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BEYOND FLAT SPACE

REPRESENTING ARCHITECTURE IN VIRTUAL REALITY

BEYOND FLAT SPACE:
REPRESENTING ARCHITECTURE IN VIRTUAL REALITY

Request for Approval of Thesis Research
Project Book Presented to:

Professor Chris Welty and Professor Arief Setiawan

And to the
Faculty of the Department of Architecture
College of Architecture and Construction Management

By

HOLDEN ZACKERY HOLLEY

In Partial Fulfillment of the Requirements for the Degree of

BACHELOR OF ARCHITECTURE

Kennesaw State University, Marietta, Georgia
Spring Semester 2018

DEDICATION AND ACKNOWLEDGMENTS

THIS BOOK AND THE RESEARCH WITHIN IS DEDICATED TO:

My parents, **Zack and Ginger Holley,** for dealing with countless phone calls for money, the support you have shown throughout all of my work, and the gray hairs we now share

Rob Evans and family, for instilling in me at a young age my love and passion for architecture, and fostering that throughout my youth

Caroline Montague, for your donation of supplies, advice, and time throughout my entire time in school (I still use that drafting board today) and **Ben, Patty, and Tyler Montague** for everything - even opening their home to me for the summers I had nowhere else to stay

The members of Hughes Turner Phillips, for their genuine interest in my thesis and in me as an individual. I am so very grateful to have had a work environment as amazing as you have given me while in school, and for the many lessons outside of the classroom

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And the KSU Architecture Class of 2018, for pushing me to be my very best through every late night in studio

SPECIAL ACKNOWLEDGMENT

I would also like to thank my advisor, Professor Chris Welty, and his partner in crime, Professor Arief Setiawan, for the countless critiques and support throughout this entire project. From the start of this project, you and the multifaceted experiences you bring have taught me much about architecture, technology, and myself, and I will carry those teachings with me for life.

Also, thank you for the most important lesson of all, that sometimes, you just need to sit down, shut up, quit asking questions and just get to work. In a world full of unknowns, you have taught me the best way to find an answer is to just try it.

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SECTION 1: THEOREM

DESIGN_THEOREM
1

1.1_ABSTRACT

In a world where we need to communicate our design intentions, where some people cannot read a plan, we can utilize digital representation to graphically communicate and influence design intentions and client understanding.

As architects, most of us go through years of training and experience just to read and draw plans, sections, and elevations. As students, we are taught how to read a plan and dissect the information we need to understand the spatial relationships. There are many times, however, that a plan doesn't really tell us what experiencing this space is like. And how is the untrained client supposed to understand how this space really works? Isn't that our job as architects, to represent our designs well enough to our clients that we communicate to them everything necessary for understanding this space that THEY hired US to design? How then, especially to the untrained eye, are we to use a packet of drawings of the space to really allow them to understand?

In the past, we have used renderings and perspectives to achieve this. But this comes at a cost to the client, and doesn't always give the full detail of the space. Every type of media we use has strengths and limitations to represent and communicate design, but each new medium has affected the way we think about design. What if, through the way we use our knowledge of representational media, we could not only give clients lacking the years of training we have the ability to experience the designs we are making, but also enhance the way we communicate design so as to minimize the false perceptions in the built process?

I think the answer for architects lies in the power of virtual reality as a graphic representational tool. Yes, I'm talking a change from architecture being represented in 2D to a 3D representational style. My thesis explores virtual reality and its potential to allow architects to draw and design in 3 dimensional spaces, and takes a look at how this medium can affect our techniques of communication and representation of design.

The process was simple. My first semester would be spent doing research on Virtual Reality, what it is, how it compares to traditional means of representation, and who is using it in practice. I then would spend the second semester designing in VR myself, using a few different programs to see the versatility of VR within design, and the final project would be a collaboration where I could prove VR's representational capabilities by representing another project to prove its validity. From there, I learned just how powerful a tool Virtual Reality is, and after this project, I would recommend the means and methods to any designer wishing to improve their project. Enjoy!

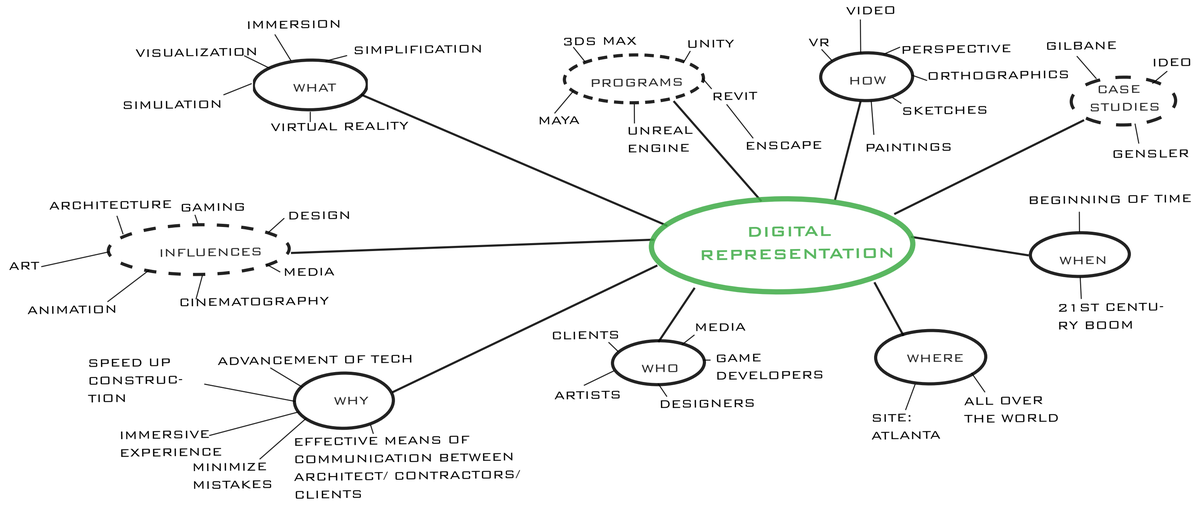
1.2_THESIS PROPOSAL

After hypothesizing that virtual reality could be a good graphic representational tool, I need to set some ground rules for my project. The outcome of this thesis is split into 2 phases. Phase one: Theorem is all about researching the topic of representation through virtual reality and producing questions to base my second phase on. These questions should drive the outcome of the thesis project itself and bear significant relevance to the topic at large.

First, I want to know **how we represent and subsequently communicate our designs to clients**. Yes, we show them things, but what do we show? What do we leave out? Does your audience matter or is there a specific presentation that works for most anybody? These questions help direct my research.

Next, I read a lot of scholarly resources on the subject. This is important because **it is not just about VR, its also about representation.** To fully cover that topic of representation, we have to more clearly understand representation from primitive to futuristic.

Finally, because this thesis does focus on virtual reality as a graphic representational tool, I knew I had to physically put myself within the virtual space to fully grasp its implications. This would hopefully lead to me discovering more on the topic of representing architecture.



Mind mapping exercise ^

1.3_UNDERSTANDING VIRTUAL REALITY

Within the Virtual Continuum, there are some major categories that we can look at:

Reality - This is “what is”, “what already exists”, or “the norm”.

Augmented Reality - This is digital overlay on real scenes. Hardware used would be the Microsoft HoloLens.

Augmented Virtuality - Using virtual imagery with a layer of realism. It is more in depth and more virtual than augmented reality.

Virtual Reality - This category is “what could be” and is the area of my research. Using VR allows for us to experiment virtually unconstrained. Method uses HTC Vive or Oculus Rift.

FIG. 1.3.1

VR/ IMMERSIVE DESIGN TOOL COMPARISON

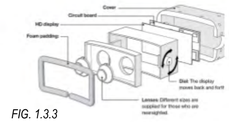


FIG. 1.3.3

FIG. 1.3.7

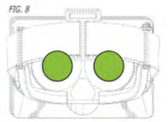


FIG. 1.3.2

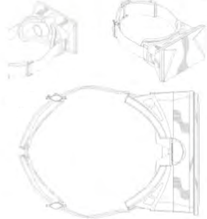


FIG. 1.3.6

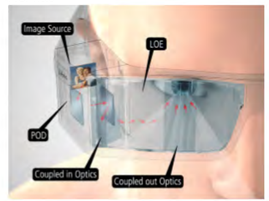


FIG. 1.3.8

OCULUS RIFT | HTC VIVE | MICROSOFT HOLOLENS | CURVED PROJECTION SCREEN

FIG. 1.3.9

FIG. 1.3.4

FIG. 1.3.5

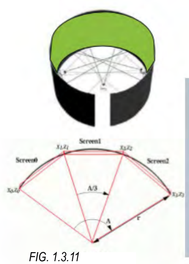


FIG. 1.3.11

FIG. 1.3.10

1.4_RELEVANCE TO DESIGN

Many firms across the United States, as well as many abroad, have already accepted virtual reality as a tool to help within the industry. The big question is WHY? What is so special about this odd-looking headset no one wants to wear that could possibly have any relevance to our design or representational processes?

That answer lies in our definition. Whereas reality is, by definition, “what is” or “what exists”, virtual reality is “what could be”. This means that virtual reality allows us to design things without some current constraints that reality imposes on us.

One such constraint may be gravity. We know that when something goes up, it gains potential energy, and will eventually come down unless inevitably held up. In virtual space, this may not be the case. We can hang elements in the air for the sake of design, adding in supports later, something you cannot do with a physical model unless you have an extra set of hands.

Another constraint may be structure. In architecture, there is a fine balance between aesthetics and tectonics - this much we know. To create a beautiful surface, there has to be structure holding that surface up. That structure requires thickness. We previously used sections to show thickness of walls and columns, and I’m not suggesting this goes away. Rather, I simply say that while a section is good at one angle, what if I look at it from another angle? Well, with virtual reality, you do not have to make another whole drawing. Simply move a little to the right or left and your understanding of that sectional space may very well change because new information will be revealed to you.

Map of Integration in USA

Virtual reality is a potential tool for architects because it gives us more than just a 2D surface to view. In other words, instead of looking at that section head on, VR simply puts that paper with the section drawn on it upright in front of you and then allows you to walk around your own drawing, changing it from a section to a section perspective from any angle and this new angle allows you to learn more from the original drawing.

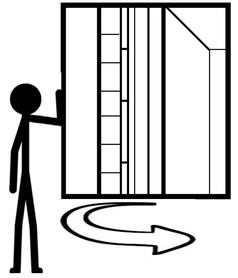


Illustration showing the ability to rotate a wall section drawing to enhance understanding

Virtual reality is simply showing a multitude of drawings from a Digital Model taken from different points throughout the model IN SCALE. Therefore, it is like you just took your section, elevation, or perspective, and simply moved where the camera was pointing or where the frame was being cropped, showing you more information about the building model that the original drawing was not.

FIG. 1.4.1

FIG. 1.4.2

Drawings that were once done on a drafting board are now being drafted in programs like AutoCAD and Revit. The most amazing part of this entire process is the integration of virtual software within these programs.

For instance, Revit can use almost any BIM file type and convert to almost any file type as well. This allows for seamless transitions through different design software and allows for the use of virtual design methods without changing too much of our current design process. It can be as simple as a plug-in for our current software or as complex as exporting to another software. This is why so many firms have already adopted this technique.

To the right, you can see the tradition design work flow and how virtual reality could be integrated into the process. Essentially, virtual reality could be used anywhere from late stage schematic design to construction documentation, due to its integration within our current processes and software.

VALID QUOTE

It's a great tool for communicating to everybody, whether they understand architectural drawings or not.

- Simon Manning, Co-Founder Bevel Space

bevel

Integration into Project Delivery

TRADITIONAL PROJECT DELIVERY

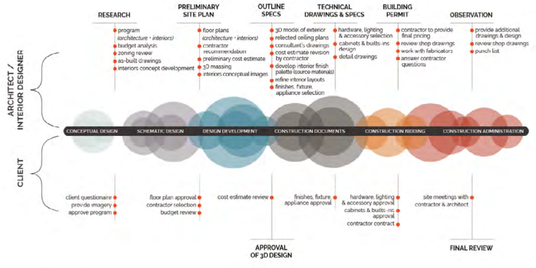
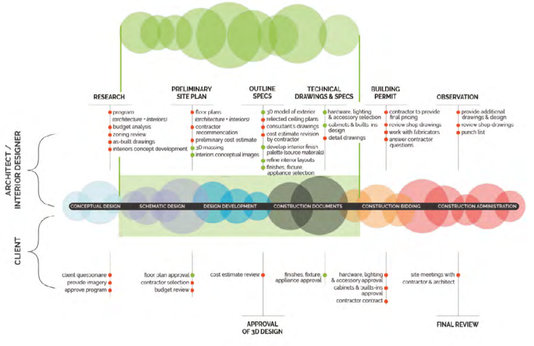
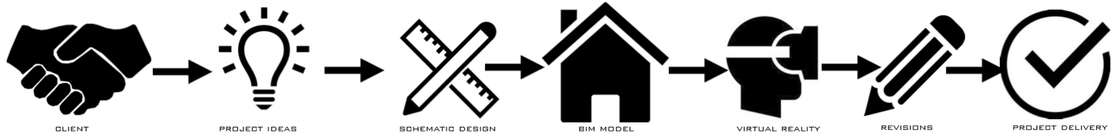
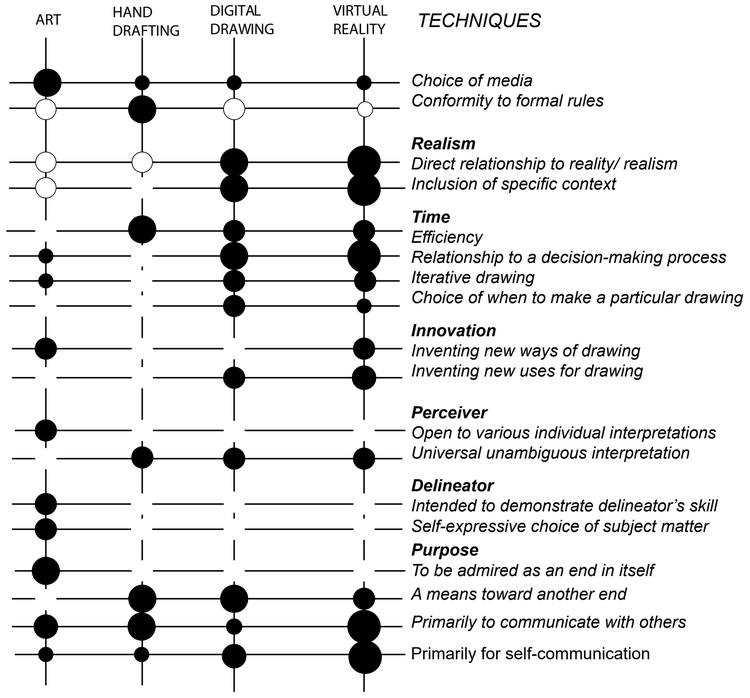


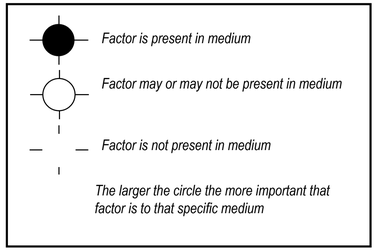
FIG. 1.4.3

TRADITIONAL PROJECT DELIVERY WITH VR INTEGRATION









The chart shown on this page illustrates different types of design media and the strengths and weaknesses of each based on measurable attributes. The chart style is taken from one of my readings by Lockhart, who is very well known for his understanding of hand drawing and its role within drawing experiences. I used its style to show traditional or previous design techniques in comparison with virtual reality. What I learned is that virtual reality is very good at simulating realism and is the only type of design technique that I studied which can be used for both Self-Communication and Communication with Others. This means that virtual reality not only helps us as designers see realistically how these spaces come together, but it also is EQUALLY AS GOOD at showing clients the same information about these spaces.

IN SUMMARY:

5 REASONS TO USE VR IN ARCHITECTURE:

1 - ***THE ABILITY TO MAKE CHANGES ON THE GO***

2 - ***AN ADDED, BILLABLE VALUE TO THE PROJECT (AND COMPETITIVE EDGE)***

3 - ***KEEPING ATTENTION AT REVIEWS***

4 - ***ALLOWS FOR LONG DISTANCE MEETINGS WITH CLIENTS***

5 - ***THE ABILITY TO PERSUADE A CLIENT BASED ON VISUALS***

CHAPTER_2.0

DESIGN_ANALYSIS 2

2.1_DIGITAL PRESENTATION STUDY

UNDERSTANDING VIRTUAL REALITY AS A REPRESENTATIONAL TOOL

2.1.1_DIGITAL PRESENTATION TECHNIQUES

All throughout the ages, as technology develops, so do our presentation techniques. Pretty early on, long before we even approached the modern era, we see architects use plans, sections, and elevations to communicate with each other. Simply put, picture a box. The plan is the top view, elevations are the sides, and a section is a dissection of the box itself. To get a full picture of what is inside of a complex box, we have to look at many different sections. That is, until the Renaissance, where Filippo Brunelleschi invents the drawing style we call the perspective. This allowed us to see both interior and exterior spaces with some form of scale. This drawing type also forms the basis for rules used to display digital drawings we see come to life years later. We introduced CAD and BIM software as a means of using all previously established drawing types with the ability to make changes to one view without having to change this detail in all drawings. The next step, which this thesis focuses on, is on virtual reality and how it can enhance our understanding beyond a perspective by putting us within a scaled model, though it builds off of the same rules as a perspective.

