DIY VR: The Development of an Inexpensive Headset for Makers

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Abstract - *Virtual Reality looks like "the next big thing" but between the disposable Google Cardboard and the pricey Oculus Rift there is still much room for makers to experiment and students to learn the nuts and bolts (both literally and figuratively) of VR. This paper is a report on an ongoing project to develop an inexpensive, customizable VR headset kit appropriate for use in the classroom and beyond. The project's goals include using off-the-shelf materials, keeping costs low (current cost is approximately $25), and supporting student software and media development. Conference attendees will have hands-on access to assembled headsets running student-developed software, as well as being able to see the unassembled components and assembly instructions.*

Keywords: Virtual Reality, VR, DIY, headset, smartphone, Molly

1 Introduction

While Virtual Reality has been the big story in computing for the past year or so, it is not a new area of research and development. One of the authors (Vullo) began experimenting with Virtual Reality Markup Language (VRML) in the mid 1990s as a way of visualizing dentition and restorations in electronic dental records. It is, however, only recently, with the rapid development and immense popularity of smart phones, that the technology for truly immersive virtual reality experiences have become practical and inexpensive enough for use in the classroom as a student development environment. It is our belief that as this rapid development continues, VR will soon be a mainstream consumer technology. At the very least, VR is an interesting combination of technologies that engages students across multiple disciplines in learning and development.

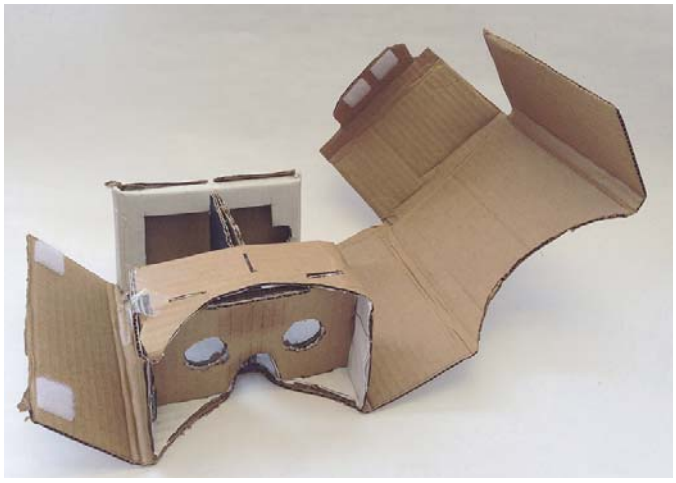
The goal of this project has been to develop a quality, yet inexpensive VR system design available to students and makers interested in exploring this exciting emerging field. Designed by Professor Vullo, it uses LASER cut plywood, acrylic, and fabric components making for an easy to assemble and customize headset. This approach allows both VR pros and hobbyists to gain easy insight into the hardware side of the VR equation.

2 A Series of Prototypes

This project has been one of successive prototypes and tests; experimenting with various materials, optics, phones, and software. The history of these is hopefully instructive.

2.1 The Beginning

The Initial design was inspired by Google's "Cardboard" design, which was originally made for the Android platform. That design was modified to work with an available iPhone 5 and the lenses, which were on hand from a previous 3D photography project.



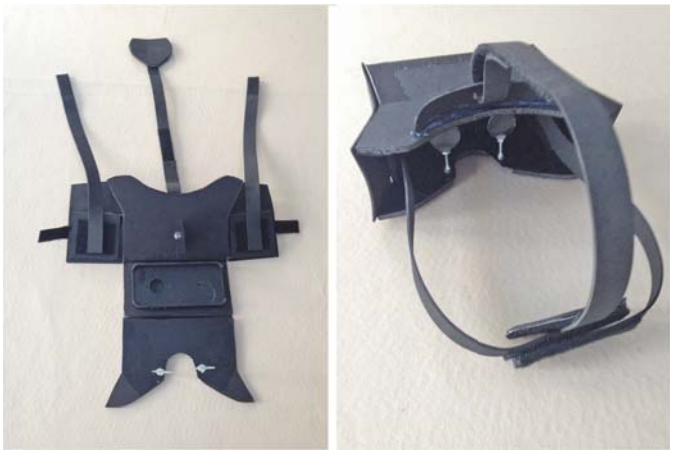
2.2 VR "Goggles"

The initial prototype proved awkward and difficult to assemble, so for the second prototype the design was based on modifying an inexpensive pair of safety goggles.

Better lenses, removed from a pair of binoculars, with a shorter focal length (about 3 1/4 inches) allowed for a smaller design and a better field of view in early tests. However, lens mounting diminished this field of view advantage. Development of a lightweight, yet rigid structure proved problematic, therefore this design approach was abandoned.

2.3 It's Not Cardboard

This prototype combined the box-shape of the original cardboard design, the face-hugging shape of the safety goggles, and a new material: foam core.



