

# Virtual Reality Enabled Scientific Visualization Workflow

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## ABSTRACT

For decades Virtual Reality (VR) has remained out of our offices and everyday workflows due to its high cost, its custom-built nature, and its often narrow design for highly specific tasks. These characteristics create a very high entry barrier for most users to use VR technology. Users typically had to be well funded, possess a high degree of expertise, spend weeks of effort porting VR capable software, or go to a specialized visualization laboratory. Recently, the cost is coming down significantly as new affordable consumer-grade VR devices are becoming available (e.g., zSpace). However, in order to incorporate VR technology into our everyday office settings, the entry barrier must be lowered significantly. This paper describes a VR framework that lowers the entry barrier for everyday users. The framework is designed on the visualization workflow of typical users working with scientific visualization in university settings. It includes a regular desktop computer, a typical non-VR display, a consumer-grade immersive VR display (zSpace), and frequently-used visualization applications (ParaView, EnSight). By designing and building this framework, we aim at measuring and studying the usefulness and effects of integrating VR technology in everyday office settings. While the framework will be initially tested with ParaView, the study aims at producing generalizable findings that extend to users of other 3D desktop applications such as 3DS Max or Maya. This can help users and software companies to add similar support in their packages and allow users to experience VR in everyday environments.

**Keywords:** Virtual Reality, Immersive Visualization, Scientific Visualization.

**Index Terms:** I.3.7 [COMPUTER GRAPHICS]: Three-Dimensional Graphics and Realism—Virtual Reality; I.3.4 [COMPUTER GRAPHICS]: Graphics Utilities—Virtual device interfaces; I.6.3 [SIMULATION AND MODELING]: Applications—Immersive Visualization;

## 1 INTRODUCTION

Virtual Reality (VR) has always been a highly specialized custom-built technology, developed to solve very specific problems, and carrying a high price tag. VR components such as tracking systems and immersive displays can cost anywhere from thousands of dollars to hundreds of thousands of dollars. This high cost has often restricted the user population to a few well-funded research laboratories.

Even though VR technology is proven to be useful in research laboratories, applying the technology to everyday user settings has proven challenging. However, Facebook's purchase of the immersive display technology company Oculus VR has started a development race among companies such as Google, Samsung,

zSpace, and Sony to bring VR technology to the mainstream. This has had the positive effect of lowering the cost of VR displays, tracking systems, and interaction systems like OptiTrack, Leap Motion, and MS Kinect. Nowadays, a functioning VR system can be put together with only a few hundred dollars instead of thousands of dollars.

As VR technology becomes affordable, the research community is increasingly interested in incorporating VR into their projects. However, as Shetty et al mentioned, the availability of low cost VR hardware will also need the supporting software framework for researchers to include the technology in their research workflow [1]. Software companies are starting to adapt their applications. For example, Kitware has added VR capability to their ParaView [2] visualization software to support immersive visualization and 3D interaction with the data [1].

The decreasing cost of VR technology and the availability of stable open source software solutions lower the barrier of entry for a wider adaptation of VR technologies in our daily office work. ParaView is a visualization software used by many users in the visualization community for visualizing 2D and 3D data [3]. ParaView is a Qt based interface to Visualization Toolkit (VTK), a well-known open-source visualization library. Similarly to VTK, ParaView is also an open source application, actively supported by its user community for free (although Kitware also provides a professional support option). ParaView is currently on its 4.3 release [3] and it has been proven to be a stable and very mature visualization software. The stability and flexibility of ParaView make it an ideal platform for building a VR framework for everyday office settings.

In the following section, we review the related work to our paper. The next section will describe the proposed framework and a prototype implementation that we have developed. Section 4 discusses our preliminary findings of the prototype with our user base. Section 5 concludes the paper.

## 2 RELATED WORK

There is some work within the VR community to include VR technology into the day to day scientific workflow. Kreylos et al in [12] described a scientific visualization workflow involving VR technology with a 4 sided CAVE system. Kreylos described the advantages of using VR technology for data interpretation efforts for the geoscience community at UC Davis. Scientists are able to use both the 3D perception and 3D interaction with data and models while exploring their data in the VR environment.

However, there is very limited research of how to incorporate immersive VR into the workflow of scientific visualization within an office setting. In the following section, we propose a framework that can allow users to use VR when working with scientific visualizations in their offices.

## 3 VR FRAMEWORK

At a high level, this project aims to incorporate VR technology into the workflow of people creating and using scientific visualizations. The hypothesis is that this can improve the quality of the users' processes and outcomes. In order to test this hypothesis, we built a prototype that integrates different consumer grade hardware and software components.