As shown to the right, we go from plans, sections, and elevations, to axons, to perspectives, to specialty diagrams, then to CAD and BIM models, movies, and finally, virtual reality.

Plans, Sections, and Elevations are orthographic projections where the drawing plane is perpendicular to the projection. This is the first known way architects have broken design data into understandable information.

Axonometrics are a representational style where the drawing plane shows 3 planes of projection, each at 45 degrees. This was the first representation of 3D data on a 2D plane.

Perspectives, however, were a different story. While orthographic drawings were used to communicate design, perspectives were used to communicate experience of space, and it takes both drawing types to understand how virtual reality works.

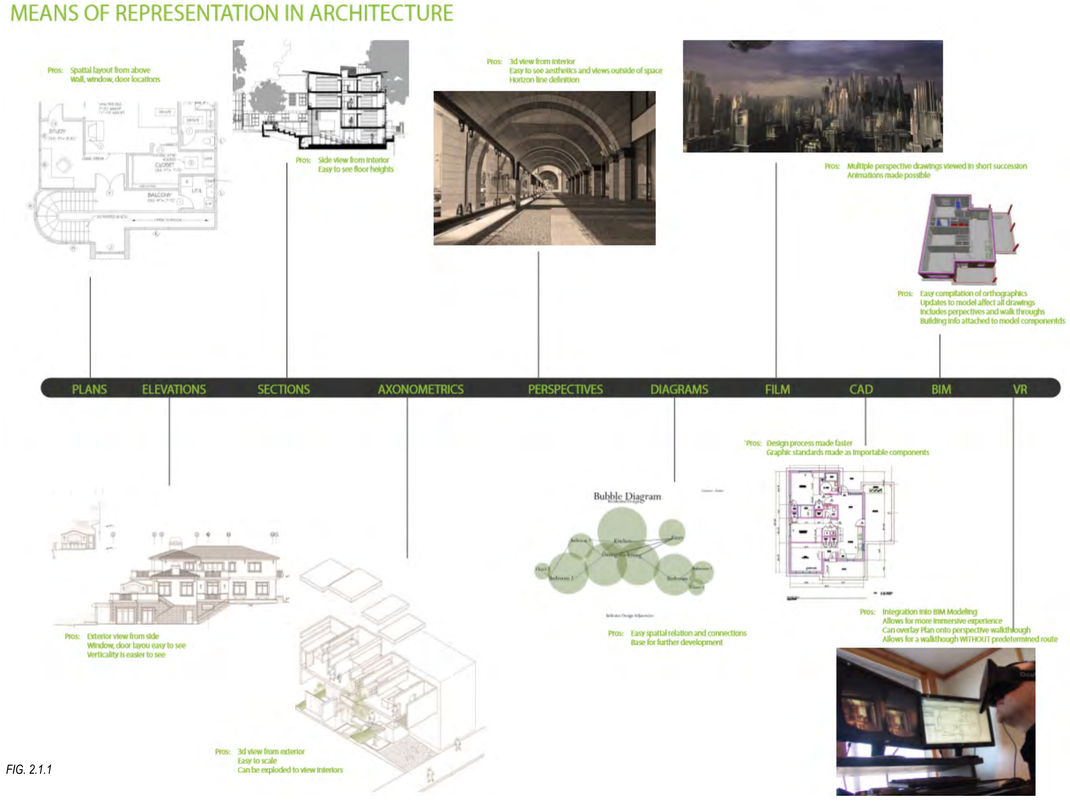


FIG. 2.1.1

2.1.2_COMMUNICATION THROUGH VR

SPACE

WHITE BLOCK
LINES

FORM

WHITE BLOCK
NO LINES

Within virtual reality, we can turn on and off different layers to look at different points of architecture. Anything from Space, to Form, to Tectonics, to Structure, to Performance, and sometimes even program can be distinguished with different graphic details. The beauty in this is that this technique can be used to show all aspects of architecture in ONE drawing type and any user can cycle through these layers with the click of a button.

TECTONICS

COLOR
MATERIAL

STRUCTURE

HIDDEN LAYERS REVEALING STRUCTURAL COMPONENTS

PERFORMANCE

LIGHT VIEW

Another way we can communicate within virtual reality is by using the software of choice to give the presentation of the project its own unique drawing style to show off different techniques to different clients. Some examples can be seen to the right using a program called Enscape, a plug-in for Revit. If you want to show the building as serene and almost otherworldly, you would turn on effects such as Bloom or Saturation, and make the building pop out from the background.

If you were focusing on presenting the overall building form, rather than the finished product, you can turn on White Mode, which essentially makes the building a white model, so you can focus on form and space without material. You can also add a cool color filter to enhance the effect. Also notice, as shown in Render Style 3, that this effect de-colorizes grass, but makes it a very different material than the building, so it's not entirely white.

There is also a mode called Light Mode, which allows us to change the time of day and track the sun pattern throughout the space as we do so. This allows us to check heat gain and assures us the ability to convince that client who is skeptical about paying for those solar shades that they are absolutely necessary.

RENDER STYLE 1

BASE IMAGE (NO EDITS)

RENDER STYLE 2

- WARM COLOR FILTER
- NO LINES OR EDGES

RENDER STYLE 3

- COOL COLOR FILTER
- LINE EDGES
- WHILE MODEL MODE

RENDER STYLE 4

- SATURATION 150%
- NO LINE EDGES
- BLOOM EFFECT

LIGHT MODE

- LIGHT MEASURING TOOL

CAN CHANGE TIME OF DAY TO TRACK LIGHT AND HEAT GAIN

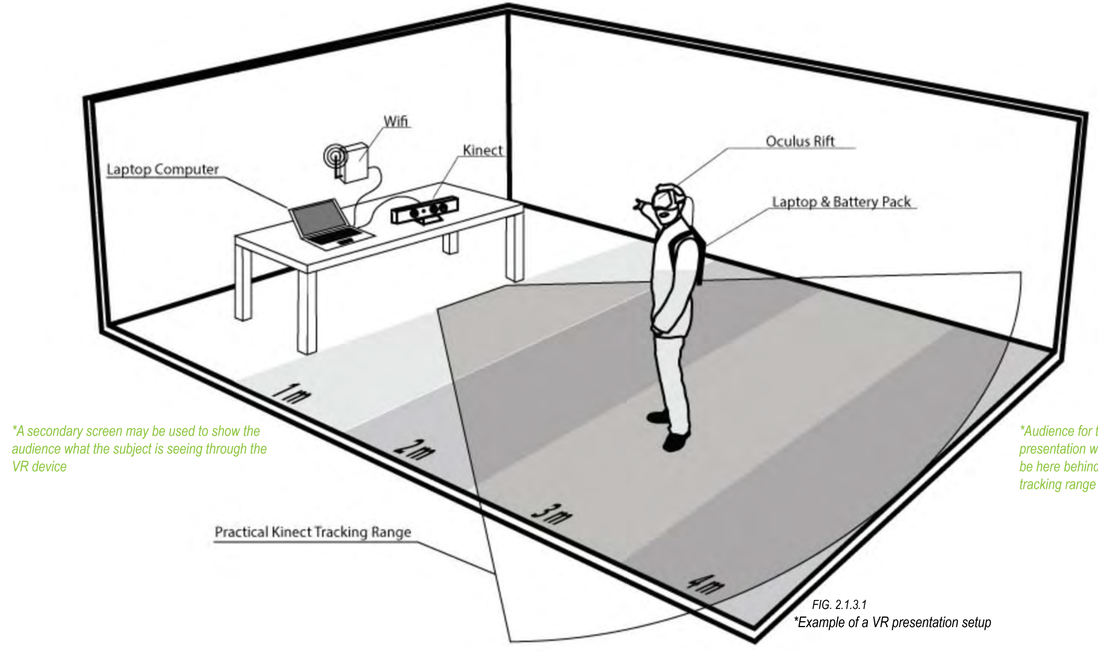
2.1.3_VIRTUAL REALITY PRESENTATION

Now that we know what virtual reality is and can do, we need to know how to set up a presentation to be able to utilize its ***capabilities. Here is a step-by-step of how to set up such a presentation you have made.***

Things you will need:

- A laptop computer that can run a VR program
- A Kinect or Oculus motion tracking hardware
- An Oculus Rift, HTC Vive, or other VR headset
- A room with plenty of space (at least 3-4 meters square)
- You may also want a secondary screen to show others what is seen through the headset (optional)

After all of this is acquired, you can show off those spaces you've created as if you are there walking through it!



**A secondary screen may be used to show the audience what the subject is seeing through the VR device*

**Audience for the presentation would be here behind the tracking range*

FIG. 2.1.3.1
**Example of a VR presentation setup*

2.1.4_BIM COMPATIBILITY

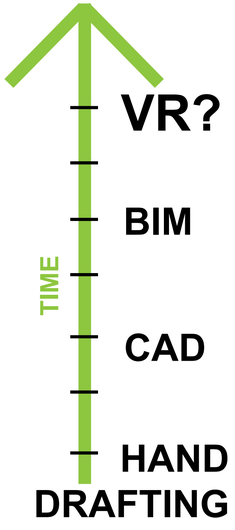
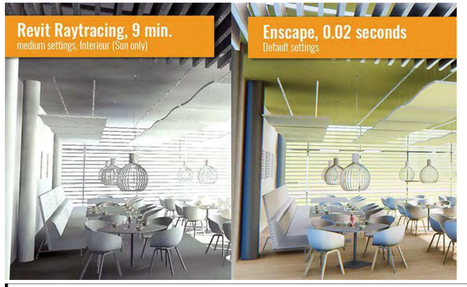


FIG. 2.1.4.1



Virtual reality sounds like such a foreign concept to us when used in the context of design. However, this is not the case. In fact, now that we live in a technological age, and most architects in practice use Building Information Modeling software, also known as BIM, virtual reality is easily compatible with the software we already use. Think of it simply as a next step to the already forward progressing computer modeling we are used to.

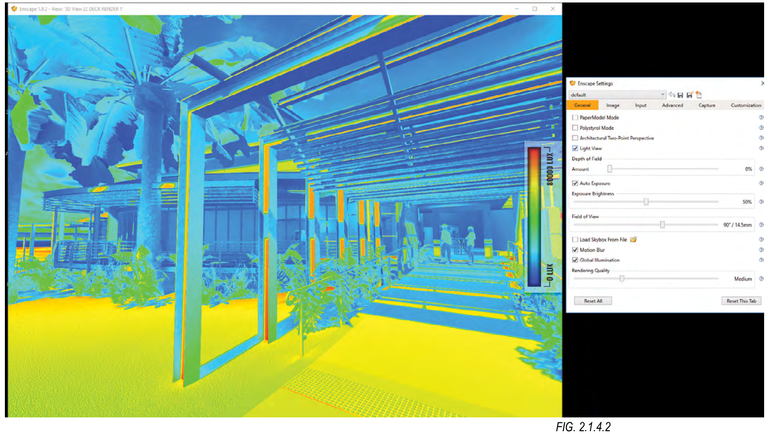


FIG. 2.1.4.2

Some virtual reality programs utilize the ability for us to export from one program to another. For instance, if you wanted to do a VR presentation using Unity, almost any design software is easily portable to that software. SketchUp, Rhino, Revit, FormZ and ArchiCAD all have portability to Unity and, subsequently, any similar software such as Unreal Engine.

However, there are a few programs that are meant to work within the software we already use daily. One such example, and the software package I am most intrigued by, is Enscape. This program is a direct plug-in for Revit. It simply adds a ribbon entitled “Enscape”, to which you are given a number of options for viewing the design you have already made, either as on screen walkthroughs or through the lens of a VR headset.

The advantage to using a plug-in versus an exported to program is that any changes made directly to the BIM model, such as furniture location change, deleting an object or wall, or a material change, are all updated in the VR experience in REAL TIME. ***This means that I can make changes on the fly DURING THE PRESENTATION.***

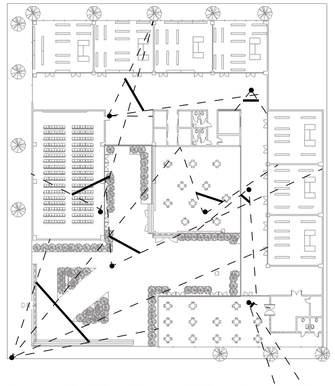
FIG. 2.1.4.3

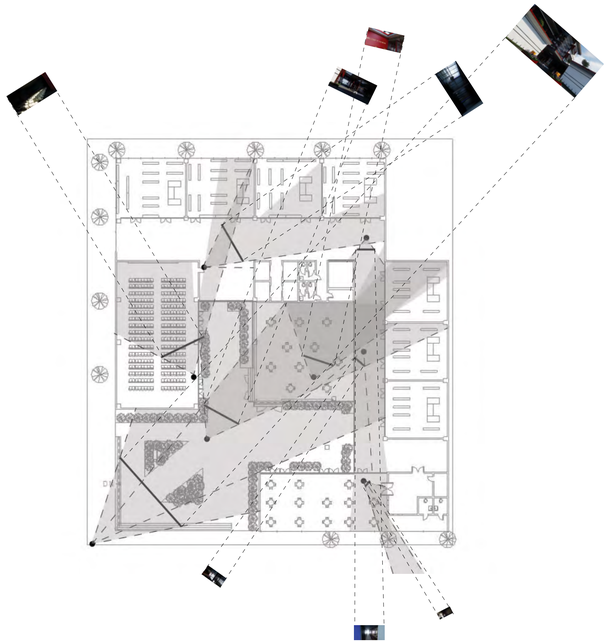
FIG. 2.1.4.4

2.1.5_CINEMETRICS AND RELEVANCE

Below are key frames from a walkthrough I did of my own project. The grayed out areas are the peripherals one would see and the fully colored areas are that of a direct cone of vision (areas of focus). Through this exercise, I have learned that a plan with a cone of vision has a direct correlation with a perspective view, and the computer will use this process to make changes based on a plan to show you what you want to see. In other words, this drawing process, called cinemetrics, is not only what we can use to identify the connection between perspectives and plans, but is also what the computer is doing behind the scenes to give you the rendered image you ask for. Understanding the process helps us know how to utilize it to get the desired view we want.

Cinemetrics, a term invented by Brian McGrath for a new drawing type I read about in his book “Cinemetrics”, is a drawing type used to analyze movement through space within films. Understanding perspectives as a screen, or frame, on a plan helps us to capture the views that we want, as well as coerce our clients to look beyond that frame, to look up, down, around, and behind what is normally just an image.





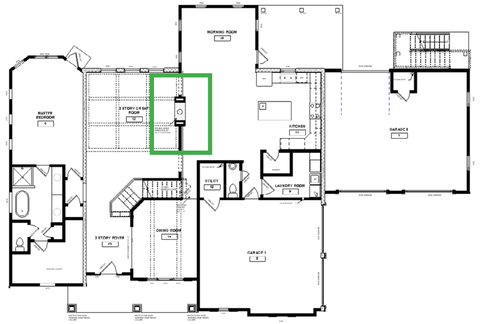
2.2_INDIVIDUAL PROJECT ANALYSIS

HOW CAN VIRTUAL REALITY HELP PRESENT PROJECTS I HAVE DONE

2.2.1_MCCOY RESIDENCE

The owner employed me to design his house because, while he was a contractor himself, he needed someone who could design a set of construction documents quickly and efficiently so he could get his building permit before the year was up and the permit requirements change. I am proud to say that he has received his permit and will begin construction in about a year. However, as beautiful as his house is from the outside renderings, plans, and elevations, when we look at the BIM model specifically, we notice a few problems. One of these, which I will show in the next few pages, is not going to be an issue once built. This is because the contractor, who in this case is also the owner, has the know-how to look at a set of plans and infer how things are built based on typical construction methods. ***THIS ONLY WORKS IF YOU ARE BUILDING BASED ON TYPICAL CONSTRUCTION TECHNIQUES***. Had this plan called for a different detail, we would either have to make detailed notes on installation, or provide a different detail to show this difference.

What if we used VR with ACCURATE BIM MODELING to show this detail WITHOUT creating more detail drawings?



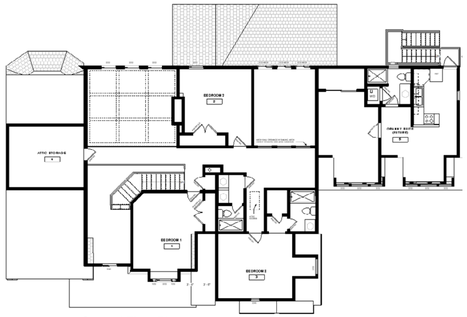
First Floor Plan

The location (shown below on this plan) is the great room on the bottom floor. This room spans 2 stories with a beautiful coffered ceiling. With the dashed lines being the location of the coffered ceiling above, and the call-out next to the blocked in box denoting a fireplace, the contractor can read this detail just fine. The issue in this is the contractor does not buy the house, nor is that the reason the house is built in the first place. Because of a client, the house is commissioned. So, we either have to show a rendering, or build a full scale mock-up of this fireplace and ceiling detail to show them what this graphic standard actually means, and that can get very expensive. Most residential firms use model homes to show off key details like this, but what if we could show that without ever having to build it? Well, we can, if we build it ***VIRTUALLY!***

HZHDESIGNS.COM

Fireplace Imagery

This image shows within the house the fireplace set within the 2 story great room. Although the plans are correct, there has been some inaccurate BIM modeling, and not only is the fireplace missing from the slot it is to sit in, notice the material we have for the exterior wall above is also on the wall for the fireplace. This should not be the case, and when building in reality, this would be no issue at all. The issue comes when a designer tries to present something like this to the client. This just means that we have to accurately BIM model everything, from house to hotel, without taking shortcuts. Though this may seem like a longer design process in the early stages, it saves time by cutting out most of the revision time later on in the process.

