real-time control to increase or decrease speed along the flight path. The current implementation enables paused movement along the flight-path through the keyboard.

3.1 Choice of Leap-Motion Controller for Implementation

The use of the Leap-Motion controller for the current prototype stems from a desire to make the interaction with the WIM more fluid and natural. While there are advantages and disadvantages to every type of input mechanism, the overall benefits of the Leap-Motion controller made it a prime choice as a tool to further the implementation of the model. The controller enables the user to interact with the WIM model as they would an object in their hands. Other methods of input, such as the zSpace or "magic wands" in an immersive CAVE™will be tested in future iterations.

One goal of the current implementation is to take the data obtained from future tests with the Leap-Motion controller, and develop an IR LED device to be placed on the front of a Head Mounted Display, much like the Oculus Rift. From this vantage point, the device would be able to track hand movements with relative ease due to the proximity of a user's hands to their face, as well as prevent the user from being tied to a monitor or inhibited by the location of a CAVE™. To reach this point, however, the Leap-Motion controller was chosen as a waypoing for future research. By developing the model with the Leap-Motion controller in mind, this next step could be taken with relative ease; for that reason, the Leap-Motion controller was chosen for the current implementation of the technique.

4 Design Challenges and Future Implementation

4.1 Miniature-Large Model Dichotomy

The miniature model-large model dichotomy proposes a resolution issue for volume navigation. In addition to providing a bird's eye view of the larger volume, the WIM model serves as a three-dimensional mini-map of a much larger volume. Any movement or interaction with the WIM model must then be transformed to the much larger volume, magnifying any loss of accuracy present by interacting with the small-scale WIM.

Current considerations for user interaction for waypoint definition within the WIM model compare tradeoffs between user control and accuracy within the model. A blunt object enables easy user manipulation but provides less precise location placement within the model. A fine interaction tool enables precise interaction. However, small, accidental user-movement in the WIM model would be amplified by a large scaling factor between the WIM and large model.

The final design of the technique will need to take this dichotomy into account and several alternatives will be evaluated. Some potential compromise solutions for the precision/accuracy problem are to enable adjustment of the path in the large model, contextual magnification of the miniature (at the area of path-tracing), and control-display ratio gains.

4.2 Flight-Path Definition

The user should be able to easily define a flight path through hand interaction with the WIM. While the use of the Leap Motion Controller enables more natural data input through hand gestures, the tradeoff comes with the ability of the controller to accurately place waypoints. There may be instances where a user wants to move to a new location in the model without collecting data from the motion path. Additionally, users may require more accurate point placement that an index finger can provide – giving the user the option to toggle data collection would provide another layer of control over data input, giving users a more accurate path to follow. A lack of accuracy in generating paths via the WIM could be countered by enabling the user to edit the path as they fly along it via the large-scale view. This would enable an improved path for future traversals.

A crucial feature of the technique is the ability to visualize the path being drawn in the WIM as it is being drawn. It may also be useful to optionally show the path ahead of the user in the large-scale view.

4.3 Fly Through

When navigating through the full volumetric model, several motion and visual controls may enhance the experience, and enable more control on the part of the user. The first proposed enhancement is the control of navigation speed, given that the user has predefined a path through the model. Secondly, a way to pause the navigation so that a user can spend more time examining certain aspects of a model may help users to quickly comprehend details of the data without the need for creating multiple fly throughs of the same area. Finally, giving the user 360 degrees of freedom allows the user to explore the model fully and naturally.

Enabling user controlled fly through speed will enable users to slow down and stop during potentially interesting parts of the data, and speed up through less interested areas. Incorporating a pause function gives users the chance to take in their surroundings more effectively, learning not only about relational context but also examining details more closely without the potential for the camera to be moved further along down the path because of imposed time limits. It's important that, as the fly through is paused, the user still has the ability to explore the volume locally, both by rotating the point of view, as well as manually translating the camera position.

