Design and Implementation of an Affordable CAVE System

Master’s Project Proposal

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# Summary

The original CAVE system was developed by Dr. Carolina Cruz-Neira as her PhD Dissertation in 1993. This revolutionary Virtual Reality device allows a group of users to be immersed in a high quality environment (Cruz-Neira, et al., 1993). Today, businesses can purchase a CAVE system through integrators such as Mechdyne, Visbox, and Barco. The CAVEs produced by these integrators are bulky, permanent fixtures, expensive and difficult to maintain. Since the original CAVE, numerous research attempts have been made to minimize the cost of the system.

At the Emerging Analytics Center in UA Little Rock, we have been providing VR/AR solutions for companies since the founding. One of the ways we gather new clients is to invite them for a tour of the facility. After showcasing our professional CAVE installation, there is typically a discussion about how they can use this technology. We have seen that businesses would benefit from having a CAVE, however the steep price and the immobility of a traditional installation hinders them.

I would like to build a CAVE with a focus on mobility and affordability. I propose to follow the strategy of (Cruz-Neira, et al., 2010) and (Stuerzlinger, et al., 2015). However, I would like to utilize the new HTC Vive / SteamVR tracking system, the Unity game engine, and a new custom management tool (called The Dashboard) to run and maintain this system. These improvements should lower the cost of the CAVE and massively increase the usability from a business perspective.

# Selected Preliminary Research

(Pape, et al., 2002) describes how to create an affordable immersive display. The final product of this workshop was a 1 screen projected display where the single user can where a electromagnetic tracking system.

(Cruz-Neira, et al., 2010) designed an affordable CAVE system for the Army Research Laboratory’s Human Research & Engineering Directorate. This CAVE used off-the-shelf components such as the DepthQ®-WXGA HD 3D video projector. The system was rear-projected and driven by a cluster of computers. Overall, the CAVE cost approximately $60,000 where the PC cluster was the most expensive component. The researchers also created a remote control application to control the projectors.

(Juarez, et al., 2010) developed a CAVE system using the commercially available CryEngine2 game engine. Their CAVE system relies on consumer projectors to cut costs, however they utilize a small cluster of computers to drive the graphics. CryEngine2 had a blueprint system (programming apps using nodes and flow), the SDK allowed the end user to seamlessly integrate the CAVE into blueprints.

(Stuerzlinger, et al., 2015) created a temporary immersive virtual environment (TVIS) for the Simon Fraser University. This implementation is low cost and most importantly it is portable. Constructed out of aluminum profiles, this CAVE had a final estimated cost of $9,500 including 6 Optitrack cameras. This is possible by using projectors <$1000 each, do not include a floor (but include a fourth wall). Lastly, this CAVE is interesting because it is without stereo imagery, the researchers reported no noticeable side effects from leaving it out.

# Initial Design Strategy

## Hardware

Initially, I propose we follow the strategy of (Cruz-Neira, et al., 2010) and (Stuerzlinger, et al., 2015).

We should construct the projector frame structure out of aluminum and have an emphasis on portability. This CAVE I am proposing would be front-projected and driven by a single workstation. We will implement a front-projected floor and use coll apsible structures to allow the system to fit in a car.

However, we should utilize new technology where available since the TVIS was constructed in 2015. Since 2015, we have seen innovation in consumer-level virtual reality, increase in GPU computing power, and better ultrashort throw projection technology

(Maciejewski, et al., 2018) suggests that although SteamVR tracking has some error compared to the Optitrack, the system is still usable for common virtual reality use cases. Based on this, I would recommend utilizing the SteamVR tracking system over the Optitrack due to the price difference taking into consideration performance.

## Software Development Kit

With the innovation of the HTC Vive and Oculus Rift came new development in creating virtual reality content. Their SDKs, when paired with the Unity game engine, made it easier than ever to create. I propose we follow a similar route and design an SDK for the CAVE that is as easy to use as the HTC Vive.

This strategy entails structuring the SDK into prefabricated, reusable, components to minimize complexity. The Unity game engine has a system to allow developers to create “prefabs” and share them with others.

## Dashboard

The dashboard software tool will allow the end user to easily control the projectors of the CAVE in a Box, manage project builds to run, and run diagnostics on the projectors remotely. The software will be written in Python with the QT framework for easy portability, maintainability, and extensibility.

## Calibration

Calibration in this CAVE would be a two-stage process: Calibrating the tracking system and then calibrating the projection system. Calibrating the tracking system is already implemented if we use the HTC Vive. Their system has the user mark the boundaries, set the floor plane, and orient the forward vector. So, we just need to implement the calibration of the projection system.

The projectors output a rectangular onto a square screen, this inherently means that either the projection fully overfills the screen or underfills. We prefer it to overflow the screen, then we can crop the projection to match the size of the screen. As a part of the SDK, I am proposing a graphical system where the user can the corners of the projection to match the size of the screen.

# References

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