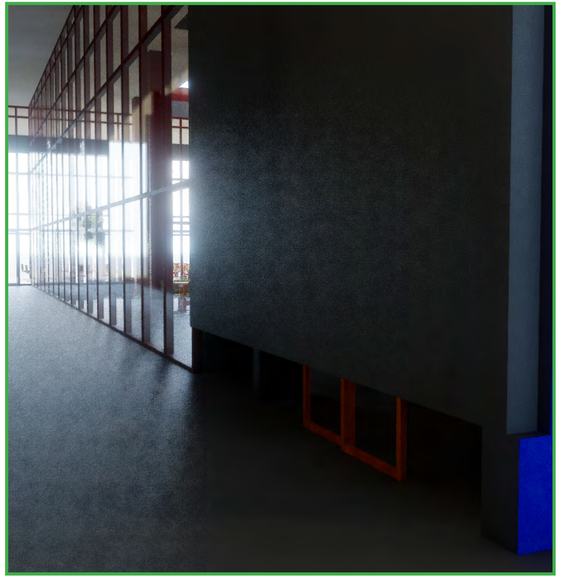


Second Floor Plan

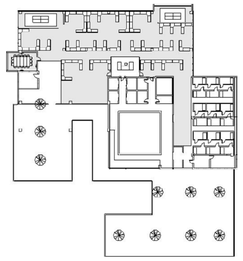
2.2.2_THE NEXUS: URBAN INCUBATOR

Within this project, which I completed in my 3rd year of architecture school, there are many different programmatic elements within: commercial stores, offices, a media library, atrium, cafe, assembly space, and core. This was the first project I ever had to use a core on, and that is where the problem with this project lies. Same as with the McCoy Residence, from the plans, section, elevations, and exterior 3D views there seem to be no problems. I then put on the headset, in this case, an Oculus Rift, and as I walk by the core, about 3 feet of wall behind an elevator shaft is missing. Come to find out, in order to get enough wall above the roof for elevator access, I had to shift that core wall up 3 feet, and the base of the wall detached from the ground floor. In building this, that would never happen for physics does not allow for a floating wall. However, as far as digital presentations are concerned, that would be embarrassing to show a client!

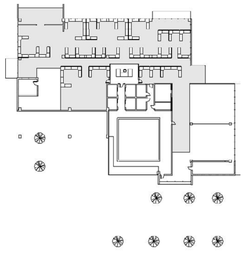
Raised wall to accommodate roof access (ground floor)



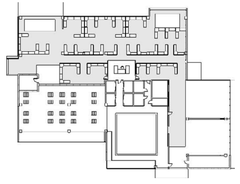
Roof access from raised wall height (roof height)



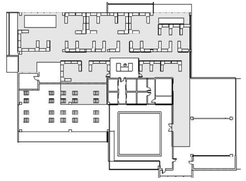
SECOND FLOOR PLAN



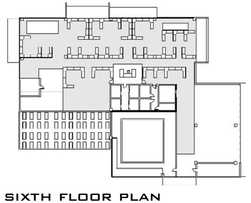
THIRD FLOOR PLAN



FOURTH FLOOR PLAN

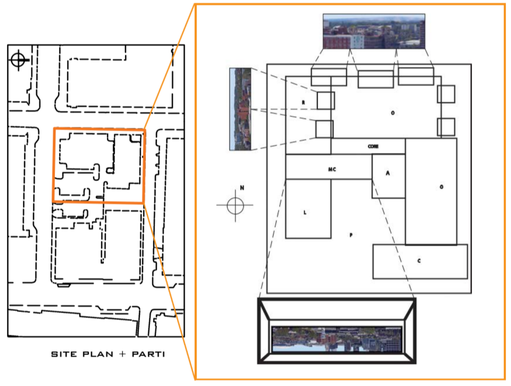


FIFTH FLOOR PLAN

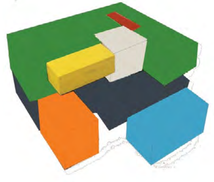


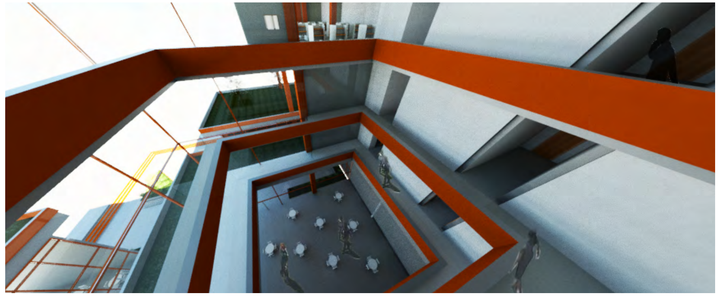
SIXTH FLOOR PLAN

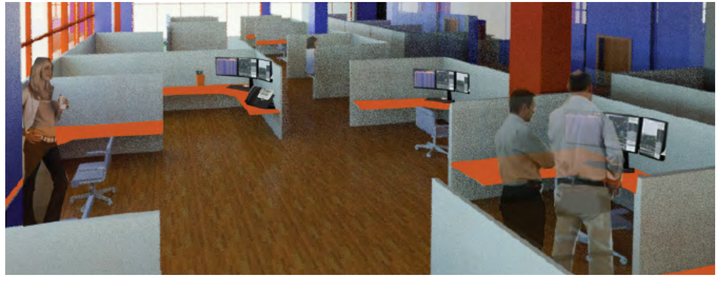
FIRST FLOOR PLAN



SITE PLAN + PARTI



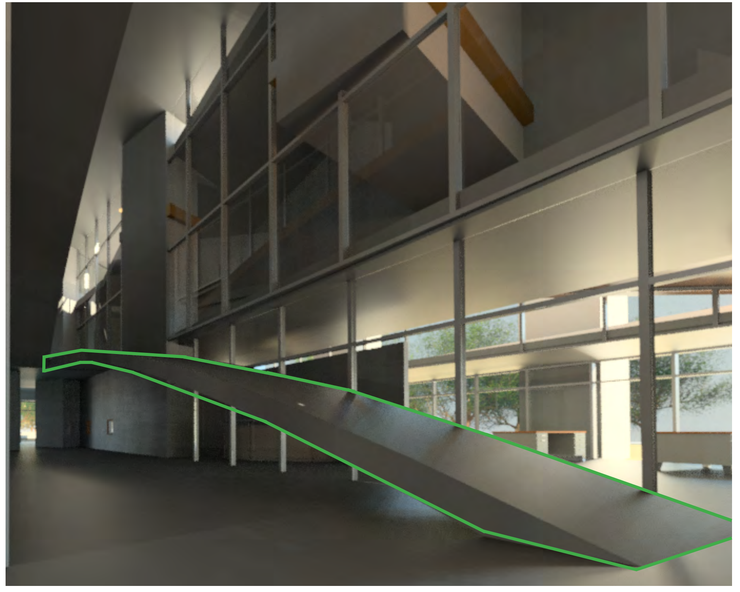


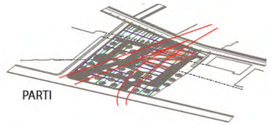


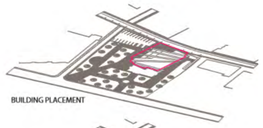
2.2.3_AIA HEADQUARTERS

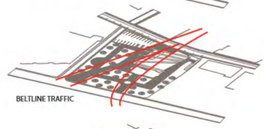
This was another project I did while in architecture school. Like the other 2, I walked through the project in virtual reality and noticed a few problems that I did not notice on the plans. Some floors were a few feet off, some walls were in the wrong locations above the cut plane of the plans, etc. However, this project also showed something that I doubted would work in reality, putting to rest my negative suspicions. You see, this project gave me a hard time because of the non-orthogonal grid I made for the building form based on exterior site constraints. This made connecting floors together via ramps very hard. So to connect the floors, I used a ramp system that was very non-conventional. It was curved, and from the bottom side of the curves I framed views outside from the floor below. Using virtual reality to test how this ramp worked with the views proved it could be a useful tool to architects as far as immersion goes.

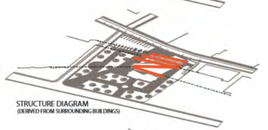
**Image showing one of the "non-conventional" ramps in the project*

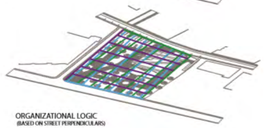


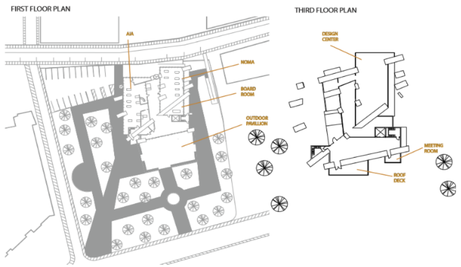


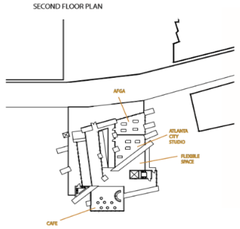


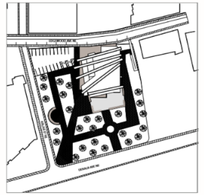


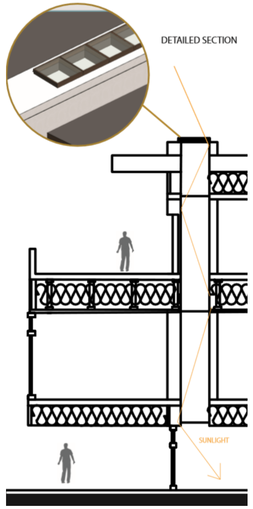


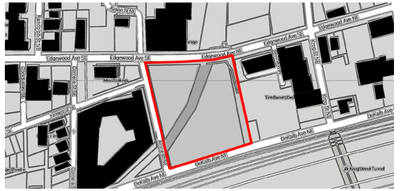








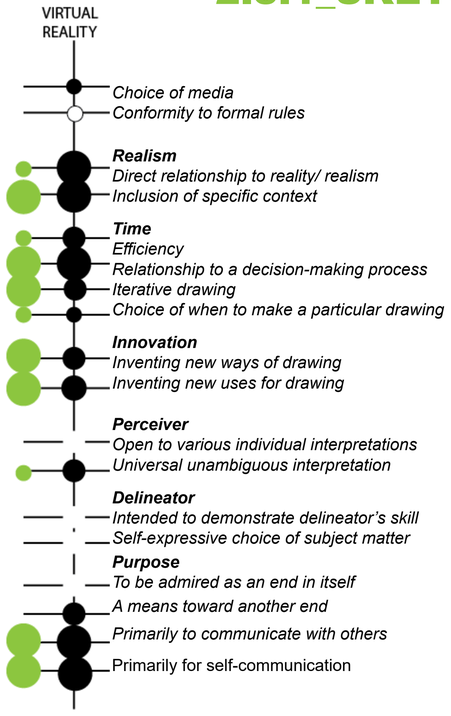



Edgewood Ave SE
Edgewood Ave NE
Ellis St
Trinity Ave
Decatur St
Jackson St
Irwin St
Irwinton Ave SE
Edgewood Ave
Trinity Ave
Decatur Ave NE
Decatur Ave SE
Freedom Pkwy

2.3_VR PRESENTATION CASE STUDIES

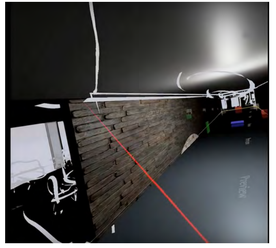
WAYS TO USE VIRTUAL REALITY TO PRESENT DESIGN

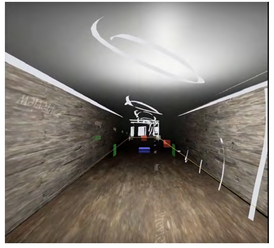
2.3.1_SKETCH/ FREE-FORM PRESENTATIONS

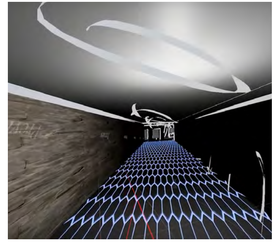


Within virtual reality presentations, there are two different major types of presentation styles and both serve a different purpose. The first style we are going to talk about is based around a sketchy/ free-form look. These types of presentations are good to use to show PROCESS and make for a less formal, but more constructive presentation. We have previously looked at VR presentations as a whole, but within that category, each type of presentation has its own strengths and weaknesses.

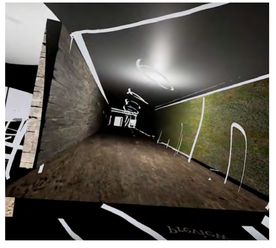
To be more specific, Sketch style presentations are better at showing an iterative process than VR presentations as a whole, but are less realistic looking as a result. This type is still very good at communicating with both the designer and the client. The only difference is using this presentation style will sacrifice some immersive realism.

