Towards the Use of the Digital Library of Mathematical Functions (DLMF) with Virtual Reality

Kevin Chen[1] and Sandy Ressler[2]

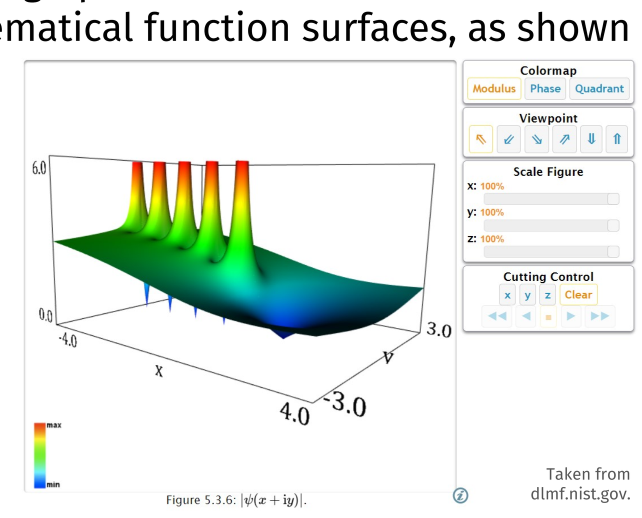
[1]Poolesville High School, Poolesville, MD [2]High Performance Computing and Visualization Group, Applied and Computational Mathematics Division, Information Technology Laboratory, National Institute of Standards and Technology, Gaithersburg, MD

An INTRODUCTION

The NIST Digital Library of Mathematical Functions (DLMF) was developed as a digital replacement for the *Handbook of Mathematical Functions with Formulas, Graphs, and Mathematical Tables* and serves as a compendium of mathematical content with interactive 2D and 3D visualizations of function surfaces. As an experiment, we decided to explore the use of virtual reality as a method to qualitatively interact with large numbers of function surfaces at once.

Virtual reality, or VR, describes a computer-generated environment which gives the user a sense of immersion. Mainstream VR has caught on and the full implications for such a technology are being made available to the general population.

The existing DLMF website already utilizes Web3D graphics which allow researchers to explore mathematical function surfaces, as shown below:



This project is looking to extend those capabilities into a virtual reality environment.

MOTIVATIONS and METHODS

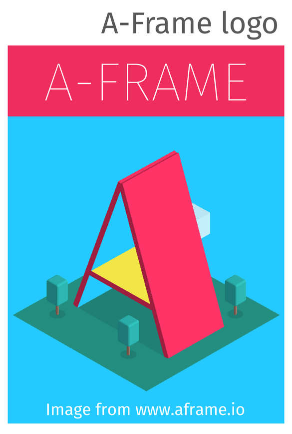
There are many advantages of a Web-based virtual reality (WebVR) application. The Web is accessible from nearly anywhere, from a mobile device to a desktop computer. In addition, international standards organizations such as the World Wide Web Consortium (W3C) have worked for the purpose of developing standards to make the benefits of the Web available to all people regardless of hardware or software.

This was thus the aim of my project: to develop a WebVR application allowing interaction with a library of mathematical function surfaces to allow for greater availability of such a tool.

