Towards Off-the-Shelf PlasmaVR: Simplifying Interactive Visualisation of Plasma Simulations

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***Abstract*—Plasma physics simulations generate complex 3D datasets that are challenging to analyse with traditional 2D visualisation methods. Virtual Reality (VR) provides a promising alternative for visualising these intricate spatial structures in an immersive 3D environment, improving depth perception and engagement. While the existing *PlasmaVR* prototype showed this potential, its usability was limited by a complex technical setup. This work addresses these barriers, aiming to transform the prototype into a practical tool for daily research use. This process will involve developing a streamlined application that can be easily used on a standalone VR headset, as well as adding features and improving usability. As a final step, this work seeks to evaluate the resulting tool against traditional visualisation methods to determine if VR provides a significant advantage.**

***Index Terms*—Virtual Reality, Immersive Visualisation, Scientific Visualisation, Plasma Physics**

I. Introduction

Traditionally, physicists have used conventional computer tools to visualise the results of plasma simulations. These tools typically display data on 2D screens, showing static images or simple animations of plasma behaviour. While effective, these methods have limitations. Plasma is a three-dimensional and dynamic phenomenon, and representing it on a flat screen can make it difficult to fully understand its behaviour.

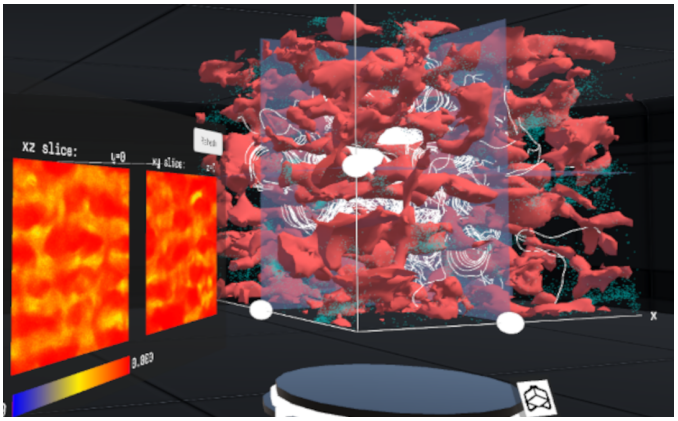

Fig. 1. *PlasmaVR* prototype's environment.

Recognising the limitations of traditional visualisation methods motivated the development of *PlasmaVR*, a Virtual Reality (VR) platform designed to visualise and interact with plasma simulation data in an immersive 3D environment as can be seen in Figure 1. The initial development of *PlasmaVR* [1] showed the potential of VR to transform how researchers interact with simulation data.

Focusing on the *PlasmaVR* prototype, this work aims to transform it into a research tool, improving its usability and functionality to better meet researcher needs. Additionally, the final goal is to systematically study its effectiveness against existing traditional visualisation tools.

II. Related Work

The integration of VR in plasma visualisation has seen significant developments in recent years. Research institutions like the National Institute for Fusion Science (NIFS) and ELI Beamlines have been at the forefront of this evolution, demonstrating the potential of immersive environments for scientific analysis [2], [3]. NIFS's recent work transitioned from a high-cost CAVE VR system to a more accessible one using a head-mounted display (HMD). This platform made advanced VR visualisation more democratic, but still faced challenges with its user interface and rendering speed. Similarly, ELI Beamlines developed a web-based application that supports both screen-based and immersive VR exploration. This solution runs directly in a web browser, making it highly accessible and versatile. These efforts validate the potential of VR in plasma research and highlight key areas for improvement, which directly inform the approach of this work.

III. Our Approach

Building on the demonstrated potential [1] of *PlasmaVR* as a VR visualisation platform, this work aims to evolve the prototype into a practical tool for the plasma physics community by streamlining the application pipeline and improving functionality.

Transforming the prototype into a tool: While the prototype is functional, it is not yet usable in practice. To guide the development of the improved *PlasmaVR* prototype, an initial interview was conducted with physicists to evaluate the current state of the application and identify areas for improvement that had not been previously identified. Notably, researchers expressed a need to easily go from simulation data to a visualisation that is accurate and visually appealing.