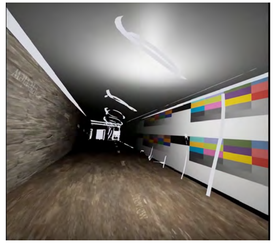


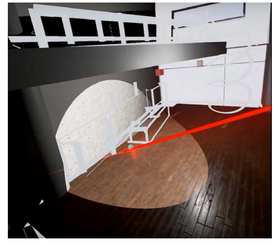


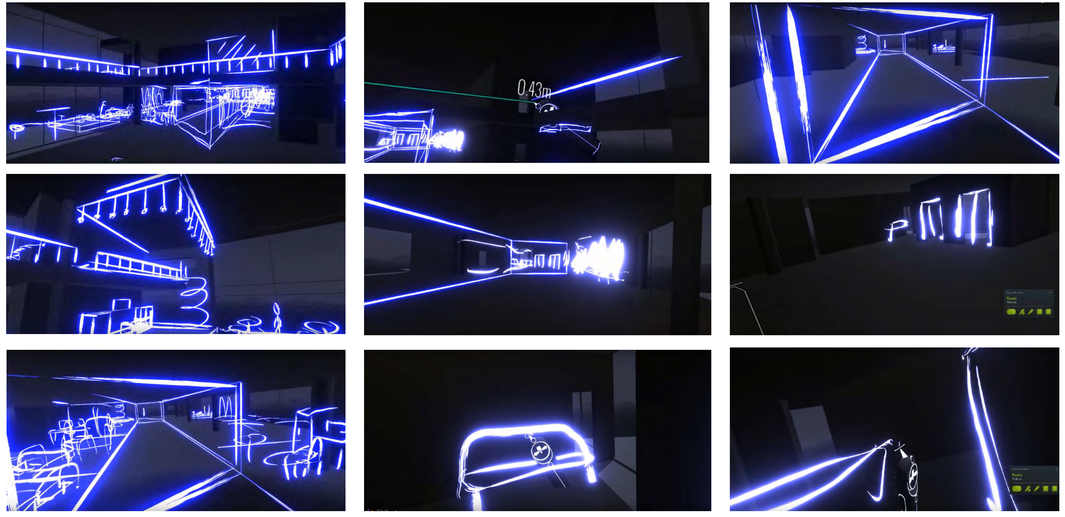


EXAMPLES OF USE OF MATERIALS IN A SKETCH STYLE PRESENTATION

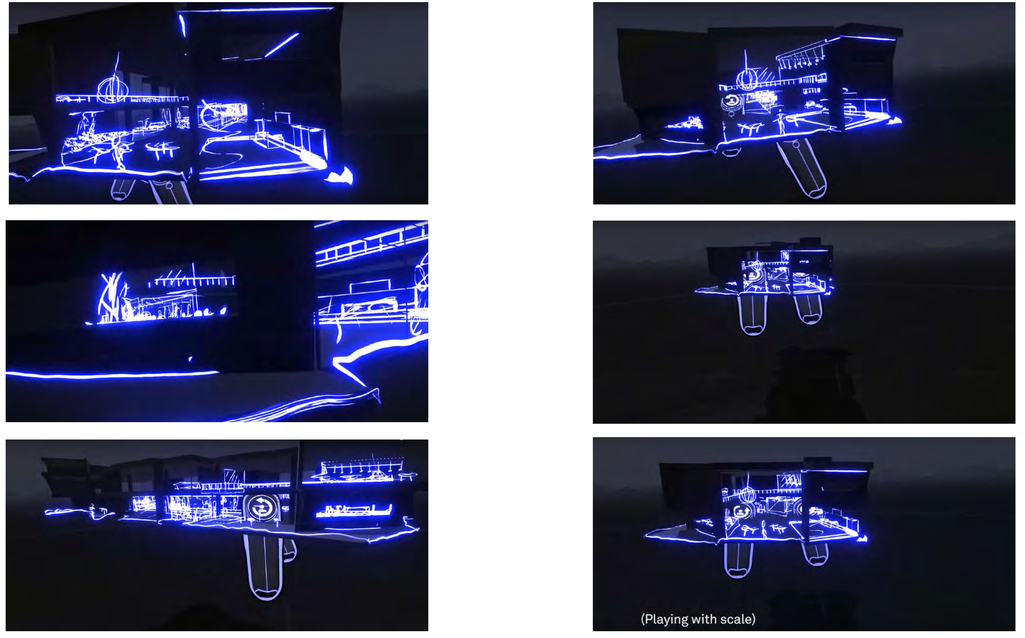






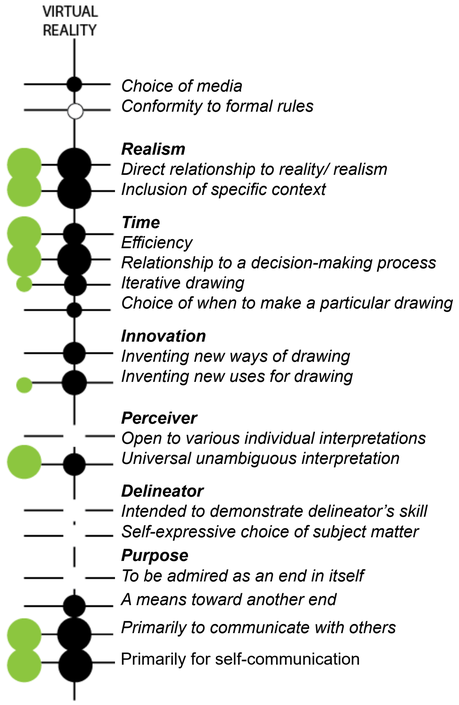


GENEALOGY OF VR SKETCH PROCESS



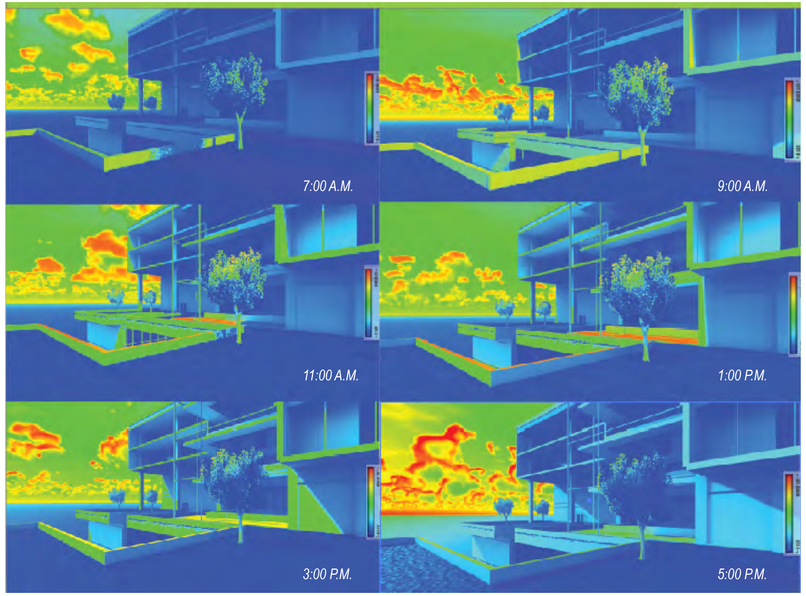
EXAMPLES OF SCALE AND DRAWING STYLE WITHIN A SKETCH STYLE PRESENTATION

2.3.2_PRECISION/ MODELING PRESENTATIONS



As previously stated, there are two different major types of presentation styles and both serve a different purpose. The second style we are going to talk about is based around a more precise/ modeled look. These types of presentations are good to use to show a MORE REALISTIC, true to picture model, and are typically used later in the design process as a more refined presentation. We have previously looked at VR presentations as a whole, but within that category, each type of presentation has its own strengths and weaknesses.

To be more specific, precision style presentations are better at showing a direct relationship to realism that is EASIER TO INTERPRET than VR presentations as a whole, but are limited in design variation as a result. This type is still very good at communicating with both the designer and the client. The only difference is using this presentation style will sacrifice some variation in representation due to simulating realism.

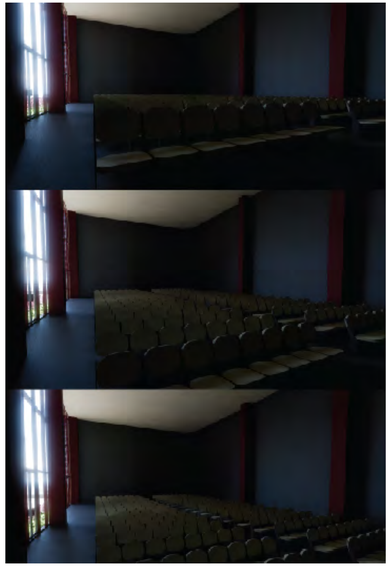


EXAMPLES OF PERFORMATIVE SOLAR HEAT GAIN TRACKING WITHIN A PRECISION STYLE PRESENTATION

BRIGHTLY LIT ATRIUM

DIMLY LIT ASSEMBLY SPACE

INCREASING ACTOR HEIGHT



INCREASING ACTOR HEIGHT

EXAMPLES OF SCALE OF PERSPECTIVE WITHIN A PRECISION STYLE PRESENTATION

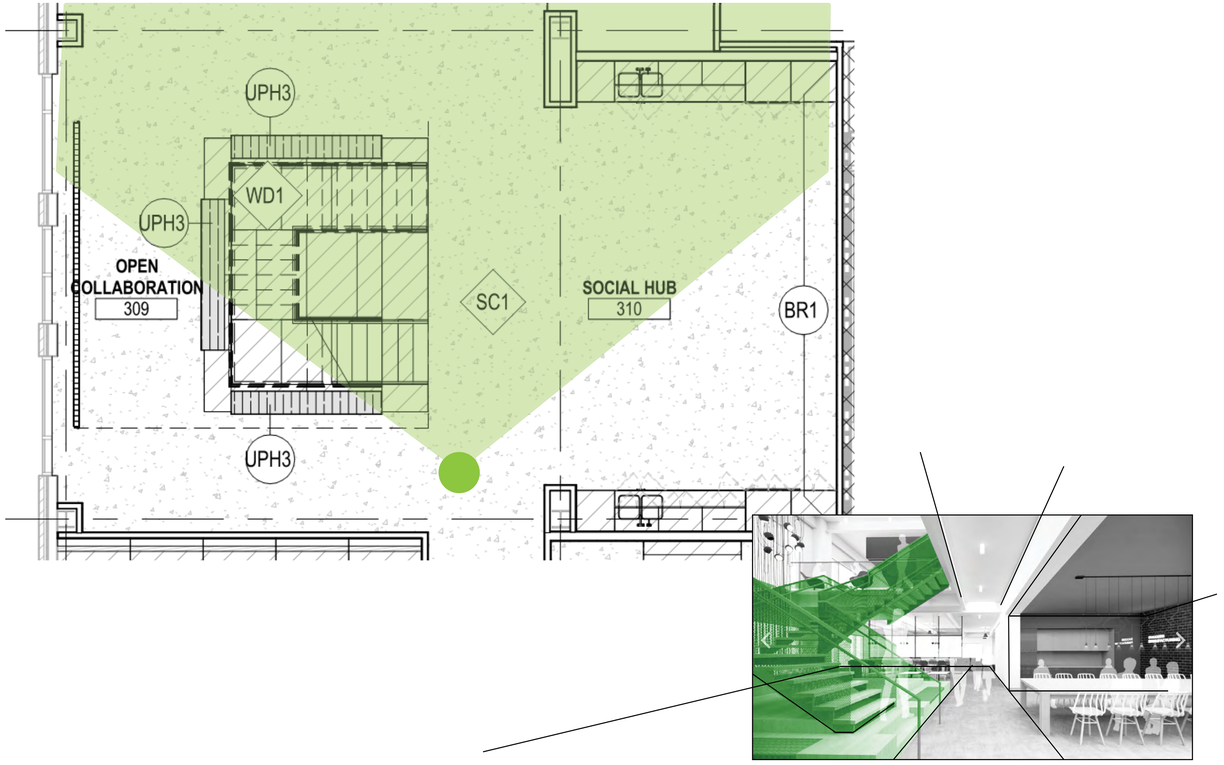
EXAMPLES OF MATERIALITY WITHIN A PRECISION STYLE PRESENTATION

2.3.3_CASE STUDY_ERWIN PENLAND BUILDING

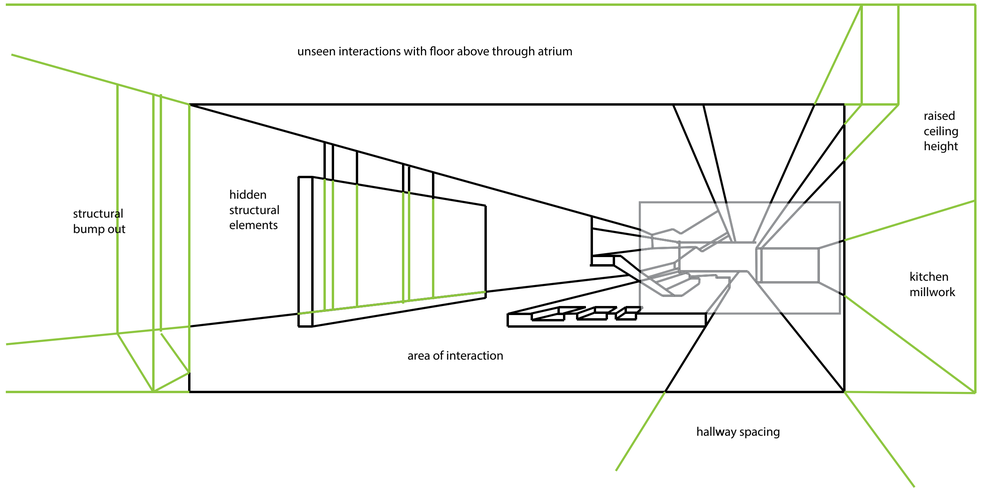
Gensler, the largest strictly architecture firm in the world, used the facilities at their Atlanta branch to design and show off the Erwin Penland Building. On Gensler's website, they have renderings of the space as shown below. However, as nice as these are, they do not give the space the justice it deserves, nor do they communicate what the designers wanted to get across to the clients. I met with the 3 representatives at Gensler Atlanta who spearheaded the virtual part of the project, and I learned a lot from our discussions. For starters, VR can be good for ALL TYPES of buildings, not just large scale projects, as I previously believed. It is deemed necessary based on what you want to show. Because of VR's ability to work well with current BIM software, the biggest reason for using VR is to SAVE TIME when showing a lot of information. Instead of making 12+ renderings you can use the VR presentation to show everything those 12 or more would in just one place.

FIG. 2.3.3.1

Gensler



This is a line drawing taken from the lines in the previously shown rendering. What VR shows us in detail that we cannot see are pointed out in the spaces normally hidden from view. Gensler could use a hybrid drawing type to show all of these details at once, but the biggest point here is TIME IS MONEY, and the VR presentation just saves more time.



BASED ON MY RESEARCH:

SKETCH STYLE PRESENTATIONS SHOULD INCLUDE:

- A design that shows process
- A design that focuses more on progress rather than realism
- A free-form drawing style that still uses dimensions and scale

ALL VR PRESENTATIONS SHOULD INCLUDE:

- Layers. Lots of detailed layers
- A style that is tailored to the client
- A style that represents the progress of the project at the time it is shown
- A design that shows relevant information as realistically as possible
- An attention to detail, ranging from material to expression of form
- ACCURATE BIM MODELING

PRECISION STYLE PRESENTATIONS SHOULD INCLUDE:

- A design that reflects a more finished product (toward the end of design process)
- A design that focuses on realistic representation and clarity
- A more rigid design technique focusing on experience

SKETCH (PROCESS) PRESENTATION ATTRIBUTES:

Presentation was an accurate representation of the progress of the project at the time it was made

Used material in order to make decisions rather than focus on realism

PRECISION (SPATIAL) PRESENTATION ATTRIBUTES:

Presentation was primarily made to show accurate spatial relationships

Was designed with rigid techniques rather than free-form sketching

Though there are 2 major types of presentations within VR, there are many presentations, as we have just seen with this one, that use a mix of the 2 styles to target the client they are designed for. The big take-away here is that whatever your needs for a VR presentation are, make sure they are tailored specifically to both your client and your progress with the project at the time of the meeting.

2.3.4_CASE STUDY_VR AND CONSTRUCTION

FIG. 2.3.4.1

FIG. 2.3.4.2

Virtual reality has its applications beyond that of architecture. If we look at construction, that industry, too, realizes the importance that virtual presentations can have on our building process.

The images to the left show a project that is scheduled to be built and is taken from a video demonstrating the planning process. However, this is not an aerial view. This is a table and a plan drawing on top of it. The building you see on top of that drawing is generated by augmented reality. The contractor can then turn on and off layers to see the construction of the building. They can even zoom in and see bolted connections and welding joint types in detail from the same model.

You can see the check boxes on the right side of the images. These represent the different layers of information within the model. This AR model is taken straight from a BIM model created in Revit. Within the Revit model, these layers are already present based on the information attached to components already in the model. If you draw a column, it is already counted as a structural component and put on the structure work layer. You also have the ability to edit a component layer manually. Using BIM attributes can really help us understand the information we need and hide the information we don't.

In the first picture to the right, we can see that this AR presentation will also go through the entire building process from the ground up. It gives for every step a COST ANALYSIS for all the materials in that step throughout the project as well. This is an incredible way of pricing out your building to ensure effective pricing and to get the best bid price you can.

In addition to the augmented reality presentation, there is also a virtual reality presentation for the same project shown in the bottom two images to the right. The first of these two show us a walkthrough of the project from the ground floor, again with the layers to the right side of the images. Where AR presentations let us overlay information on an existing drawing, we can use VR presentations to physically put ourselves in that space and walk around, yet we can still turn on and off layers of information like with the AR presentation.

Another perk of VR presentations, shown in the second image here, is the ability to edit BIM information within the presentation itself. Say we don't like the column height. Well we can change that right there in the presentation, and it will update in real time. This allows us to simulate changes virtually before we need to make those changes in the field.

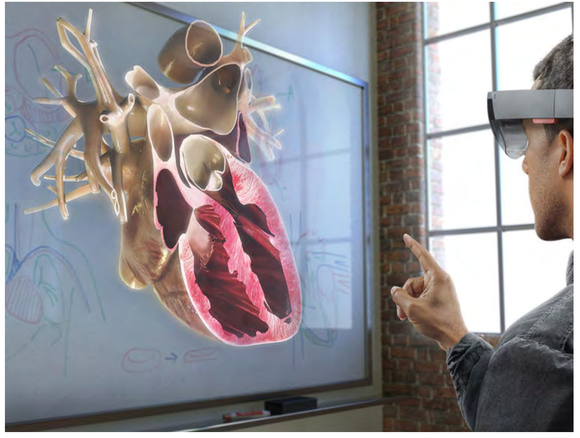
FIG. 2.3.4.3

FIG. 2.3.4.4

FIG. 2.3.4.5

2.3.5_CASE STUDY_VR AND EDUCATION

FIG. 2.3.5.1



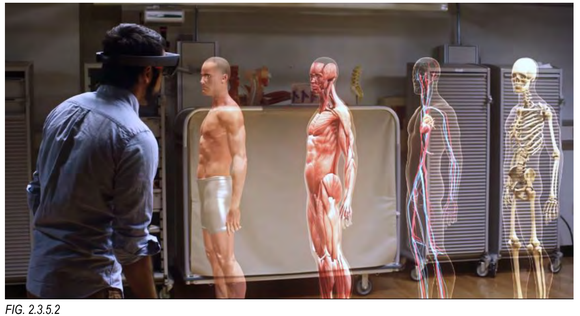


FIG. 2.3.5.2

Virtual reality, however, is not just limited to design and construction. It has potential in the field of education. In the past, doctors and medical students, whether they were going into practice or research, had to cut open or dissect living beings to have the students learn. It can sometimes be hard to acquire enough living specimens to teach each student every year.

This is where virtual reality can help. Instead of having to dissect the specimen themselves, or just deal with the flat image in their textbooks, students can now use VR to learn about anatomy in any way they choose. The professor, whether they have 10 or 100 students, can show everyone what the inside of a heart looks like AT ONCE. Students don't have to crowd around a half cut specimen. They can remain in their seats and let their goggles project the image they need to see. Also, each student can zoom, rotate, or scale the projected image independently so they can see exactly what they are learning about. This saves material, time, and I would even argue one can learn more. Oh, and there's no formaldehyde, and that's always good!

Universities all over the country such as Harvard, Yale, Duke, and many others are adopting technology that allows for virtual learning because of its potential within education. The screen shown to your right will work with most VR headsets and is designed to be used with said hardware.