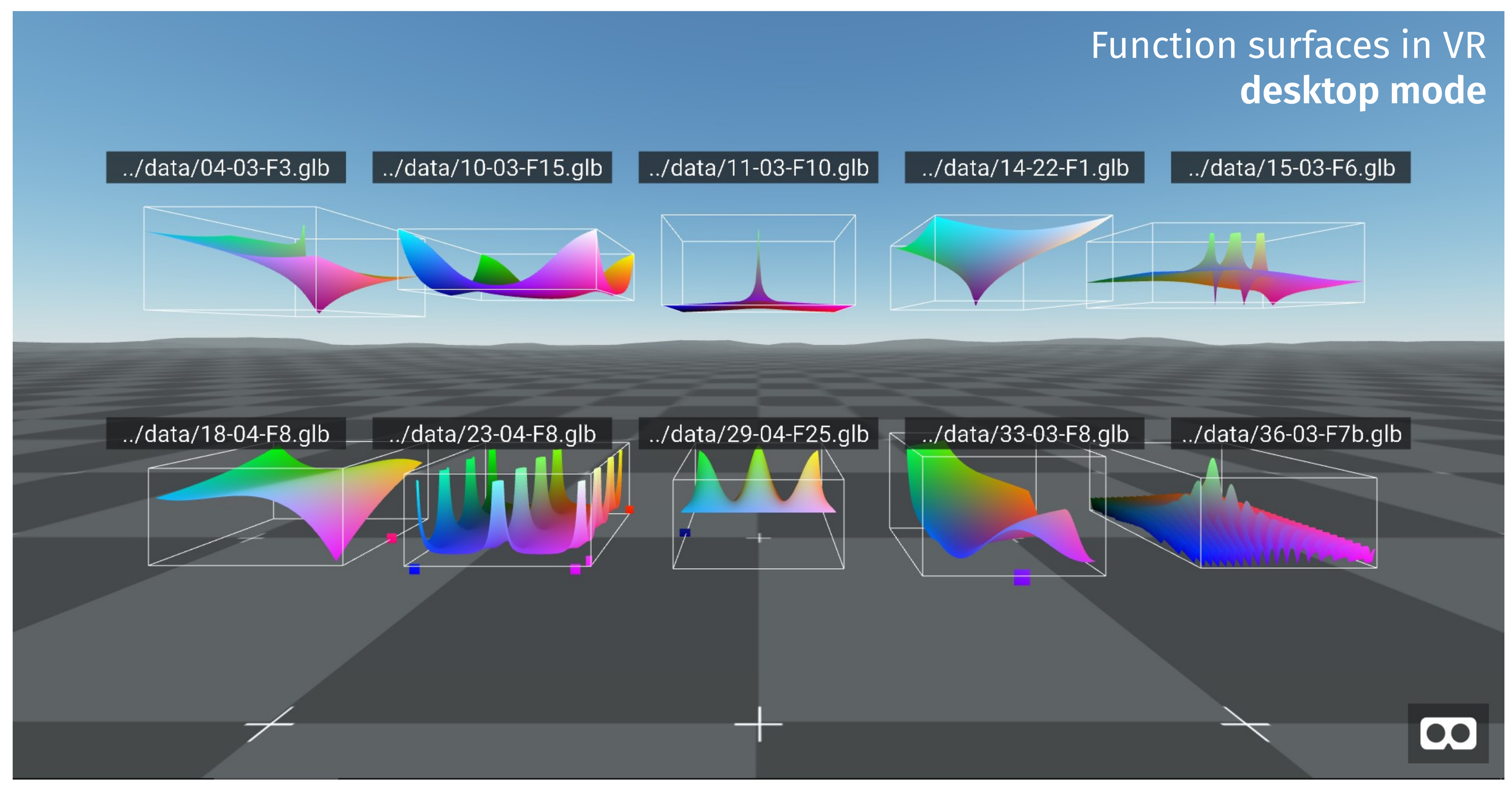
METHODS

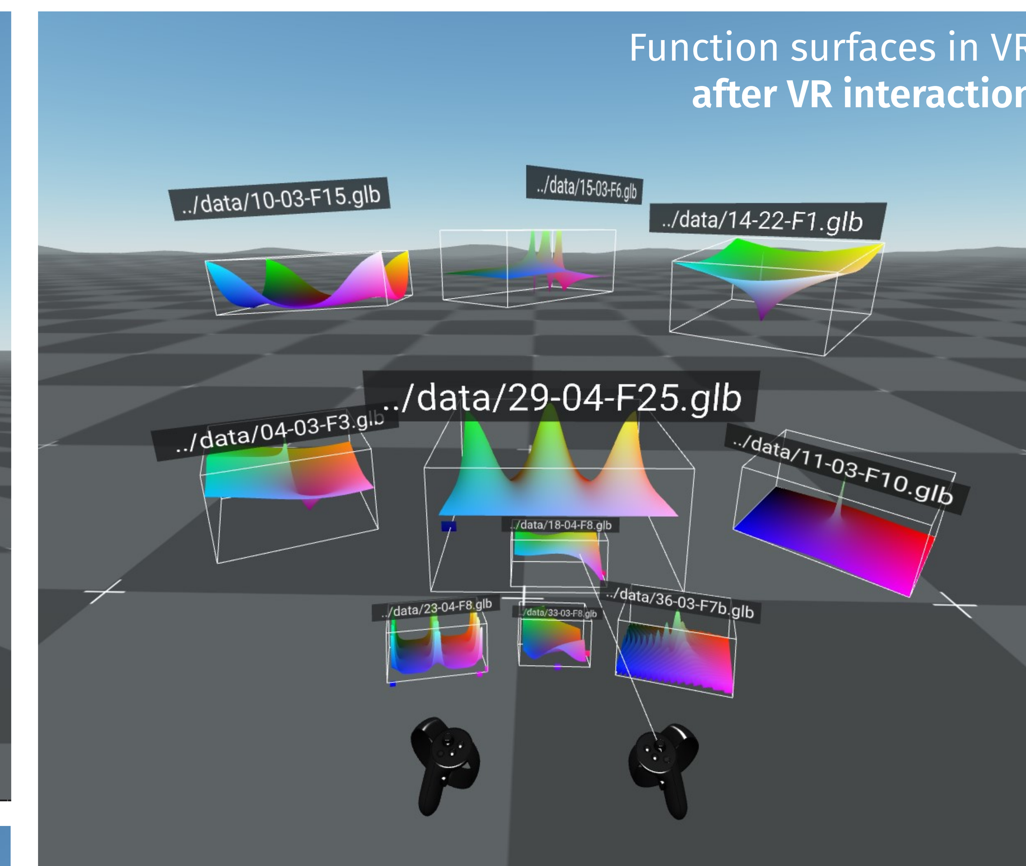
- The Hypertext Markup Language (HTML) and the JavaScript programming language were used to develop the virtual reality application.
- A-Frame, Mozilla's OpenGL WebVR framework and a JavaScript framework built upon THREE.js, was used as the framework to display the DLMF function surfaces and add support for virtual reality interaction.