Foam core proved to be lighter and more rigid, as well as easier to cut and assemble with hinges of duct tape, compared to the cardboard design. Mounting the lenses, now extracted from inexpensive loupes, via foam core, then 3D printed mounts secured via rare earth magnets allowed for adjusting focus and inter-ocular distance of the lenses.

The availability of foam core with plastic rather than paper coating gave hope that this approach would result in a design that would be much less disposable than cardboard.

2.4 Burning Holes with Light

Hand cutting components from both cardboard and foam core proved slow, tedious, and imprecise. Taking advantage of a colleague's lab's new LASER cutter became the obvious solution. Cutting foam core on a LASER cutter is, at best, dangerous however, as the material tends to catch fire. Returning to cardboard, which is easily cut on a LASER cutter was not appealing, for other than quick throw-away tests, however the ability to cut thin inexpensive plywood was promising.

Plywood is considerably heavier than either cardboard or foam core, so this needed to be addressed. Taking a hint from honey bees, the wooden frame was honeycombed with hexagonal holes such that rigidity was maintained, but weight was greatly reduced. Instead of the square corners of earlier box-based designs, the ability to precisely cut accordion slits in the plywood made it flexible enough to bend into rounded corners.

Honeycombing lets light into the headset, so LASER cut fabric is used to seal out the light.

Lens mounts for this design were LASER cut from acrylic, held together with rare earth magnets and fastened to the frame with wing bolts and nuts. While this design was adjustable, in the end it still was not optimum.

2.5 Pursuit of Optics

One of the most difficult aspects of this project has been the optics; specifically, identifying and adapting inexpensive and off-the-shelf optical components suitable to the task. Many lenses were tested, most of which are not detailed here. The current design uses what has thus far proven to be the best solution. For each eye we LASER cut a pair of acrylic 2X Fresnel magnifiers to provide space for the user's nose. We sandwich them between two LASER cut acrylic shields which slot into the headset allowing adjustable intraocular distance. This compound Fresnel lens design gives us excellent field of view and the nature of Fresnel magnification reduces the screen-door effect of the magnification of the phone's pixels as observed with traditional lenses.

3 Software

The other half of a Virtual Reality solution is the software. We have used existing software, primarily designed for Google's Cardboard, for testing during the development process. However, we have also used our own 3D images and begun developing 3D and VR content. It is worth noting that similar to VR hardware platforms, the software and engines to drive VR content is also in a state of rapid-evolution with a wide range of capabilities: low-end or casual-end solutions exist using basic web technologies such as MozVR or Three.js which utilize WebGL rendering techniques, and scale to professional 3D engine technology such as Unity, Unreal, and Cryengine, all of which are leading industry tools that output to multiple platforms including PCs, game consoles, mobile devices, and hand-held systems. RIT has recently joined the VRFirst initiative, and is working with hardware partners at Oculus, HTC, Microsoft, and others in support of exploring this range of devices and capabilities.

3.1 Non-VR 3D Content

Production of 3D images is an old and well known process, and allows for easy testing of the headset's optics. Similar, but somewhat more complex and labor intensive is the production of 3D video, which we (Vullo and Catalfamo) have begun experimenting with. This requires mounting and aiming a pair of video cameras, to which end we have built several twin camera tripod mounting adapters which have proven successful in early tests.

We have also experimented with mounting paired IP cameras to test use of the headsets for telepresence. Early experiments show promise, though there are some technological hurdles to overcome, primarily in combining two audio-video streams on a phone's screen.

3.2 Virtual Reality

As of the writing of this paper we have two VR software development projects underway. The first, is based in the School of Interactive Games and Media's Research Studio course (Phelps). This course allows students to work as domain specialists on teams completing one or more research and development projects. Typically, the faculty member teaching the class will provide the research themes, with the exact project goals and objectives emerging from these base ideas or pre-production materials. The goals of the course are to engage students with research methodology and production-level design theory to implement, test, deploy, and evaluate the results of digital-media projects. Students complete research reports and final assessments of themselves and their teammates, as well as the studio processes and communications paradigms of the team, in addition to completing their assigned responsibilities on the main projects. Recently this course has produced two well received commercial videogames: Splattershmup and Hack, Slash, and Backstab that have garnered numerous awards and recognitions in the professional community.

The second project (Vullo) is exploring the use of web technologies, specifically AFrame and Molly, to develop an experimental prototype VR social media environment. (Still in early stages as of the submission of this paper.)

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5 About the Authors

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Miss Catalfamo is an Alumna of the Rochester Institute of Technology's Motion Picture Science program and a member of the Society of Motion Picture & Television Engineers (SMPTE). She also earned a Minor in Web Design and Development during which she was first exposed to the DIY VR project.