VR allows for us to explore things beyond physical boundaries such as the decaying matter over time and scale or size without a microscope. It is hard for 100 people to see a demonstration all at once with clarity in a large lecture hall. Because this technology is becoming more and more accessible, we are learning more and more about the things we study.

FIG. 2.3.5.3

FIG. 2.3.5.4

2.4_SYNTHESIS OF FINDINGS

WHAT WE HAVE LEARNED:

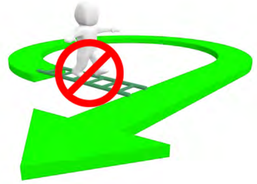
1 - Virtual reality, just like any previous design medium, has its own set of strengths and limitations, but its strengths seem to be in simulating realism to increase design understanding for BOTH client and designer.

2 - Virtual presentations allow for us to see things in a similar way to flat renderings, but allow us to look BEYOND THE FRAME this image sets for us.

3 - As time progresses, so does technology. Current practice utilizes BIM software for most of the design process, and because of the compatibility between BIM and VR software, VR presentations can be EASILY INTEGRATED into current design practice without too much hassle.

ENSCAPE™ → REVIT

4 - To fully utilize VR software for presentations, designers must adopt a habit of ACCURATE BIM MODELING. While a plan that hides the hiccups is all you need for the contractor, we must learn not to cover up these mistakes, but instead fix them in order to show clients a complete model/ presentation. Yes, this takes a little more time early on, but that time is made up for in the time you save for making edits/ changes to the space.



5 - Why use VR? VR has (5) major benefits to architects within practice specifically that make it worth looking into:

- The ability to make changes on the go
- An added, billable value to the project (a competitive edge)
- Helps keep attention at reviews (due to user control of exploration)
- Allows for long distance meetings with clients
- The ability to persuade clients on decisions based on visuals

6 - Different VR software types have different strengths and weaknesses. Depending upon the type of project, the client, and scope of work, you should tailor your presentation type and the program(s) you use to suit those requirements. Refer to the presentation types section of chapter 2 for generic example types, plus a real firm usage example.

THE BIG QUESTION:

HOW DO WE USE THIS INFORMATION TO CREATE A SUCCESSFUL VIRTUAL REALITY PRESENTATION?

Based on the research presented earlier within this book, I will now break down the steps to creating a successful virtual reality presentation:

1) **Start with an Organizational Structure for the Project based on what's important to the project - This could be:**

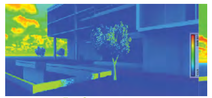
Chronological - either by floors or from entry to back-of-house
Programmatic - by the use of rooms/ spaces
Density - High traffic areas to Low traffic areas or vice versa

REMEMBER: Your Organizational Structure will be the focus of your presentation. Choose the project organization based on what is important TO THE CLIENT!

2) Know what Aspects of Architecture are important to show and/ or highlight. These include:

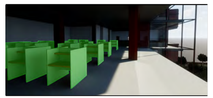
A good VR presentation looks at all aspects of design and takes those aspects into consideration as to whether or not they are important enough that they should be shown in the presentation. Here are some examples of attributes and their use in VR presentations:

Color defines Temperature and Heat Gain



Performance

Expressed Furniture Elements that Show Intended Use of Space



Program

Bump Maps and Patterns on Surfaces to Express Realistic Materiality

Materials

Sequence of Layers to Show Stages of Building Process

Tectonics

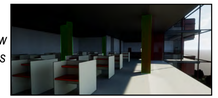
Expressed Exterior Factors Highlighted in Relationship to Building

Site

White Object Layer Takes Away Color and Line Weights to Focus on Pure Form

Form

Hidden Layer Highlighted to Show Structural Elements



Structure

Size Within a Virtual Space by Zoom

Scale

Desaturated Color with Expressed Line Weights to Show Spatial Relationships

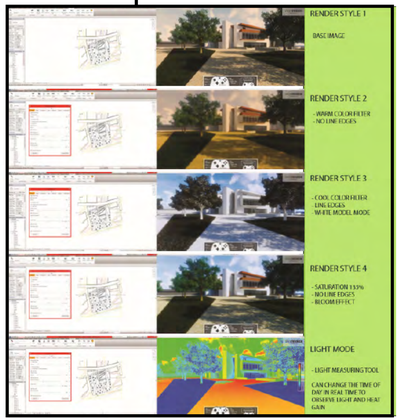
Space

Not all aspects may be visible in a VR presentation. A good VR presentation focuses on the attributes that are important to the project, without showing too much information. When in doubt, ask yourself what would the client most want to see, and what aspects show the client what they want? Remember, make it Complex, not Complicated!

3) Using steps 1 and 2, model the space and details into the spaces that are important to show the client.
Focus resources on the main program or money shot, not on the restrooms (Unless thats important to the client!) Keep in mind, if you made it explorable, you should have it detailed. If the client won't go there, don't spend time detailing it!

4) Keeping the client in mind, render out those important spaces using a style and post-processing technique they would appreciate.
If your client is a laid-back kind of person, focus on the experience of space rather than graphic aesthetics. If your client is the serious businessman type, make your presentation focus on the details of important spaces and making those simulate realism as much as possible. KNOW YOUR CLIENT. Also, cool filters or depth of field and similar effects may be used to highlight certain spaces. Refer to the Render Styles Section (2.1.2) for examples of graphic filters and effects.

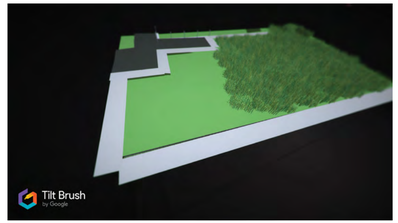
5) Always experience your project before showing the client.
Mistakes can and will slip through the cracks, but 90% are caught just by experiencing the space yourself. Always try it yourself first!

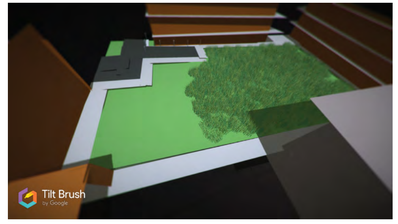


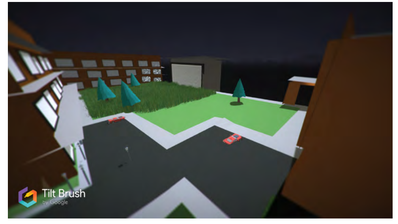
SECTION 2: PRACTICUM

SITE_DEFINITION 3

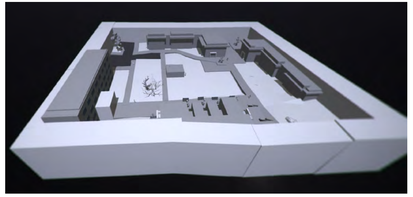
3.1_STUDY PARK: MODELING THE SITE

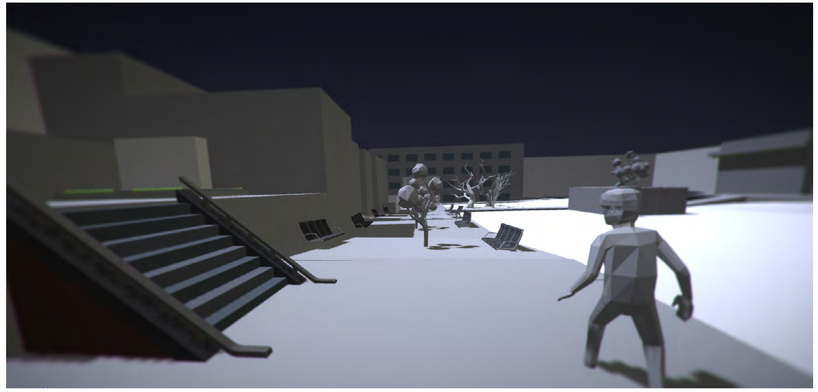






Google Tilt Brush Exercises

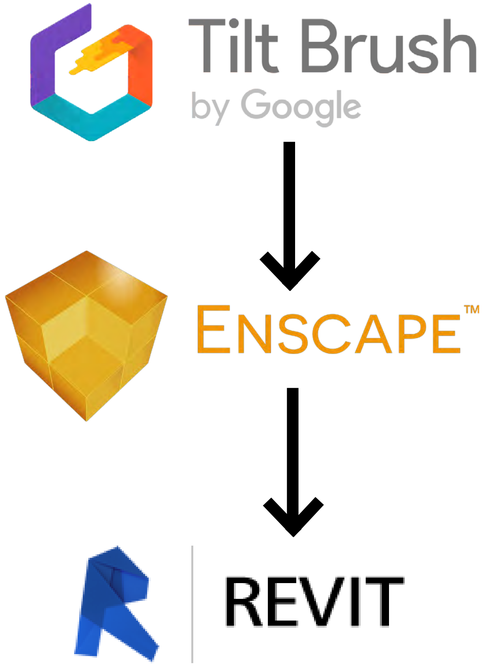


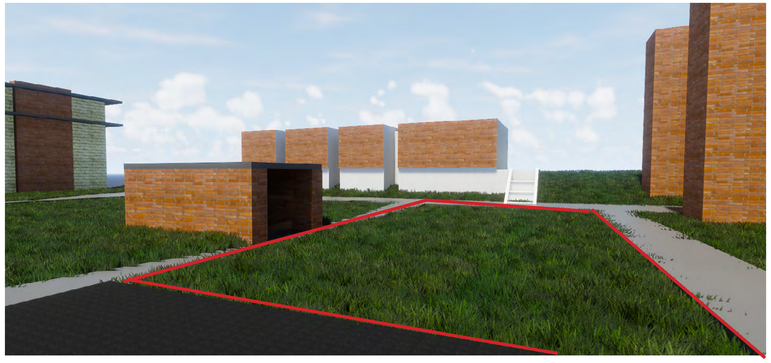


From Tilt Brush to Revit

Site Exploration with Enscape in Revit

Using Revit to “skin” surfaces

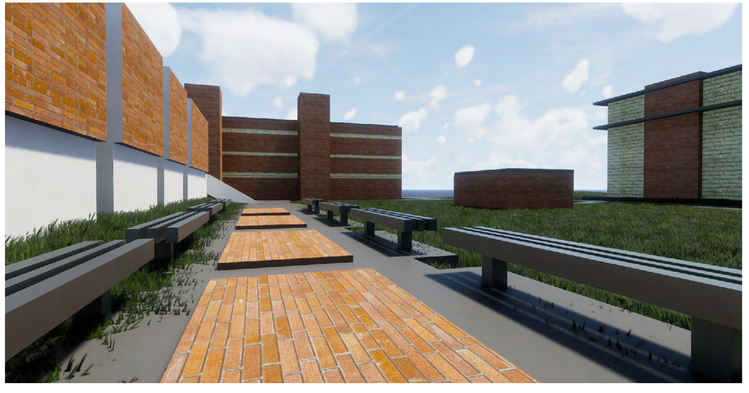




50%

SITE COMPLETION IMAGERY

Here is the site for the study park at 50% completion. I stopped here, around level 2 detailing, because the study park was not the final project, but it would be used to further the final, and I was running out of time. This was enough to show me that BIM software is so much more detailed in its representational qualities than other software types in virtual reality. So, I then began to model the study park and began to look at it through the lenses of virtual reality.



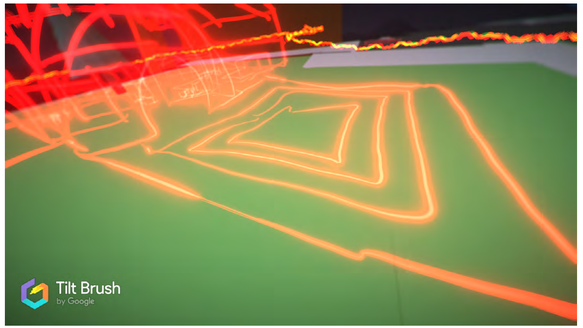
CHAPTER_4.0

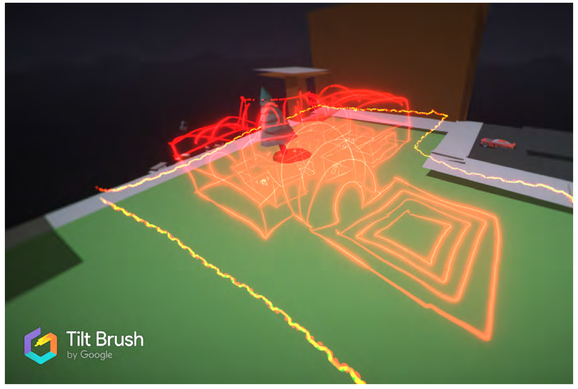
FREEFORM_PRESENTATIONS

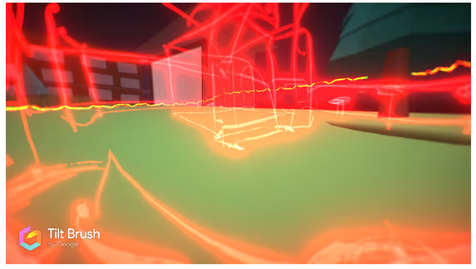
4

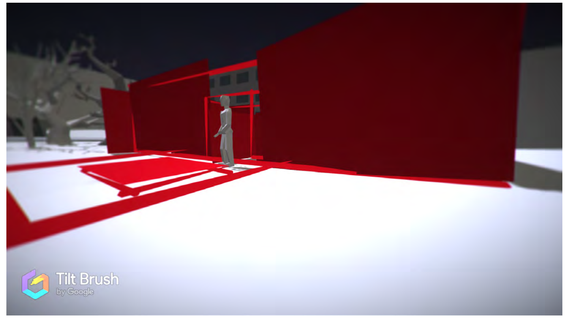
4.1_RED GESTURE MODEL

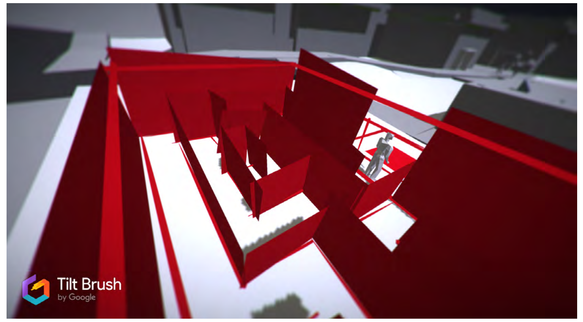
These modeling exercises were the precursor to the final project. In modeling these abstract sketches, I was able to determine how virtual reality without BIM integration performed, showing the antithesis to my claim. Although the program I used for this, Google Tilt Brush, is a very intuitive and fun program, it doesn't represent realism and immersion, which is the purpose of VR in terms of furthering design. However, learning this was not a waste of time, but rather proved my point on BIM integration further. These are the 5 sketch examples I chose, and I will then take the final one (Violet) to Revit with Enscape to further the design.