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### 3.1 Hardware Framework

The hardware platform includes a desktop computer with an AMD FirePro V7900 (FireGL V) Professional Graphics Card. The W5100 graphics card has 4 outputs, and in our setup, we have a regular LCD monitor, and the zSpace [5] monitor, all attached to the graphics card.



**Figure 1: Hardware systems setup**

Figure 1 shows the prototype. The choice for two monitors is designed to provide the best settings for people to conduct their work. The regular LCD display is set up to be the main display where user would interact with the computing system with mouse and keyboard. The zSpace is the secondary display, which is used only when the workflow requires immersive VR. Although the zSpace display can run a desktop based application using mouse and keyboard interaction, its physical configuration is not ideal for the task. zSpace is designed to be tilted for the semi-immersive 3D optical tracking system and 3D stylus interaction. This creates a low position related to the head of the user. Ergonomically, regular displays are better suited for long-term interactions with desktop applications.

In order to connect all the VR devices (such e.g., motion trackers, joystick controllers, etc.) using a unified interface, the prototype uses a Virtual-Reality Peripheral Network server (VRPN). Since at this time the VRPN server released for zSpace runs only on MS Windows, our prototype runs on MS Windows 7 professional operating system<sup>1</sup>.

### 3.2 Software Framework

The prototype is designed to enhance the workflow of users creating scientific visualizations using ParaView or EnSight.

#### 3.2.1 ParaView and Immersive ParaView

ParaView was chosen due to its wide user base, maturity, stability, flexibility, and open source nature. Written in Qt [8], ParaView can run on multiple platforms including Microsoft Windows, Linux, and Mac. Although most users run ParaView on their desktop or laptop computer for quick visualization and analysis of their relatively small dataset, ParaView also supports a distributed computational model that allows it to do ultrascale visualization (this makes it a popular system for supercomputer users).

<sup>1</sup> A release of VRPN for Linux is planned for the near future. Once it becomes available, we will experiment with other OS configurations.

In addition to being open source, ParaView provides an extensible, modular architecture that allows developers to easily extend its visualization functionality. ParaView provides a graphical user interface to VTK's visualization algorithms and rendering libraries. These libraries are written in C++ and use OpenGL for rendering. Developers wanting a specific feature that is not currently available in ParaView can build a plugin instead of an entirely new visualization application. Furthermore, ParaView also allow developers to write Python scripts to access its functionalities.

The active support of ParaView, both by its open source user community and Kitware, help ensure the continuation of the project for the foreseeable future. This will also ensure the longevity of the Immersive ParaView plugin which is at the heart of our proposed visualization workflow.

#### 3.2.2 Immersive ParaView

The question of the effectiveness of using an immersive visualization tool in the scientific visualization workflow to improve understanding of the data has been of great interest to the visualization community. An example of this is Immersive ParaView [1].



**Figure 2: Immersive Visualization through integrated touch screen interface**

As Figure 2 shows, Immersive ParaView extends ParaView to run on a semi-immersive visualization display. In addition, Immersive ParaView can be used to visualize the output of ParaView 2D GUI within a fully immersive VR environment like the 4-sided and 6-sided CAVE [1]. However, these scenarios of use are still dependent on having access to a visualization laboratory. Our prototype is designed to bring the immersive scientific visualization workflow out of the visualization laboratory and into the offices of researchers.

#### 3.2.3 VR Plugin on zSpace

Shetty et al described the development of VR Plugin for the support Immersive ParaView in detail [1]. However, the VR Plugin is not a standard feature of ParaView's visualization package and thus it is not available on the binary release on its Web site. To enable VR Plugin [9], ParaView needs to be compiled using cmake and enabling the options:

```
BUILD_SHARED_LIB
PARAVIEW_BUILD_QT_GUI, PARAVIEW_USE_MPI
PARAVIEW_BUILD_PLUGIN_VRplugin
```

Additionally, either `PARAVIEW_USE_VRUI` or `PARAVIEW_USE_VRPN` will need to be enabled.

For our setup with zSpace, we use VRPN support within ParaView because VRUI library is not available on the Microsoft Windows platform. The VRPN library [10] will also need to be compiled and installed on the system. To include VRPN library in the compilation process, `VRPN_INCLUDE_DIR` and `VRPN_LIBRARY` will also need to be set during the cmake process. The compilation process will produce the binary for `pserver.exe` and `paraview.exe` which is needed to run ParaView in semi-immersive mode on the zSpace system.

