CubeVR: Digital Affordances for Architecture Undergraduate Education using Virtual Reality

Aditya Raikwar*
Colorado State University

Newton D'Souza†
Florida International University

Ciana Rogers‡
Florida International University

Mathew Kress§
Florida International University

Adam Williams¶
Colorado State University

Naphtali D. Rishe‖
Florida International University

Francisco R. Ortega**
Colorado State University

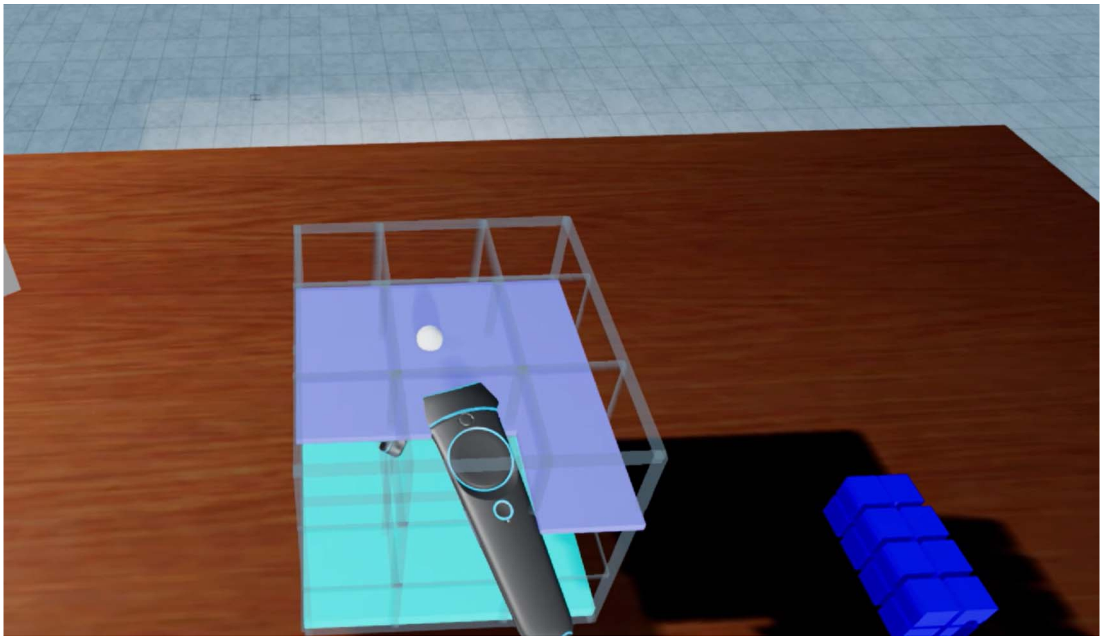

Figure 1: VRCube Prototype

Abstract

CubeVR incorporates the traditional studio-based learning in architecture with virtual reality (VR) and in doing so it enables features that are not available or difficult to achieve in the real-world. CubeVR allows students and instructors to move from the existing studio to a virtual environment, allowing for a more impactful learning experience. This paper presents our current state of the CubeVR prototype, informal impressions of users, and the use of different affordances in the virtual world.

Index Terms: Human-centered computing—Visualization—Visualization techniques—Treemaps; Human-centered computing—Visualization—Visualization design and evaluation methods

*e-mail:adirar@colostate.edu
†e-mail:ndsouza@fiu.edu
‡e-mail:croge041@fiu.edu
§email:mkres006@fiu.edu
¶email:Adam.Sinclair.Williams@colostate.edu
‖email:ndr@acm.org
**email:fortega@colostate.edu