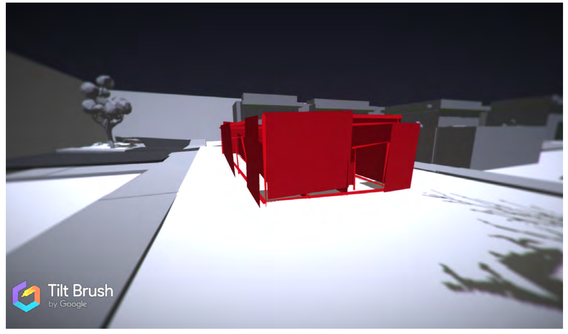


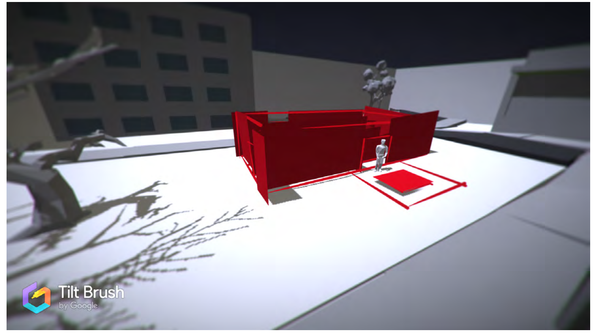




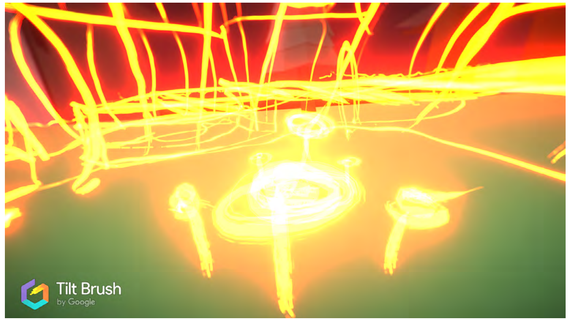


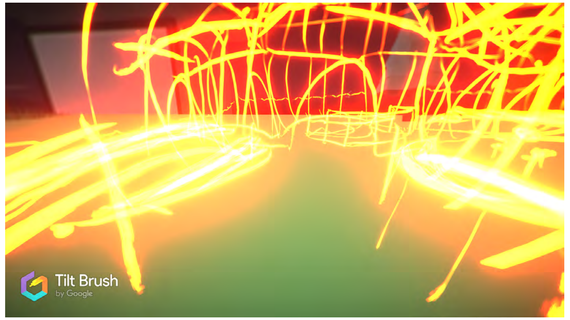


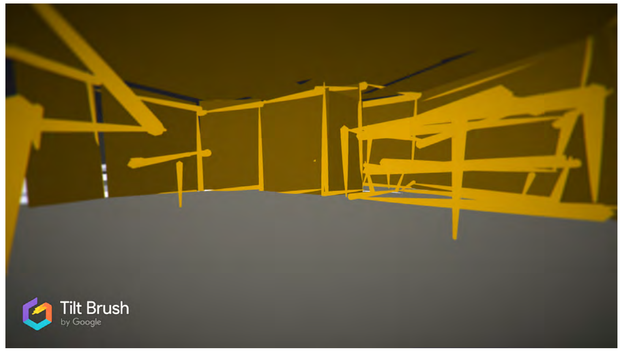


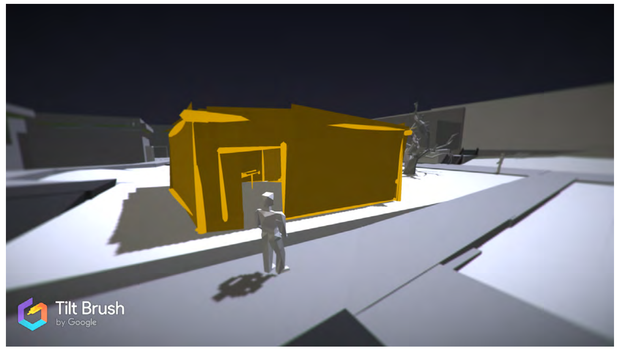


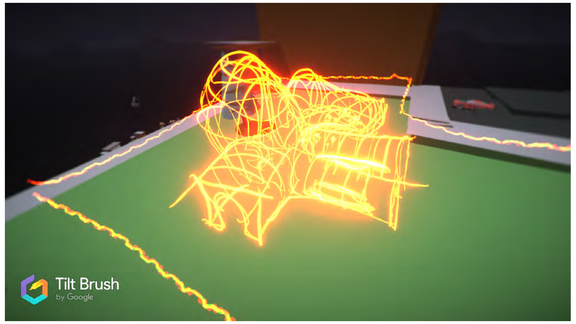
4.2_ORANGE GESTURE MODEL

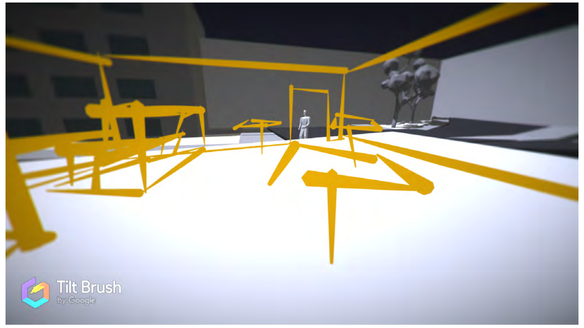


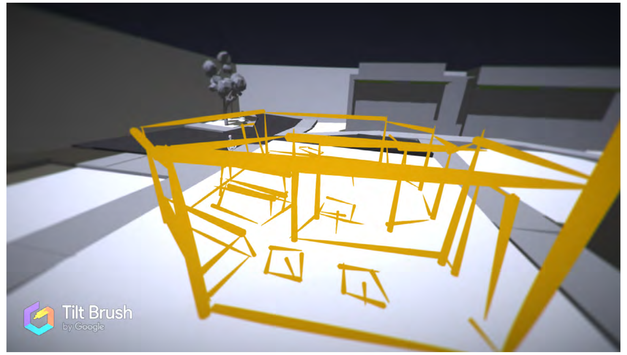


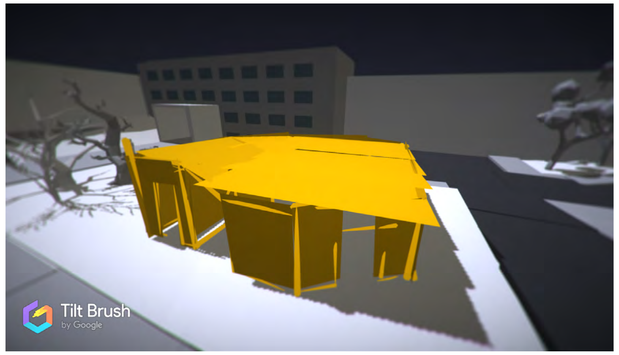




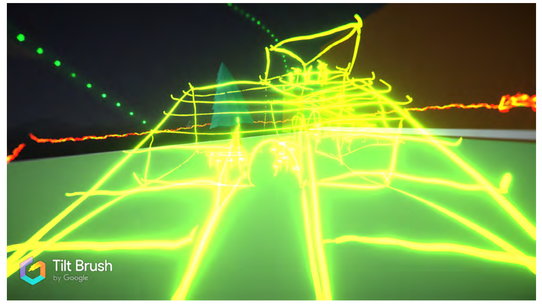


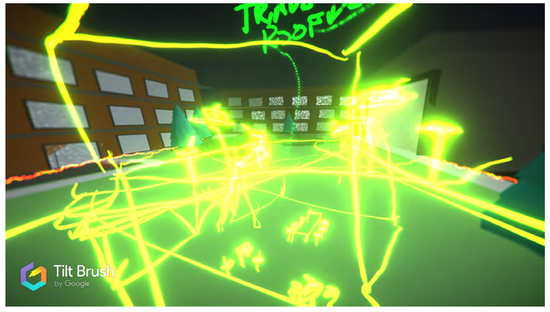


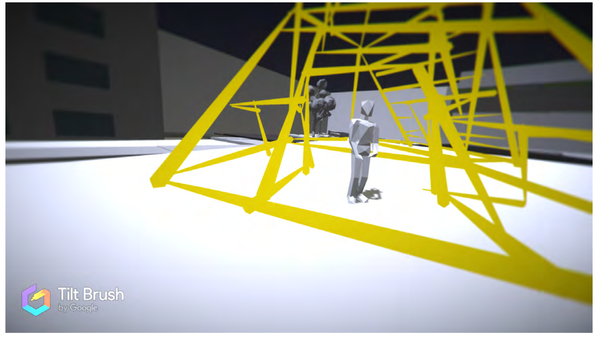


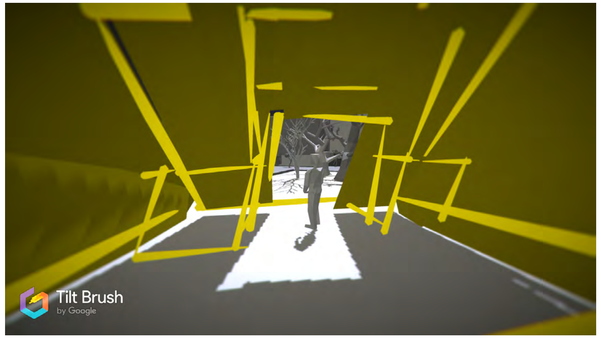


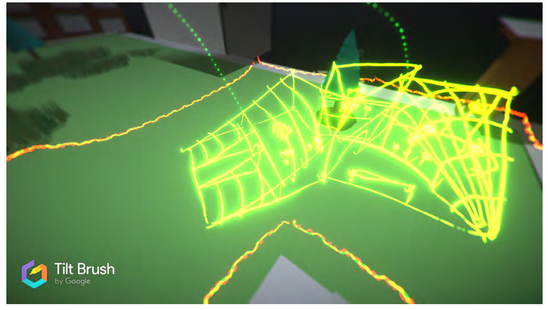
4.3_YELLOW GESTURE MODEL

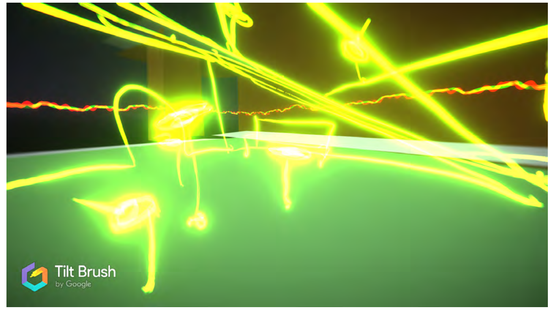


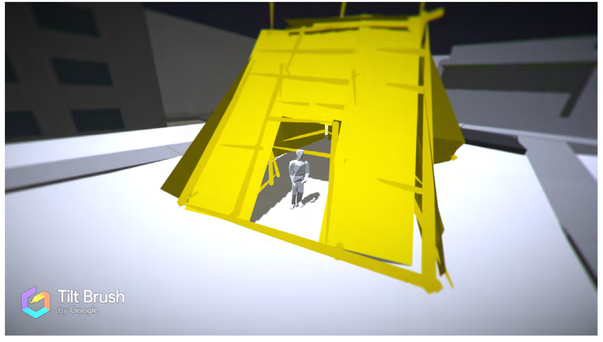


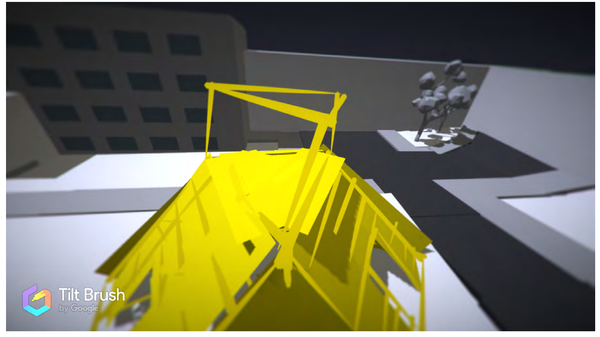




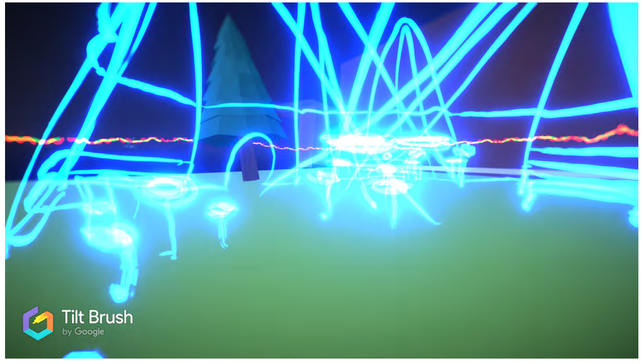


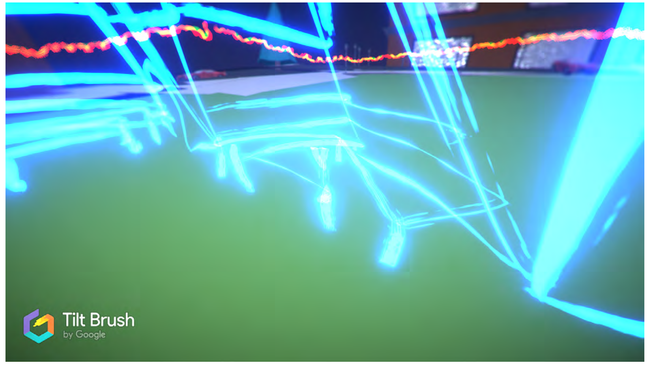


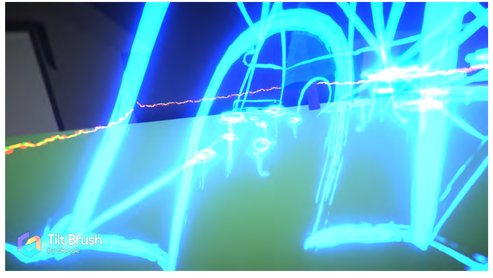


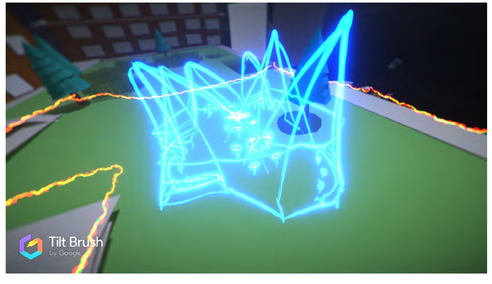


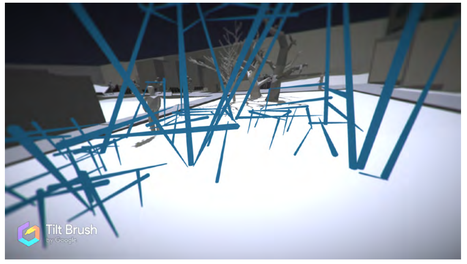
4.4_BLUE GESTURE MODEL

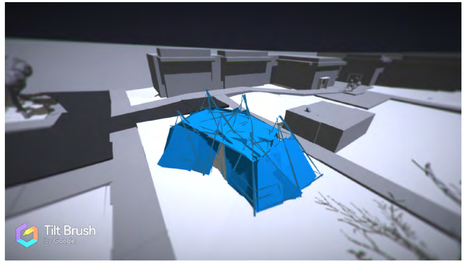


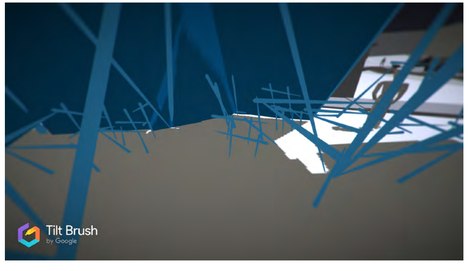


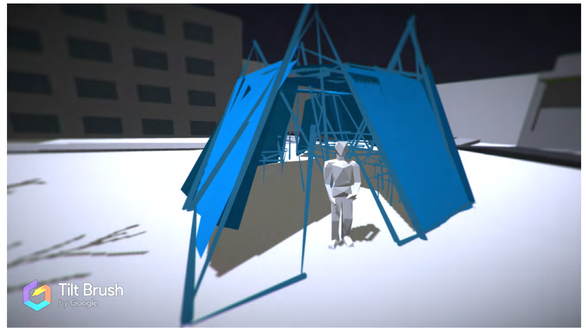


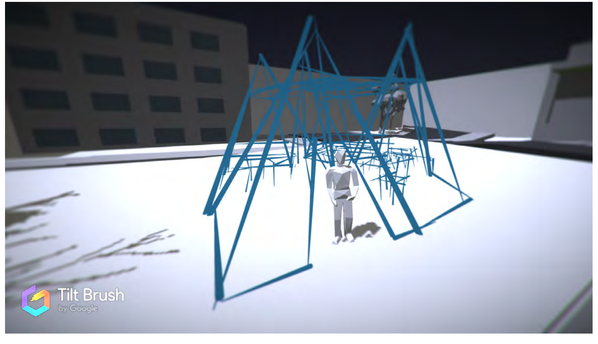




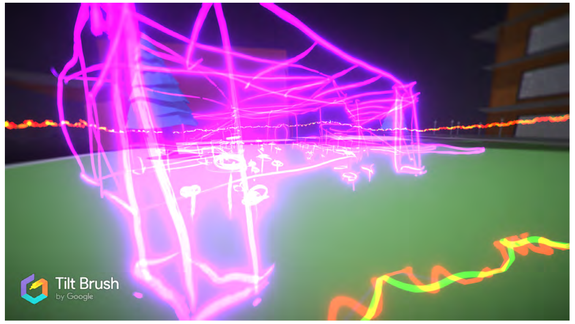


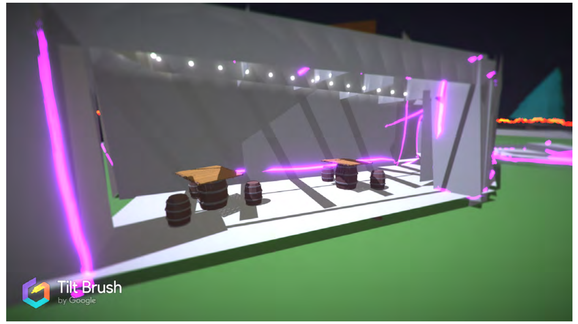


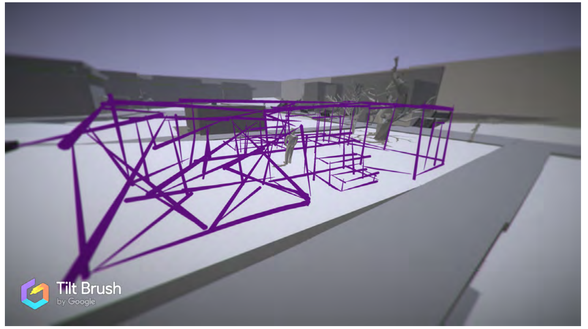


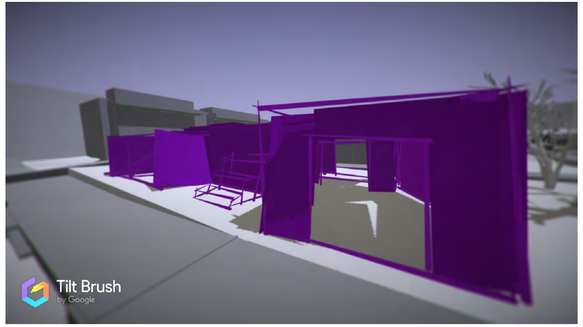


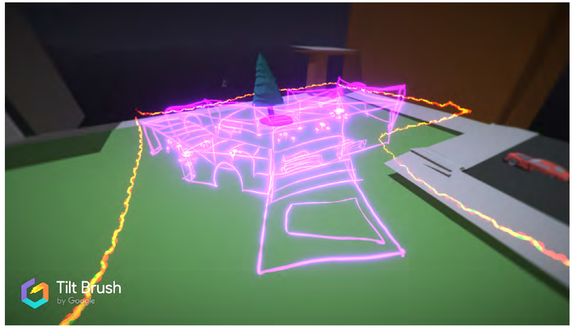
4.5_VIOLET GESTURE MODEL

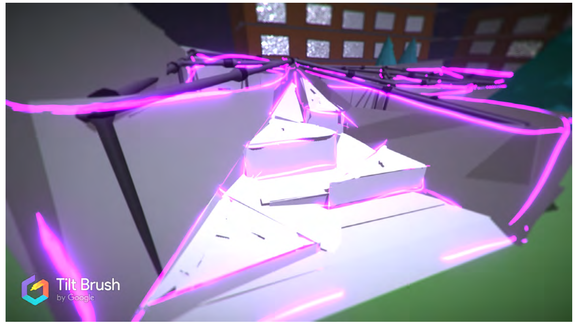


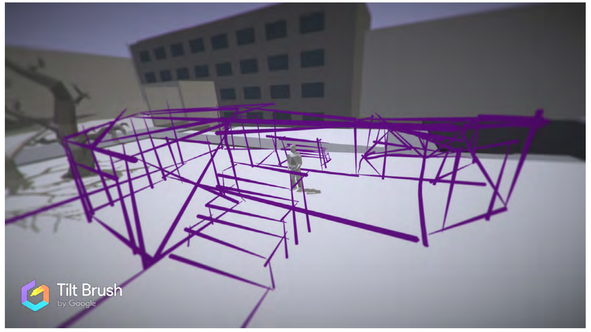


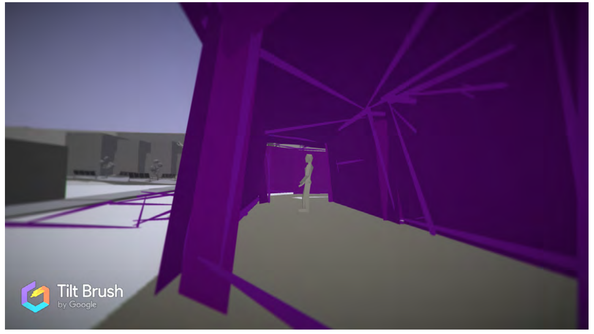


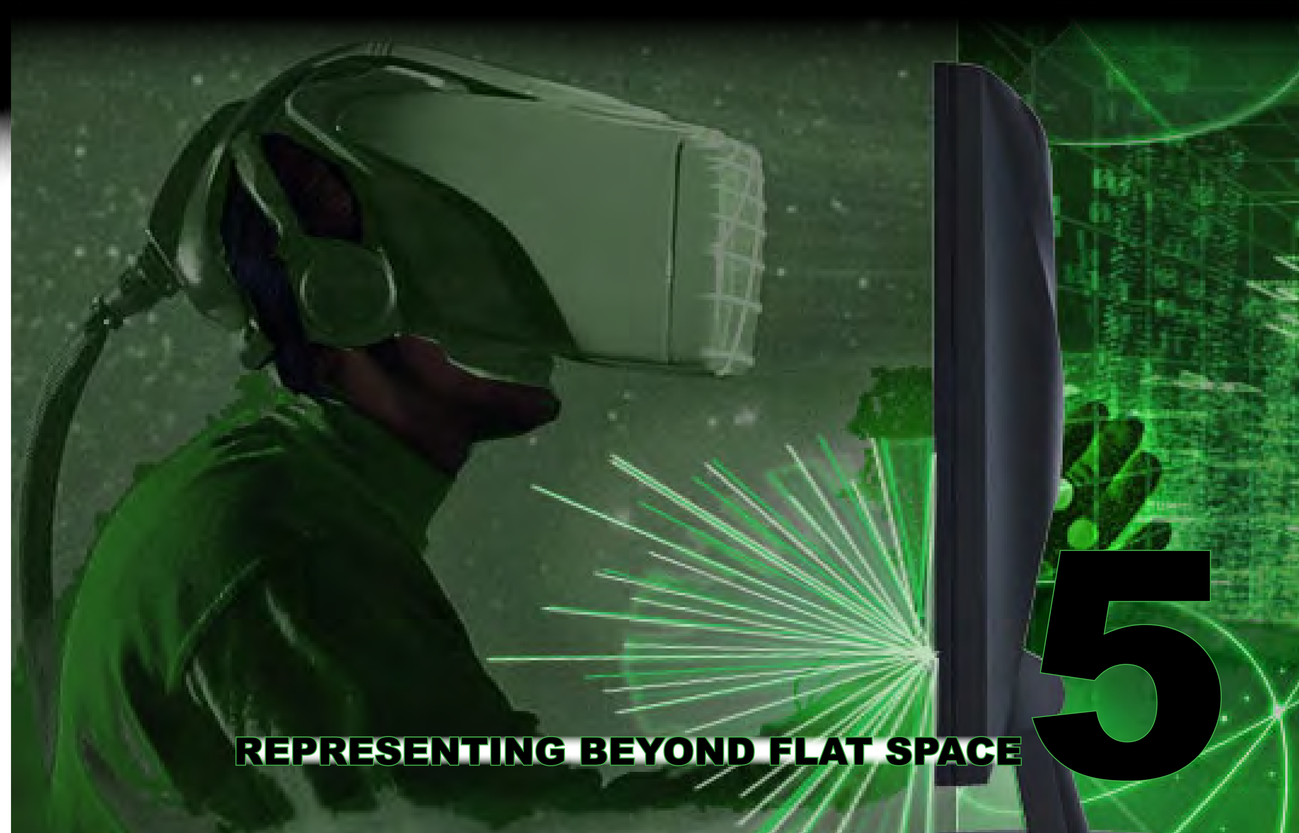








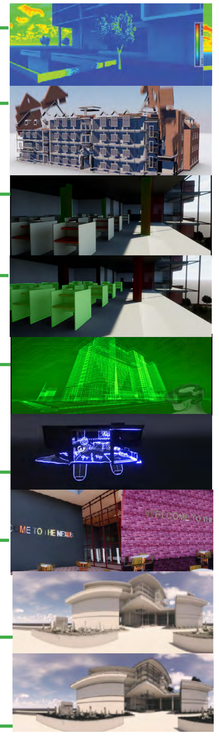




5

REPRESENTING BEYOND FLAT SPACE

5.1_ASPECTS_OF_ARCHITECTURE



Performance Color defines Temperature and Heat Gain

Tectonics Sequence of Layers to Show Stages of Building Process

Structure Hidden Layer Highlighted to Show Structural Elements

Program Expressed Furniture Elements that Show Intended Use of Space

Site Expressed Exterior Factors Highlighted in Relationship to Building

Scale Size Within a Virtual Space by Zoom

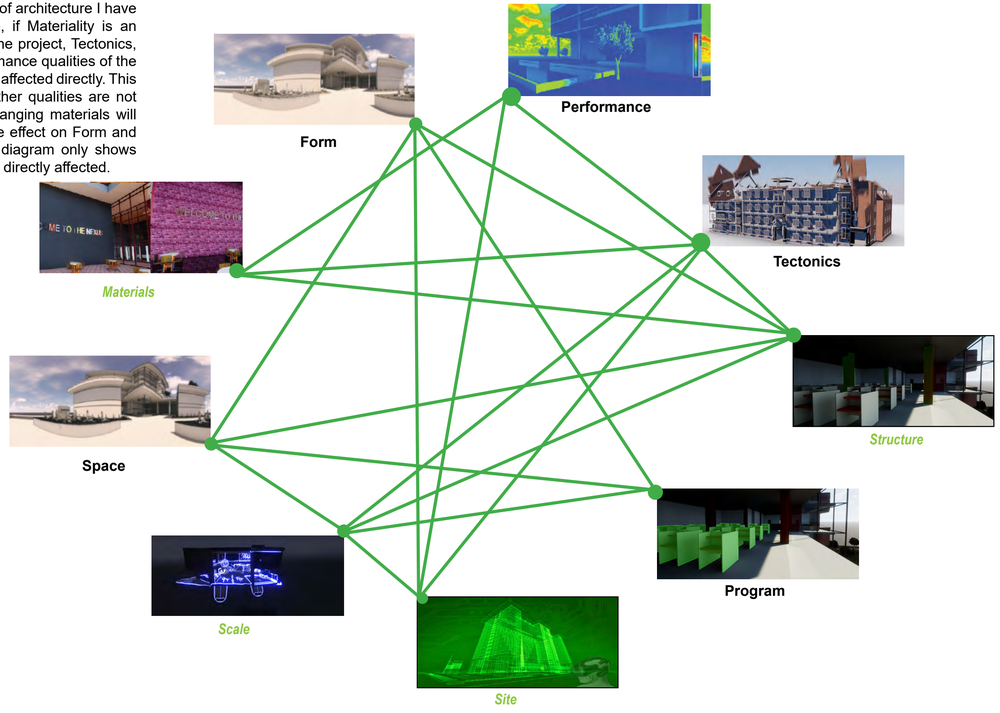
Materials Bump Maps and Patterns on Surfaces to Express Realistic Materiality

Form White Object Layer Takes Away Color and Line Weights to Focus on Pure Form

Space Desaturated Color with Expressed Line Weights to Show Spatial Relationships

In addition to studying how each aspect is represented within a VR presentation, this section is also going to implement a cinemetric drawing for each different aspect. Doing so will allow me to track not only where I look and walk within the VR model, but will allow me to track this positioning over time while ALSO relating those positions to a perspective view from that vantage point. **This bridges orthographic projections with experiential drawings.**

This diagram shows the relationship between each aspect of architecture I have defined. For instance, if Materiality is an important quality for the project, Tectonics, Structure, and Performance qualities of the design are going to be affected directly. This is NOT to say that other qualities are not affected indirectly (changing materials will most likely have some effect on Form and Scale), however, the diagram only shows items that are for sure directly affected.



5.1.1_PERFORMANCE

STEPS:

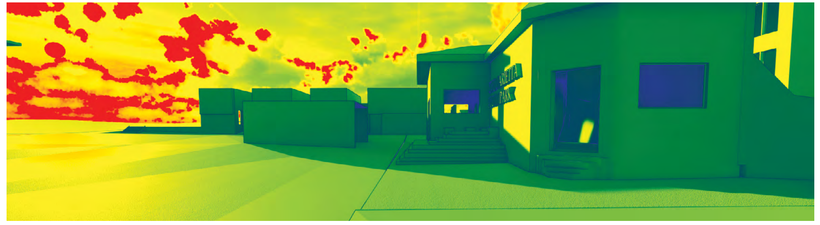
1 - Under the Enscape Ribbon, go to Settings

2 - Under the General Tab, check the box labeled “Light View”.

3 - Start Enscape, then while in the model, use the right and left bumpers to pass the time of day.

*Be sure the season, date, and location are all set in your Revit model, as Enscape will pull this information from the Revit model itself to perform its lighting calculations.

