Eikonal+ training and simulation platform: enabling a new generation of optical systems

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1. Narrative

Introduction

The year of 2016 was proclaimed by many to be the year of virtual/augmented reality [Forbes]. The public attention was captured by the idea of wearable and immersive devices that can be used for communication, training, simulation and much more. However, the realization of such AR/VR displays has been staggered due to limitation of the optical/light engine of those devices. Furthermore, head-worn displays are only one example of a new generation of optical systems that require non-traditional technologies to achieve high optical performance, in a compact and light form factor. The development of these technologies requires a new set of optical training and simulation tools that can bridge the gap between computational optics and advanced optical manufacturing and design.

In my work, I have focused on freeform optics and related technologies. Freeform optics can provide broadband, folded, all reflective designs [Bauer14]. Combining technologies can allow for optical systems with unprecedented form factor and performance. In the current work, we have demonstrated the realization of emerging technology for use in freeform based reflective head-worn display designs.

The research requires a new set of computational and experimental tools for design and manufacturing. Specifically, in the current work we are focused on the development of Eikonal+ - an optical/mechanical design platform. Eikonal+ is based on the Eikonal source code that was donated in 2009 to Prof. Rolland by the family of the late Juan Rayces, with whom she worked in 1986 [Rayces87]. We have developed tools that enable the Eikonal+ ray tracing code to interact with external software. Moreover, we have created a new user interface built from the ground up for 3D visualization of complex, folded optical systems.

Results

I have demonstrated the realization of light tailoring in freeform head-worn-displays (HWD). The designed components were optimized to have uniform performance over a large range of angle of incidences allowing for use in HWD.

An experimental setup to measure performance was built, meeting the industry standards for characterization. The measurements and theoretical predictions matched well.

The experimental realization of the components is the first step to creating novel freeform based optical devices. In the next step, we have developed computational tools that can allow the integration of the designed components in optical design software. The main platform to achieve this goal is Eikonal+. In a previous work the Eikonal legacy Fortran code was modified and modernized to work on any software or hardware environment. However, a bridge was required between the ray tracing computational backend of Eikonal+ needed for the design of freeform systems and software used to design custom components. The solution was to create an interface layer to serve as a middleman between the Fortran backend code and any other software as shown in Fig. 3 (the green box). This interface layer was realized in Python due to the relative ease of integration with other languages [Python]. As seen in Fig. 3, the user (being a person or another program/server) can access the backend computational functionality trough this interface layer without the need to modify the low-level Fortran code (blue box). This is an elegant and most importantly portable solution which allows communication with other scientific packages or computational and visualization tools written in any modern programming language (C, C#, C++, Java, Matlab, Mathematica and many more).

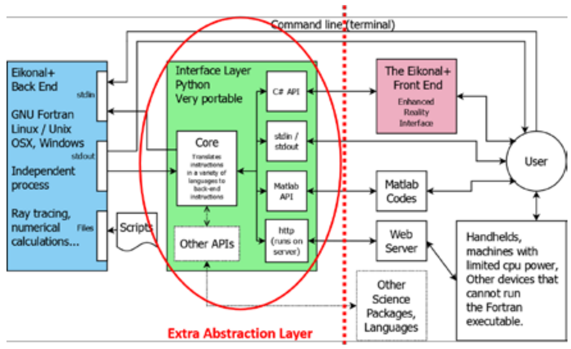


Figure 1. The Eikonal+ workflow. The Python wrapper which was part of the current work is circled in red. The user interacts with the software components on the right of the red dotted line

Due to the folded non-symmetric nature of most compact freeform designs it was required to also develop a modern visualization tool to display the optical systems in 3D (shown in pink in Fig. 3). The first Windows prototype is shown in Fig. 4a. It includes a system data spreadsheet, the 3D model window and command line access to the Eikonal+ backend functionality. To further expand the capabilities of this visualization tool we chose an industry standard 3D rendering engine [Unity] for a cross-platform user experience that can work on any hardware including AR and VR displays and other wearables. The full user experience is still being developed but a demo is shown in Fig. 4b including hand motion controls enabled by Leap Motion (Plemmons15).

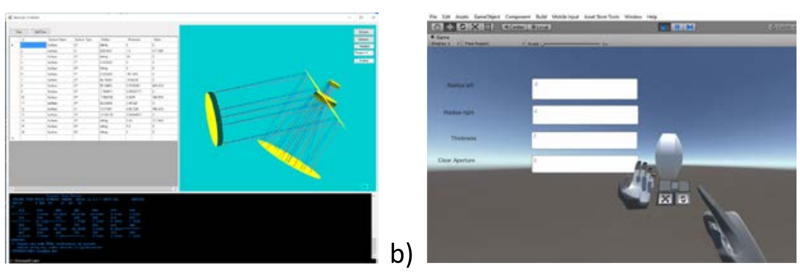
a) 

Figure 2. Eikonal+ 3D User Experience: a) Windows prototype of the UI, b) Unity cross-platform UI and hand motion controls

Significance and impact

The current work was a first step towards demonstrating an optical system that can leverage the novel light tailoring components. Bridging both the physical and the computational gap hasn't been done before and lays the road towards new and exciting generation of optical systems that can achieve high optical performance with compact form factors.

Where might this lead?
This demonstration will be the first example of a new generation optical system.

2. How did the fellowship make a difference?
The Link Fellowship has allowed me to work on a challenging problem in the context of training and simulation. I was able to explore some of the most cutting edge optical technology and advance the application of such technology by developing design and simulation tools as well as realizing experimental demonstration of those concepts. The work I have done is an essential part of my progress towards a PhD degree.

3. Future Plans
The first step in my plans is to complete my PhD degree. After graduation, which I anticipate being in 2019, I plan to pursue a career in optical design and simulation initially focusing on consumer devices for AR/VR. I would like to leverage my programming skills and optical engineering knowledge to work on challenging problems on the boundary between optics, scientific visualization, and computational science.

4. Publications, Presentations, and Other Outputs.
There were no publications during the fellowship period. We are however, working on two publications, related to the presented work. Any future publications that include the current work will acknowledge the Link Foundation and the final citations will be send to the Foundation.

Further Acknowledgments
The manufacturing of optical components to validate my simulations was combined work by Necdet Basaran, Liangyu Qiu and Fei Cheng. The backend Fortran development of Eikonal+ is handled by Adam Hayes. Unity development has benefitted from the support off Li Zhang and Yifan Niu.

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