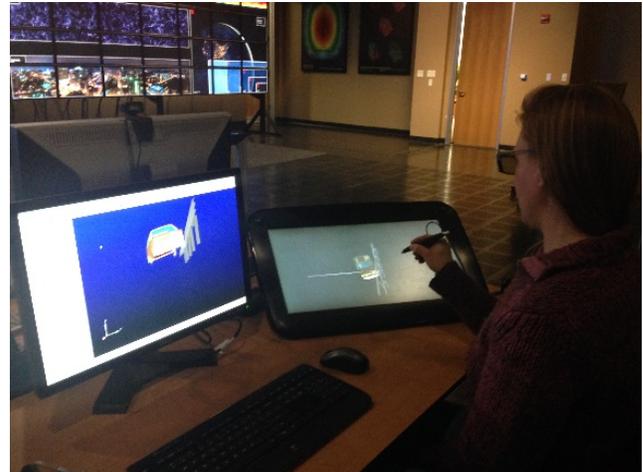
In order to run Immersive ParaView on zSpace, we also need the configuration file for the display setup and the configuration file for the input connections [9]. The wiki page for Immersive ParaView [9] has examples and GUI snapshots on how to create the two configuration files needed. Figure 3 shows ParaView running on the zSpace system.



**Figure 3: ParaView running on zSpace**

### 3.2.4 EnSight for zSpace

Besides Kitware Inc.'s effort with ParaView, CEI Inc. [13] has also realized the benefit of using VR technology for visualization with the release of zSpace support for EnSight [7]. Figure 3 shows a user visualizing the simulation data using the zSpace in semi-immersive 3D stereoscopic display with 3D interaction using the stylus. The visualization pipeline and the data is actually loaded into EnSight using the mouse and keyboard interaction on the non-immersive desktop display next to the zSpace. This workflow is showing the use of VR technology for immersive visualization as an augmentation to existing desktop display. Since the EnSight visualization package is not designed to run natively with VR technology, this setup allows a 2D desktop application to run on the desktop monitor and when VR technology is beneficial to the visualization workflow, it can be made available to the user. Figure 4 shows CEI EnSight running on the zSpace System.



**Figure 4: CEI EnSight running on zSpace**

## 4 DISCUSSION

Our prototype integrates a 2D desktop computing and 3D VR hardware system together with a scientific visualization application that is capable of taking advantage of both the 2D and 3D hardware based on the workflow of the user.

Our prototype allows users familiar with ParaView to use semi-immersive or fully immersive visualizations of their data without additional programming efforts. Users can work in 2D using the regular desktop display, mouse, and keyboard of the system to setup the visualization pipeline of their data in a way familiar to them (the user interface provided in ParaView is optimized for mouse and keyboard type interaction and setting up the visualization pipeline in the 3D environment is not supported.) Once the visualization pipeline is setup, users are able to visualize their 3D data using the VR Plugin in ParaView on the zSpace display with full VR interaction support. Users can interact with their 3D visualization using the stylus and manipulate it in a true 3D environment.

While the project is still in its early phases, we have discussed the usability of the project with users and researchers at our visualization lab. These informal discussions have provided very positive feedback on the added value of using 3D immersive visualization and 3D interactive interaction. In particular, the researchers expressed interest in the ability to gain true insight into the 3D spatial orientation of the 3D objects in their data when exploring the data using the zSpace system as compared to the 2D desktop monitor.

Having developed this first prototype, the project will now focus on expanding its functionality and developing a systematic evaluation of its usefulness and effectiveness.

## 5 CONCLUSION AND FUTURE WORK

It is important to use the hardware and software in a manner suitable for the task at hand. VR technology is not a technology that is suitable for every computing task for the home or office. It is a technology very well suited for visualization and interaction of 3D objects within a 3D environment. For some of us, our daily workflow often includes a 3D component. Visualization of the 3D object on a 2D display system and using 2D interaction to manipulate the 3D object has been the normal workflow. However, with the current advancement and availability of the VR technology components, there is no reason not to take advantage

of VR technology to interact and visualize 3D objects in a true 3D environment.

By adding VR technology into an otherwise standard desktop computing system, we hope that it will help users in general to enjoy the benefits of VR technology in the portion of their scientific visualization workflow where VR technology is applicable. The easy access provided by the hardware setup and software framework will also help VR integration into other everyday workflows.

The hardware and software framework described in the paper above will be made available to all researchers using the TACC Visualization Laboratory. We intend to provide training classes to researchers interested in using the setup. An empirical study will be conducted to determine the usability of the system and if the VR enabled visualization workflow can help improve researchers' workflow. In addition to the user study, we also plan to extend the plugins to support direct user interaction with the different features of ParaView from within the 3D environment in addition to the Qt based GUI interface. This will allow the user to keep on working in the VR environment and not have to switch to the desktop GUI to interact with ParaView.

In addition to zSpace VR system, we are also planning on adding support for other low cost VR devices like the Oculus Rift [6] display system and LEAP [11] interaction for a fully immersive visualization and interaction experience in our immersive visualization workflow.

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