5 Initial Observations

The implementation and usage of the prototype exhibit several benefits of the proposed navigation technique. The interface presents a natural approach to handling the three dimensional models being investigated. Designing paths, while not as accurate as would be desired for the technique, is a quick and easy process that enables the user to promptly explore complex models with little outside knowledge of the model. The control of the camera during navigation also gives the user more freedom to explore the models in question, which is effective both for exploration and documentation.

However, when exploring models of molecules, several issues arise beyond the initial design issues that were counteracted in the creation of the program. Most importantly, the accuracy of the path setting provides some inherent handicaps to the model that would need to be improved to validate the navigation technique. Secondly, the ability to control the camera during the actual navigation of the three-dimensional model is sometimes hindered by tangential path finding, which stems from the Hermite Controller code used to interpolate the splines. Finally, long paths with many spline nodes can hinder system performance.

The most notable issue pertains to the accuracy of the paths drawn by the hand. When drawing paths on the model, the actual spline node position is determined by the relative position of the second finger present on the hand model (typically the index finger). Due to the Leap Motion API, however, this is not always the case. Depending on how many fingers are detected by the controller's IR LED sensors, the finger used to draw the path could not be present, or be another finger on the hand. This can stem from the hand being put in certain positions that block fingers from the sensor, or gestures that are misinterpreted by the sensor.

These issues are magnified by the scaling required to translate miniature model information to the main volumetric model, creating paths that seem "jumpy" or skewed. The user may move dramatically across the main model based on incidental data collected by a mispositioned or misinterpreted finger – evidence also that more may need to be done to handle incidental data collection, perhaps by smoothing the spline control points. When creating just a few spline nodes for the camera path, the path setting is as accurate as the hand used to control the path will allow. This deteriorates, however, as more spline nodes are added to the current scene, which affects the frame rate, making the hand model jumpier and harder to control. Such issues could potentially be mitigated by node reduction techniques, or by a more precise hand tracker.

6 Discussion

The benefits of the proposed volumetric navigation technique are applicable in a number of fields. Given that the main purpose of this technique is to navigate 3D volumes more efficiently and effectively, this technique would pose the greatest benefit to fields that require intricate and immersive knowledge of three dimensional models or environments. While the prototypical program is based-off of traversing molecular structures, which could obviously benefit biological research, such a technique could be adapted to other fields using larger-scale models. Traversing data generated from medical images, such as performing a virtual colonoscopy, could benefit from this technique, as could applications in the oil and gas industry.

However, there are some limitations to this type of navigation technique. Viewing a miniature model of a large data set will inevitably make small details hard to see in the WIM. This could be problematic in determining where features of interest are in order to plan a path. Such issues could be mitigated depending on the application. For example, if it was possible to preprocess the data to determine potential areas of interest, such areas could serve as selectable waypoints. Care will also be needed to enable methods for the user to easily return to the path if they have "stepped" off for free exploration.

Therefore, future iterations of this technique could include the ability to either move freely off the guided path when necessary, or alter the guided paths on the fly to give users more freedom. Also, even with the ability to traverse larger-scale models, the ability to zoom in on details or perhaps scale up certain aspects of the WIM would enhance the small-detail benefits of the technique.

Finally, to improve the technique even further, a more natural method for manipulating the WIM would help to improve the accuracy of the technique and provide the user with the ability to dictate paths more freely. One potential improvement would be to replace the use of the user's hand with a device structured more for pinpointing sections of a miniature model. The Leap API does provide for the use of objects called pointables that could serve as magic wands–cylindrical tools used to direct motion or point to specific points of virtual environments. While incorporating this type of tool into the navigation technique would limit some of the more natural movement that the current technique offers, the benefit of this would be to increase accuracy and model manipulation to navigate the large-scale model more easily.

We plan to evaluate the system using multiple display technologies, such as an HMD, a zSpace, and a CAVE^{TM}-like display, and evaluate user ability to understand and interpret volumetric data based on navigation metrics.

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