Also, Enscape takes thermal properties of materials in Revit into consideration when using Light View. This is seen in glass material versus concrete or gypsum board.



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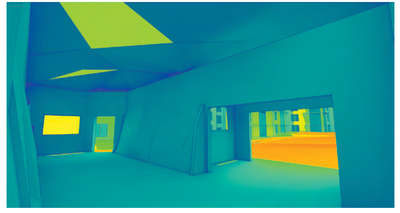

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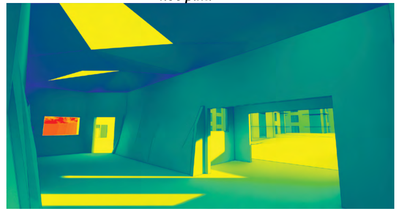
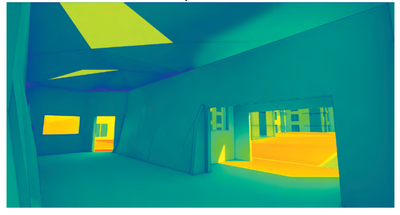


1:00 p.m.



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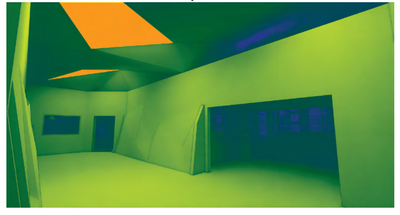
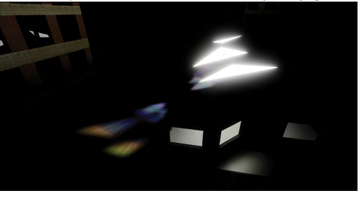
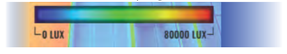


example of thermal absorbtion of acrylic skylights

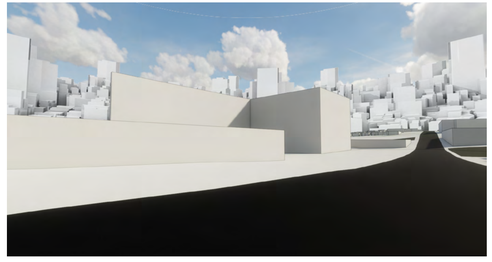


lux intensity legend

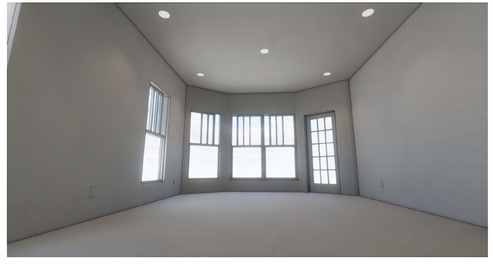


ACOUSTICS

With VR, we can use acoustics to simulate sound within space. All that is needed is an audio file, preferably recorded on site, and this file can be loaded into the project to enhance it.



EXTERIOR SPACES



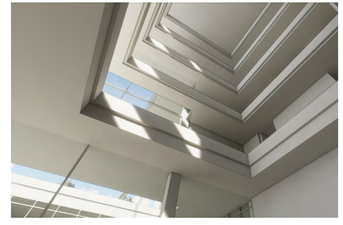
INTERIOR SPACES

ACOUSTIC ROOM TYPE

INTIMATE

CONTAINED

OPEN/ PUBLIC



STEPS:

1 - Draw out structural design in Revit using either Wall tools and Edit Profile, or by importing structural family members (i.e. beams, joists, rafters, etc.) and array them.

2 - If using Edit Wall Profile method, Go to the Manage Ribbon, and go to Materials.

3 - Find a desired wood material, and load it into your model.

4 - Modify the properties of this material to be the color you want.

5 - Under the Enscape Ribbon, under Settings, adjust your Outlines Slider to the desired look.

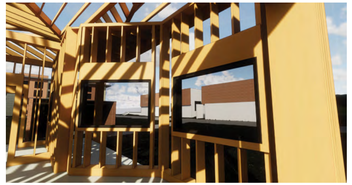
This will allow for visual analysis of different components of the building that take structural load.

studs and vertical structure

rafters and roof structure

door / doorway headers

window framing



5.1.2_TECTONICS

Tectonics - the study of how something is constructed, built, or assembled.

While **Structure** shows us only load-bearing elements that hold up the building, shows us how to construct the entire thing in steps or phases. Below are illustrations of what comes after the structural phase, from sheathing and weatherproofing, to drywall interiors and paint, to exterior finishes such as brick, to signage or other such components.

Knowing this and being able to present the order of operations to the client can help move the process along faster.

plywood sheathing

drywall and paint

brick and signage

MATERIALITY

STEPS:

1 - To load materials to the project, go to the Manage Ribbon, and select Materials.

2 - Open up the libraries and load in any materials you wish to use. If you wish to edit any existing materials, use the properties panel in the Materials window.

3 - Once materials are loaded in, go to the Modify Ribbon, and hit the Paint Material button.

4 - Select the material you wish to add, click the object you want to paint, and the material will apply itself to the surface.

5 - For components, the material must either be specified in the Properties Window, or the component must be edited in a new window and then loaded back into the project. They WILL NOT allow for material editing without using either of the aforementioned methods.

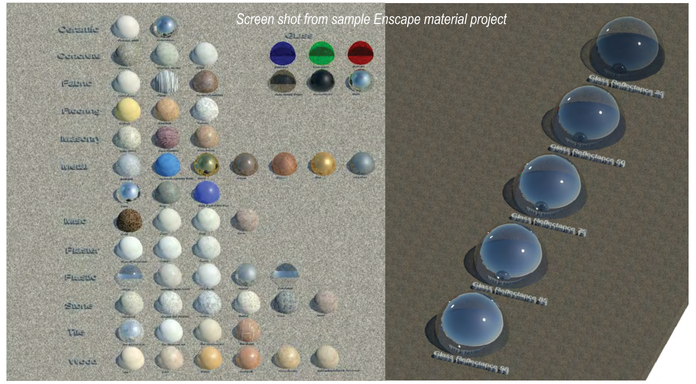
Some materials, such as brick, can required editing of a bump map in order to show any 3-dimensionality. A bump map is a gray scale image arranged below the texture image file used to determine the bump out of the texture of the material. Below is an example of why bump maps are important.

example of brick with vs. without bump map

Screen shot from The Witcher 3 video game

example of a brick texture map vs. bump map

Screen shot from author files



Screen shot from sample Enscape material project

material taxonomy

5.1.3_SPACE

STEPS:

1 - Once model is finished, to experience the interior spaces, go to the Enscape Ribbon, and hit settings.