1 Introduction

Architecture students are typically taught in a studio. In other words, Architecture education is studio-based learning where students and the instructor have a unique experience compared to the traditional classroom experience. Early in their undergraduate studies architecture students are require to work with physical models. One of these types of tasks requires them to build smaller models (with a specific allowable size, e.g., 3x3 inches). From the smaller models, they move to a bigger one. This requirement to build from smaller to larger models is designed to minimize the complexity of the tasks. While the end result may look like a house, it is still based in the size of the cube. In other words, students are restricted to build within certain measurements. While this has been the tradition in the architecture education, Virtual Reality (VR) and Augmented Reality (AR) provides improvement to take education to the next level. Larry D. Spencer wrote a profound text about teaching [6]:

> Plop a medieval peasant down in a modern dairy farm and he would recognize nothing but the cows. A physician of the 13th century would run screaming from a modern operating room. Galileo could only gape and mutter touring NASA's Johnson Space Center. Columbus would quake with terror in a nuclear sub. But a 15th century teacher from the University of Paris would feel right at home in a Berkeley classroom

Just like Larry Spender argued in [6] about why other areas have improved while education remains strictly similar. Of course, we

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have seen in the recent past a movement towards a more interactive learning (e.g., flipping the classroom). Just like the teaching requires evolving, so it is the way students acquired knowledge. Immersive technology provides opportunities to improve learning. This is why, we present **CubeVR**. An interactive prototype to bring the existing technique found in architecture education, as shown in Figure 2, into an immersive experience, as shown in Figure 1.

Here we can imagine a world of possibilities. Students interacting with other students and teachers. Students able to undo when making a mistake (no longer will a student have to start from scratch after a mistake). Students are able to see how different materials are affected by lights, and so much more. We present to you our current progress and the future of CubeVR. In this future, either our team or another team, will combine a physical model with virtual objects using an AR headset (e.g., Microsoft HoloLens or Magic Leap One).

CubeVR incorporates the traditional studio-based learning in architecture with virtual reality (VR). By providing features that are not available in the real-world or difficult to achieve, CubeVR allows students and instructors to move from the existing studio to a virtual environment. This paper presents our current state of CubeVR research and the position we are advocating for this technology.

2 Building the Physical Model

The student starts building a small physical model with a given volume restriction of 3x3 inches. It is important that volume is clearly defined. Figure 2 shows an example, where the bottom right part of the model (the one with the stairs) was a smaller cube and is now part of the larger cube. Once the student has completed some smaller models with a volume size of 3x3 inches, the following task is to incorporate this 3X3 model into a larger one. This larger volume becomes a 9x9-inch cube. Of course, it doesn't always work this way. Sometimes it is not feasible to stack up the planks. This will require lots of material and it may not have the desired aesthetic outcome. Therefore, a student may start with a larger piece (or pieces) to define the boundary. This will allow students to get a sense of lighting effects on the pieces.

Figure 2: Student working with a physical model in Architecture

3 Related Work

While we did not find an approach similar to ours in VR, there is still related work. One that encourages us to continue with our study was conducted by Im et al. [4] because of their positive results. Their study tested if VR can be used in a flipped classroom setting for an architecture class. The project was determined to design the interactive components in the course GE1125, so as to avoid rote learning for the technical terms of the Chinese architecture [1]. Another architecture example was conducted by Rodrigues et al. [5]. They introduced a system called VisAr3D, which takes 2D projected or printed software architecture via augmented reality and virtual reality to view, interact, and simulate the model in a 3D environment [5]. A similar study about architecture education was published by Shahin et al. where students learning about internal structures look at a building and their internal structures to improve their learning. The early results reported here seem to indicate that this may be a useful technique [7]. However, a more direct AR solution may provide an improved experience for the students. In terms of light effects, Boyles et al. created a Virtual Simulation for Lighting and Design Education. They used VR to simulate high quality visuals and real-world lighting effects. In addition, VR provides freedom to navigate through a space in order to look at the structure from different angles. [2].