- Function surfaces were converted from .obj geometry files to .glTF GL Transmission Format files for optimized load times.
- The application was tested using various virtual reality systems including the Oculus Rift, HTC Vive, Oculus Go, and Google Cardboard systems.

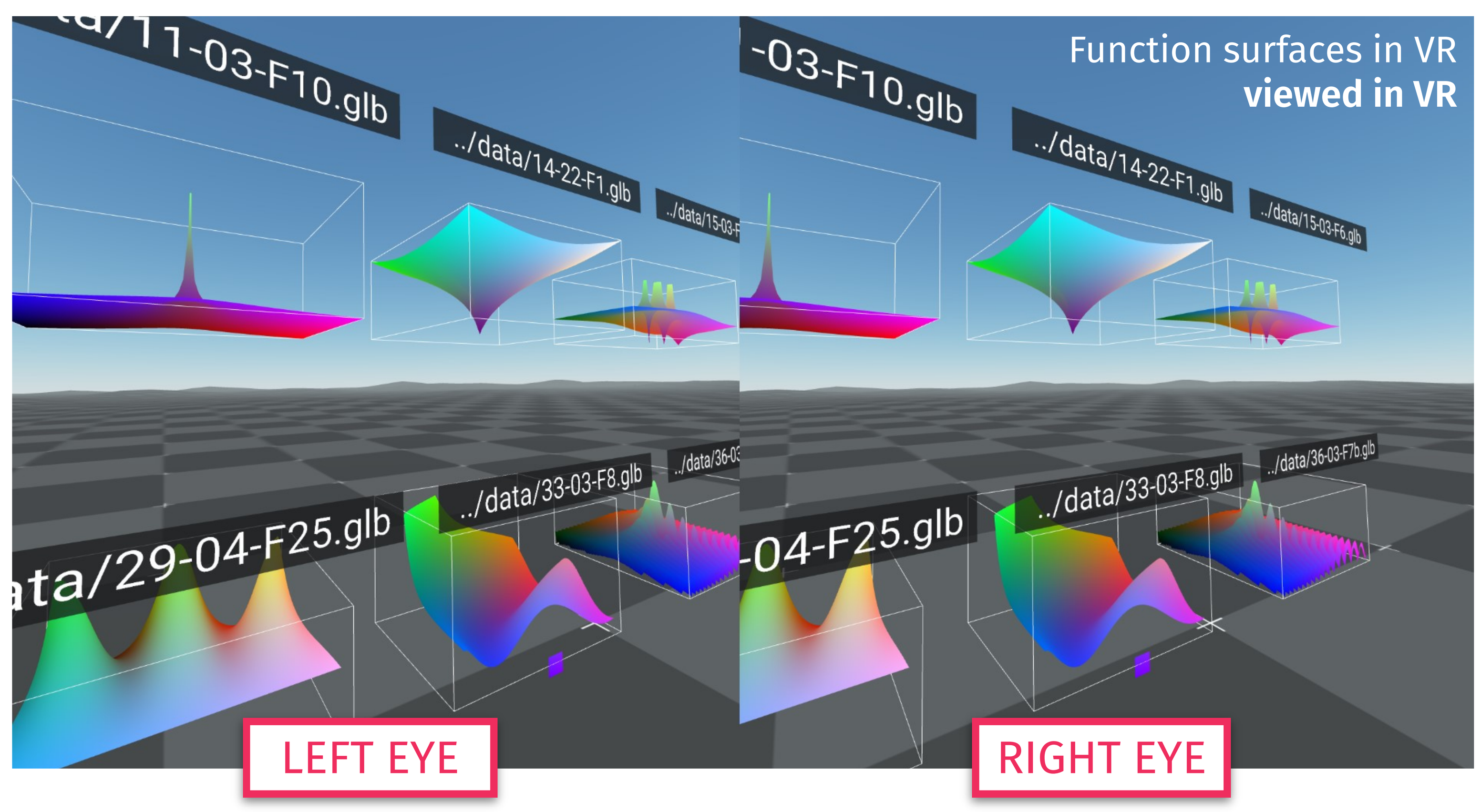
Oculus Rift (below) and HTC Vive (above) — A-Frame logo