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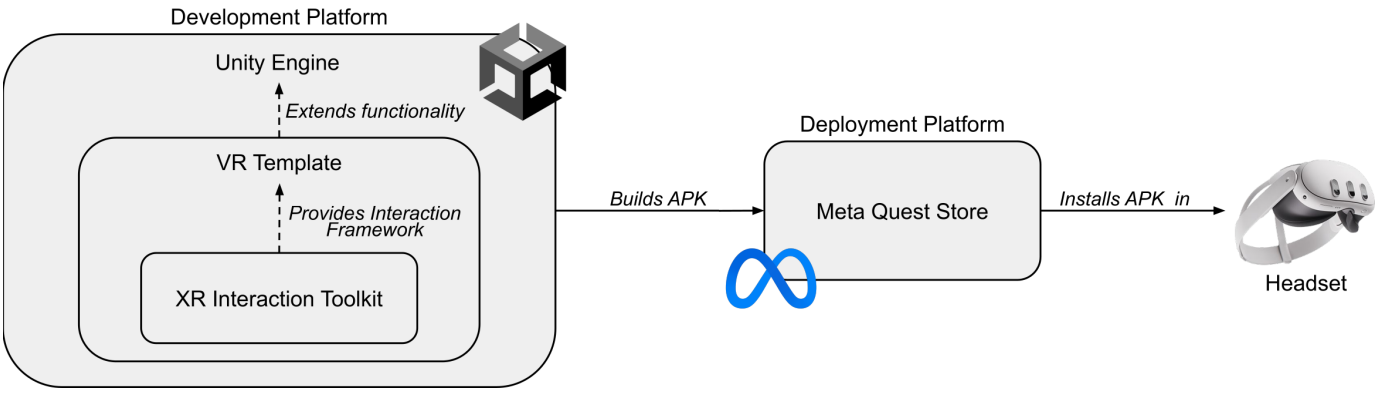

Fig. 2. Process flow: from application development, to APK build, and headset installation.

Therefore, the first priority is to streamline the application pipeline by eliminating or reducing repetitive cumbersome setup steps. This process aims to ensure that researchers can seamlessly visualise simulation data without requiring technical expertise.

Improving functionality and usability: Researchers highlighted the importance of including features from their current visualisation tool. Therefore, a fundamental step will be defining and adding these features to *PlasmaVR*. In addition to feature completeness, the user interface will be refined and intuitive controls will be added for manipulating and exploring simulation data.

A. PlasmaVR Tool

The development and deployment of *PlasmaVR* will follow a clear pipeline, as illustrated in Figure 2. This approach will use standard tools to create a practical and accessible VR application. The *Unity* game engine will serve as the core development platform due to its robust support for VR development, allowing the creation of 3D visualisations and flexible interactions essential for *PlasmaVR*.

Once development is complete, the application will be built into a self-contained application package. This package will then be installed directly onto the target VR headset. After installation, users will be able to launch *PlasmaVR* directly from the headset's application menu. The selection of these specific tools and the outlined development process reflect a deliberate shift toward ease of use and minimising dependence on high-performance external hardware.

B. Towards a Standalone and Usable PlasmaVR

Standalone deployment refers to running VR applications directly on HMDs such as *Meta Quest* headsets. Unlike tethered systems, standalone HMDs leverage mobile hardware to deliver self-contained VR experiences, prioritising simplicity and ease of use. When it comes to *PlasmaVR*, focusing on standalone deployment will help lower the barrier to entry for researchers who wish to explore plasma simulations in VR without requiring technical expertise or support.

However, this shift to standalone introduces significant technical constraints, primarily due to the *Quest*'s mobile-grade hardware. This makes real-time rendering of multi-gigabyte plasma datasets infeasible if stored entirely on the device. To overcome these limitations, the application will adopt a hybrid architecture, still relying on a dedicated remote computer or server to process and stream large simulation data. Despite this server dependency, the approach remains preferable to fully tethered solutions. This is because the end-user experience on the headset will be simplified, allowing for a one-time application installation and quick launching directly from the intuitive headset menu for subsequent uses. This reduces the repetitive, time-consuming PC connection procedures inherent to VR tethered systems, making the application more practical and seamless for researchers' daily routines.

IV. Conclusion

This work aims to transform the *PlasmaVR* prototype from a proof-of-concept into a practical research tool. By focusing on usability and accessibility, a development approach has been defined to overcome the limitations of the initial prototype. The proposed solution will streamline the application pipeline, improve functionality, and adopt a hybrid architecture to simplify the user experience. Finally, a comparative evaluation will be carried out against traditional display methods to identify the benefits and drawbacks of VR in this domain.

References

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