VR assists students with learning and knowledge retention not just in the field of architecture. This technology and software allows students to explore and move around their classrooms while learning. Other examples of VR in education are Zhang et al., who used VR technology to increase the interaction and practicability for the fire safety education [8]. Their work increased the complexity and fine details that were missing in the existing platforms [8]. Another educational example was published by Chrysoulas et al. [3]. They proposed a framework which uses AR/VR to teach the concepts of industrial automation [3].

4 CubeVR: Design and Interaction

The concept of transferring a physical object to a virtual world, ease of interaction, current technology and affordability, were designed into the goals of our solution. Considering all these points, we came to the conclusion that VR was best starting point (leaving AR headsets as a possible future work). CubeVR was developed using Unreal Engine and HTC Vive.

When you start the program you are transported into a room containing a desk with all the basic building materials as shown in Figure 3, which includes:

Cubes:
16 cubes of 1x1x1
1 cube of 3x3x3

Planes:
4 planes of 3x3x $\frac{1}{4}$ to make 2 angles
3 planes of 3x3x $\frac{1}{4}$
6 planes of 3x1$\frac{1}{2}$x$\frac{1}{4}$
1 plane of 3x6x$\frac{1}{4}$
3 planes of 3x9x$\frac{1}{4}$
1 plane of 9x9x$\frac{1}{4}$ with 3x6x$\frac{1}{4}$ section removed

Rods and base:
16 rods of 3x$\frac{1}{4}$x$\frac{1}{4}$
1 base of 9x9x$\frac{1}{2}$

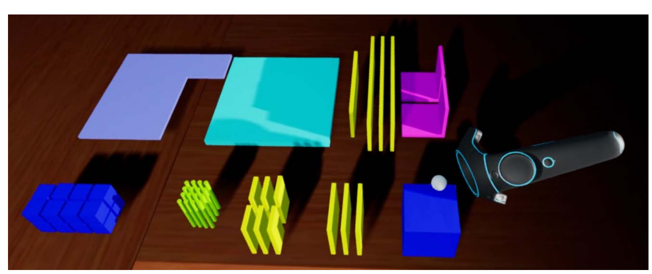

Figure 3: Basic Building Blocks

A menu is created (Figure 5) for easy switching between different settings for completing the given task. Users are able to change the material for different views, there are three materials provided. Colorful: this gives different objects in different colors with same shape objects having the same color. Wood: this gives all the objects a wooden texture and color as seen in Figure 4. Wire-frame: Displays objects in their wire-frame structure and is used to adjust the finer spacing and overlaps. For deciding the precision of the translation movement snapping can be used with options of 2 inches, 1 inch, 0.5 inch, and 0.25 inch. For rotational precision the user can use Rotational Snapping with options of 90, 60 and 30 degrees. There is also a Tutorial option for those who have never used this system before. Finally as Figure 6 shows, to assist with the volume boundaries a 9x9 transparent box is present with its edges highlighted to create nine 3x3 boxes.

Figure 4: Wood material model

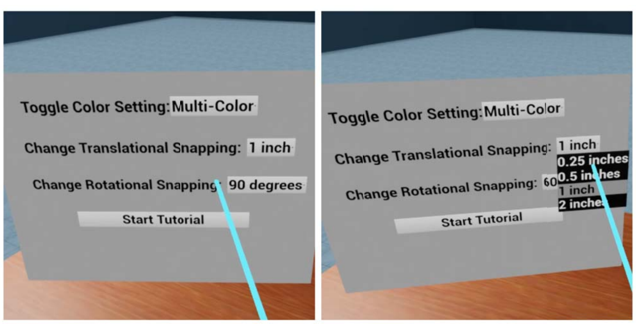

Figure 5: Menu

No physics engine is applied to the objects giving them the ability to float in the air so that you can fix them in the air and walk around to look for different angles without the hassle of holding the model. The building blocks snap together when they overlap so no glue is required for joining the pieces. Support for two controllers makes removal of a piece easy, just hold the object in one hand and pull out the non required piece with the other. CubeVR provides a platform and features that can improve the learning for architectural student.