RESULTS

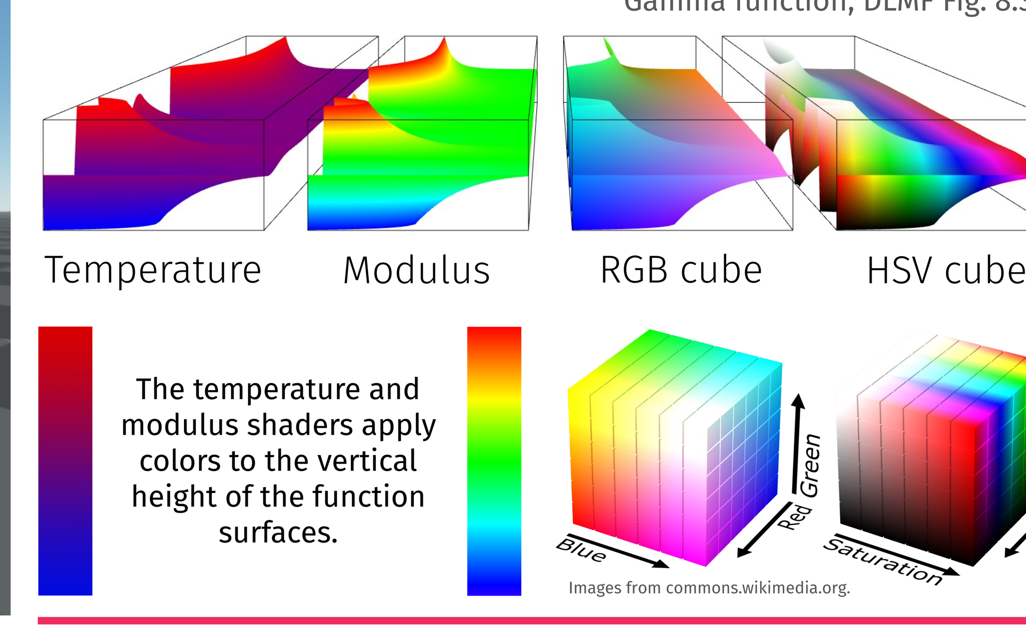




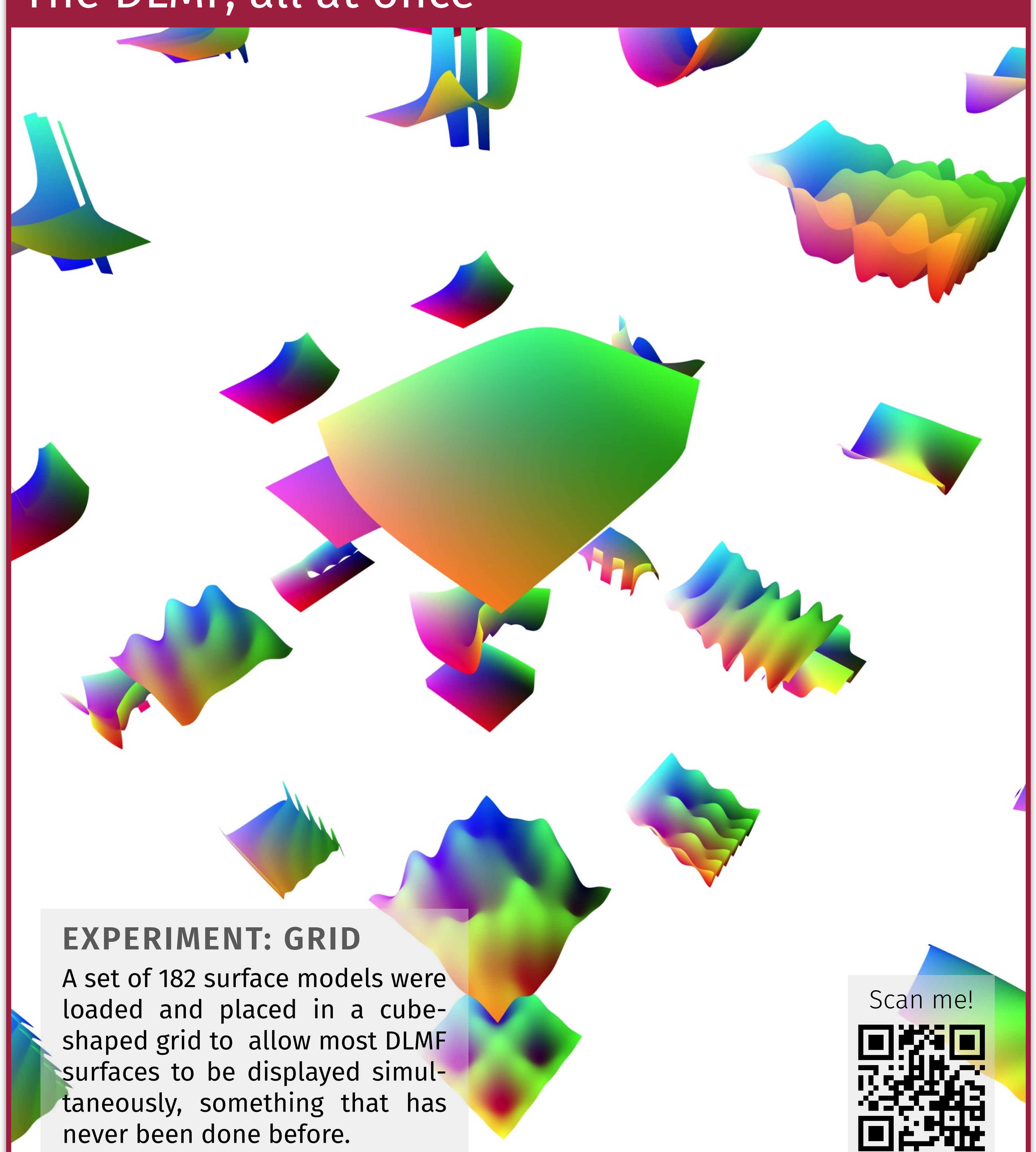


APPLYING SHADERS

Shown below: the incomplete Gamma function, DLMF Fig. 8.3.7

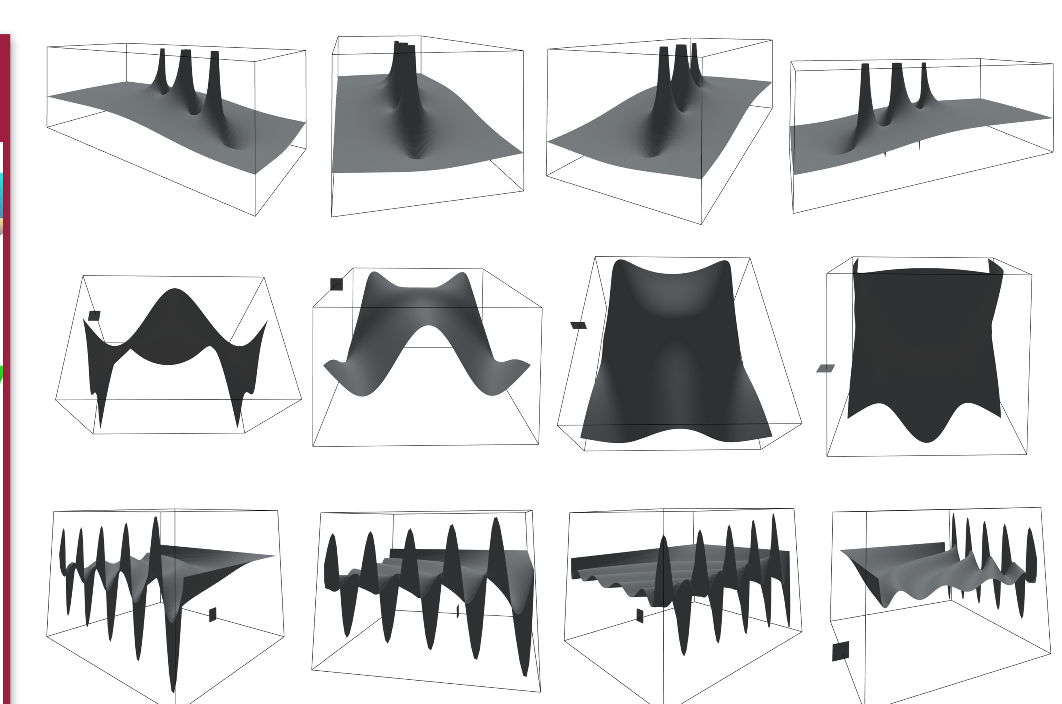


The DLMF, all at once



EXPERIMENT: GRID

A set of 182 surface models were loaded and placed in a cube-shaped grid to allow most DLMF surfaces to be displayed simultaneously, something that has never been done before.



The surfaces can be easily rotated with hand controllers.

CONCLUSIONS

We were successful in bringing the DLMF mathematical function surfaces into a virtual reality environment using a WebVR framework. Additionally, neither performance nor visual fidelity were sacrificed in the WebVR environment when run on either a desktop computer or a mobile device.

Our application allows researchers to naturally grab the function surfaces almost like holding a real physical object. The 3D surfaces are able to be scaled, similar to the pinch-zoom behavior on mobile devices. Users can also throw and spin the surfaces in the space.

The advantages of placing the DLMF function surfaces in a WebVR framework range from its accessibility, cross-platform device support, and ease-of-use compared to the existing "3D-in-2D" method.

ACKNOWLEDGEMENTS

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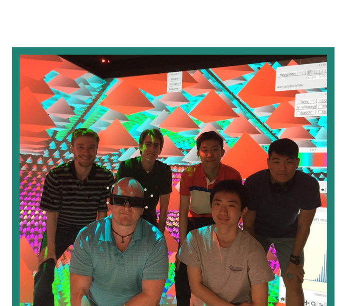
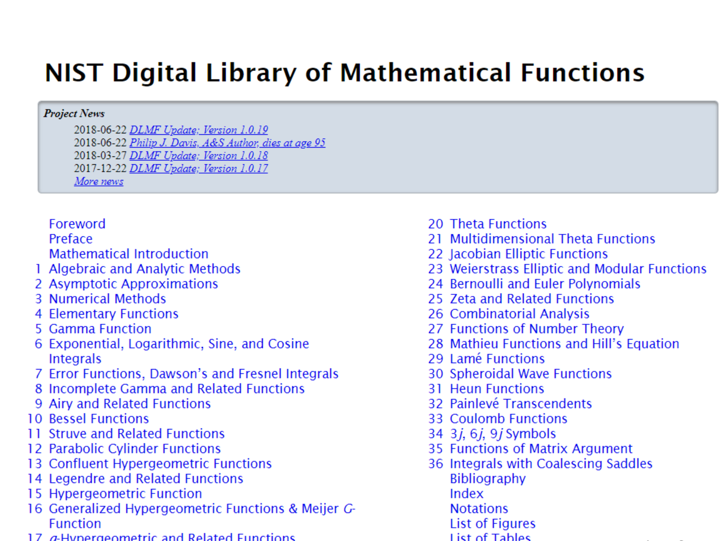


FUTURE WORK

This project is ongoing; many more features are being planned. We expect the application to allow users to navigate through the DLMF library by chapter, and sort and view functions by classifications and shape. We are planning to add more advanced features such as examining planar cross-sections, comparing and contrasting functions based on their geometry, and resizing surfaces by individual axes.

We also plan to add more traditional information visualization filtering mechanisms and other user interface techniques to make this application a truly useful tool.



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