CubeVR is currently able to:

- roll back changes if something goes wrong without starting over

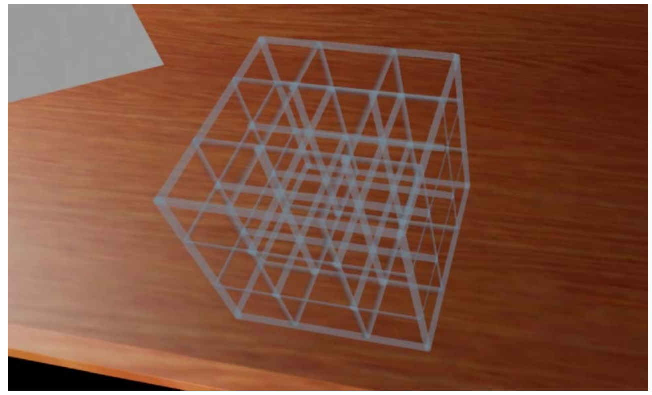

Figure 6: Volume Grid

- support multiple designers working side by side on different projects without having to worry about space or resources constraints
- change materials without spending money and starting from scratch
- theoretically infinite durability of the constructed model

We are working to add the following features (some are already in development in CubeVR version 2):

- Changing colors of the parts without any labor
- Ability to simulate different times of the day to play with different lighting conditions
- Ability to have design team from across the world working at the same time
- Ability to simulate physics to check for environmental impacts
- Simulate how the structure might look like few years down the line
- Re-sizing the structure to look at places which would be impossible without actually creating life size model
- Re-design the user interface to be more interactive including the latest research in 3D Menus. One example of an improved menu is shown in Figure 7. This is key for a more natural user interaction. Adding rendered hands and provide gesture recognition.

5 Discussion and Position

Did we just copy an educational task performed in the physical world into a virtual world? Our position is that we didn't. While we know that metaphors are great and we always want to maintain as many as possible, it is the ability to perform tasks not available in the physical world that makes something like CubeVR a powerful tool. Our initial informal testing has shown that students (including non-architecture students) have enjoyed the interface, it is still critical for us to perform a formal user study. This will provide the ability to understand if CubeVR could be a replacement or complement to the existing practice or a compliment to it. Most importantly, does CubeVR improves learning for architectural students.

One of the problems we did find when working with students, in particular non-architecture students, was that there was a learning curve to understanding the interaction of the system. While it

Figure 7: Improved Menu Version in Version 2.

seems fairly simple, some users were confused. One solution was to provide a tutorial, which we did. However, this is not the solution we were hoping for. On the contrary, we would like this to be as simple as possible for anyone outside architecture to use yet complex enough when needed.

We believe that the affordances that CubeVR, an educational tool, provide are the most powerful statement of how education is and will move towards virtual and augmented reality. The classroom will forever be changed. For example, the ability to roll back changes, multi-user collaboration, apply different lighting effects, have different textures, allow teacher to grade, provide physics engines (when required), and most importantly, and immerse students into the environment show the difference from creating an exactly replica of the physical environment to exploring the virtual environment possibilities, as CubeVR does.

6 Conclusion and Future Work

We have shown the current state of CubeVR, we hope that future work from us and other researchers continue to move towards virtual and augmented reality world in education. The ability to explore the affordances that virtual reality provides makes this prototype appealing. In other words, realizing the learning in a new world, the virtual world.

In the future, as already discussed as some of the tasks on-track for version 2, we hope to conduct a formal research study with architecture and non-architecture students. Also, we want to include the latest research in terms of interaction and providing a more natural user interaction. Another direction, which has not been explored yet (but discussed) is what does it means to use augmented reality in the same scenario. What other affordances can this provide? Would it improve learning more than CubeVR if the interaction is a combination of the physical world and virtual world using an augmented reality headset (e.g, Magic Leap One)? These are some of the questions that we are interested in answering in the near future.

Acknowledgments

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