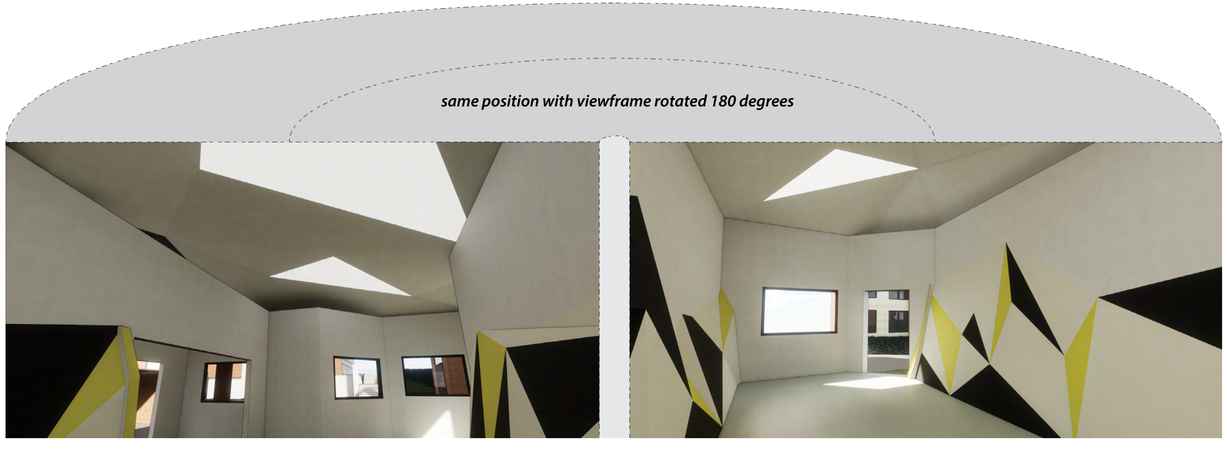
2 - Under General, make sure “White Mode” is turned off.

3 - Make sure Outlines are set to your preference. As a reference, I used 4 - 5%.

4 - Start Enscape, and enjoy the walkthrough.

SPACE - *An enclosure, usually of an interior area and consisting of floor, walls, and a ceiling or roof.*

same position with viewframe rotated 180 degrees



SCALE

STEPS:

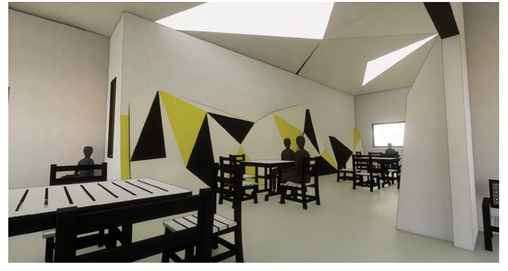
1 - Once the building is modeled, go under the Architecture Ribbon, and select component.

2 - Load in a component to help with understanding Scale. This can be a human figure, furniture pieces, plants, or entourage items. Revit comes with very few of these loaded, but any downloaded files can be loaded locally.

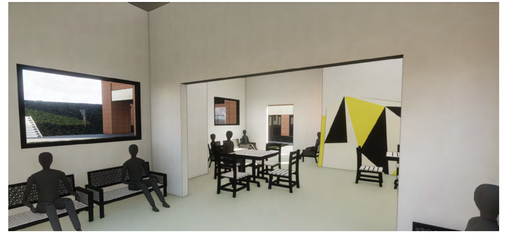
3 - Use the same display settings as materiality, as modular materials such as brick can give insight into scale as well.

Human Figures can be used to show scale of both the Macro and Micro Site

Brick is modular, and therefore relative to human scale



Furniture and Human Figures to help determine Scale



5.1.4_FORM

STEPS:

1 - Draw out design in Revit

2 - Go to the Enscape Ribbon, and go to settings

3 - Under the main panel, check the “White Mode” box.

4 - Under the same panel, change the “Outlines” setting with the slider. This will give your building a pop of contrast from the site context. (0% is base Revit, 100% will look like s SketchUp model. I tend to go 4 - 5% outlines for a thin, yet defined outline).

This will dematerialize the entire model, allowing us to solely focus on form itself.

FORM AND MATERIALITY

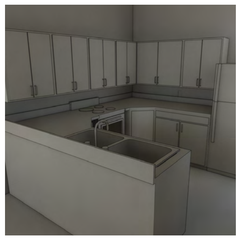
FURNITURE

SIGNAGE

LANDSCAPING

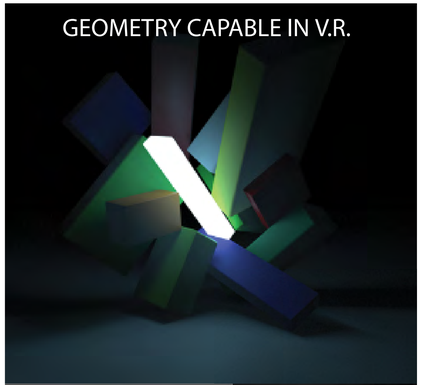
VR can create simple or complex geometry to view quickly and efficiently. This is helpful for modeling entourage and helps with immersion in a space. >

BUILDING GEOMETRY



COMPONENTS

MATERIAL OUTLINES



STEPS:

1 - Draw out programmatic layout as individual boxes in Revit.

2 - Go to the Manage Ribbon, and go to Materials.

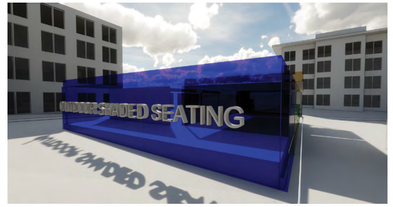
3 - Find the Glass Category, and find a glass color that is not being used anywhere else in the project.

4 - Modify the properties of this material to be the color you want associated with the program

5 - repeat step 4 for all program categories, and apply them to surfaces representing that program.

6 - For clarity, under Architecture tab, the Model Text tool is an option that will allow you to label 3D elements..

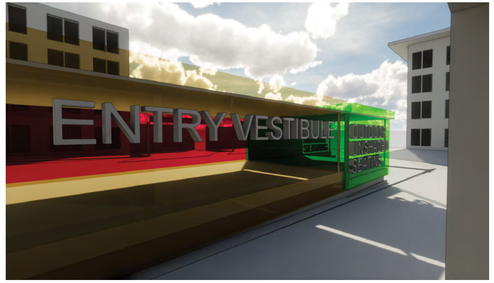
This will allow for different spaces to be read as a color themed programmed space.

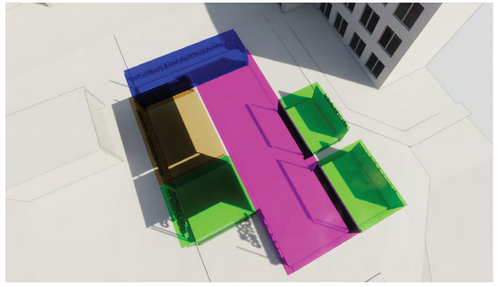


In this model:

5.1.5_PROGRAM

Purple - Interior Study Space
Gold - Entry Threshold
Blue - Outide Study Space
Green -Traversable Study Surfaces





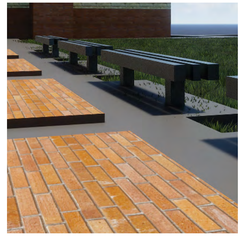
ENTOURAGE

FUNCTION = PROGRAM

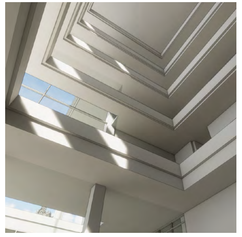
THINGS THAT CLUE US INTO PROGRAM

furniture

seating



verticality



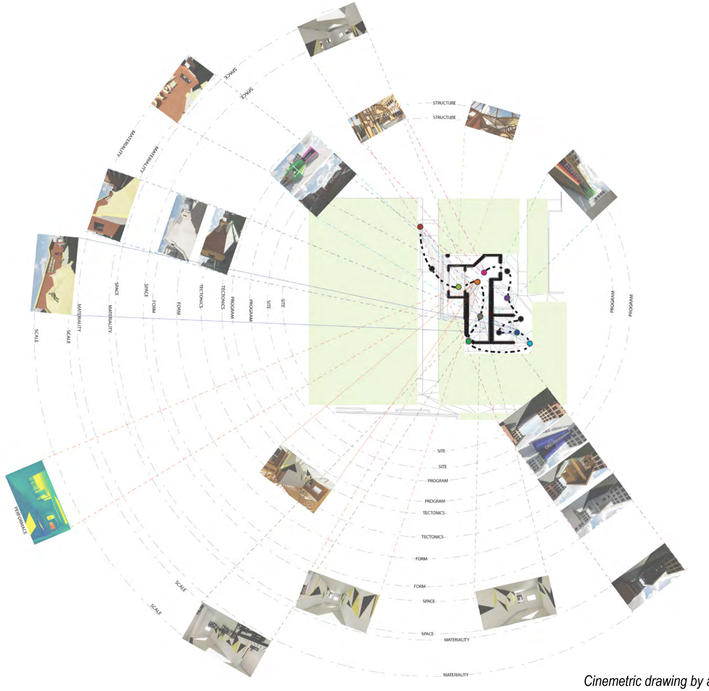
spacial qualities

additional components

5.2_SYTHESIS OF FINDINGS

Understanding Architecture as a Representation of its Aspects

Cinemetric drawings are used to convey experience of space over time. This was first used to show movement of actors through plans in movies. Here, I use it to describe the experiences through my test project while looking through the lenses of each aspect of architecture. With Virtual Reality, the ability to turn on and off layers of information allows us to gain a new understanding of space and ultimately of architrctural design.



Cinemetric drawing by author

Looking at the aspects of architecture has helped us as designers break down and categorize what is important to the client and to the project. We can use this to gain not only the clients trust, but also secure their satisfaction by displaying the qualities that are most important to them as true to realism as can be.

From the designer's standpoint, a hybrid drawing like cinemetrics helps us understand point relationships over time, and are a happy medium between understanding space and experiencing it. This is important for communicating to both designers and clients alike. In current time, I have to draw all of the views and plans myself, but hopefully, in the near future, design programs will adopt VR capabilities and add a function to draw cinemetrics based on tracking the movement of the VR viewing device. However, even though this functionality does not currently exist, we as designers can track the movements via screen shots, and thus produce a drawing that shows us relationships through space over time and experiences within it.

Immersion helps someone with an untrained eye and mind understand a design concept. Seeing is believing, or so they say, and the best way to allow a client to see what we as designers see is to show them as close to reality as possible. This series of experiments and studies has shown me the power of accurately representing our projects. Anything from a wall height not being correct, to the wrong number of lites in a window pane, to the wrong color brick, can distract from the essence of the project. This is why, say in showing off FORM, that we sometimes turn off materiality if it is not critical to show based on what is important in the project. A big key to making a good VR presentation lies in our abilities to select what is important or not important, and focus our efforts on displaying those important qualities. Hopefully this thesis book will act as a guide to help any designer show off their projects in VR in an accurate and easily digestible way.

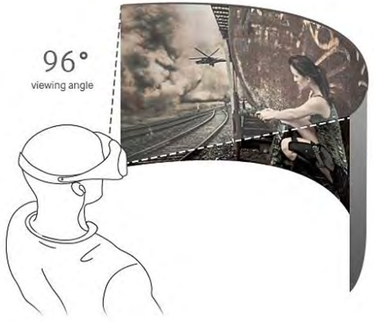


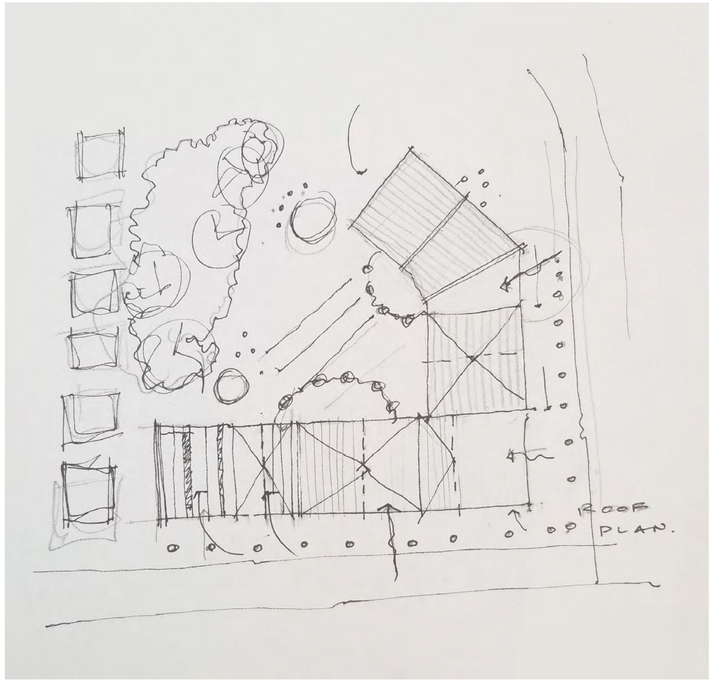
FIG 5.2.1

CHAPTER_6.0

COLLABORATIVE_PROJECT: URBAN_OASIS

6

6.1_ABSTRACT MODELING

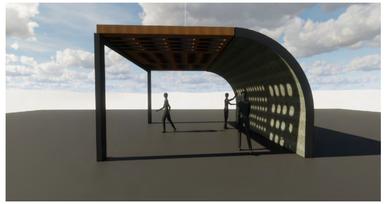


Sketch of Hailey's initial design

URBAN OASIS

The premise of Hailey Wilkins' project, Urban Oasis, is to bring much needed healing spaces to the chaotic streets in urban areas such as North Avenue in Atlanta. This served as an excellent way to collaborate and kill two birds with one stone. The goal at the end is to prove both that the healing spaces achieved their intended purpose while also proving virtual reality as a good tool to represent such effectiveness. To prove this holistically, however, we have to prove that virtual reality could also represent abstract data as well as complex data.

SMALL SCALE ABSTRACTION

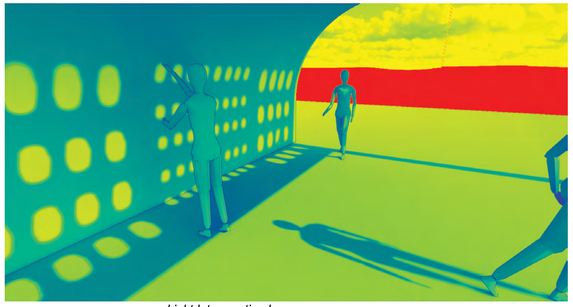


Daytime Model

Nighttime Cool Colors Model

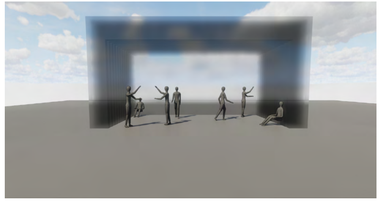
Nighttime Warm Colors Model

Spatial Interrogation Image



Light Interrogation Image

MEDIUM SCALE ABSTRACTION

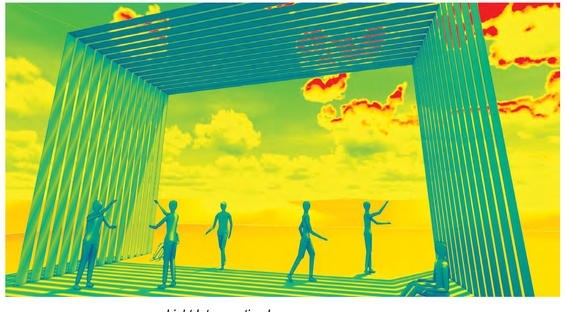


Daytime Model

Nighttime Cool Colors Model

Nighttime Warm Colors Model

Spatial Interrogation Image

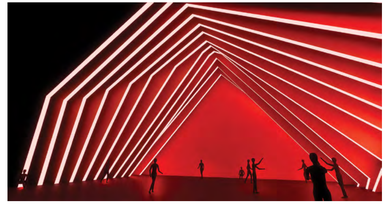


Light Interrogation Image

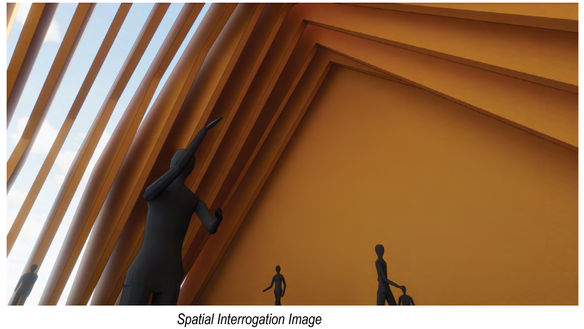
LARGE SCALE ABSTRACTION

Daytime Model

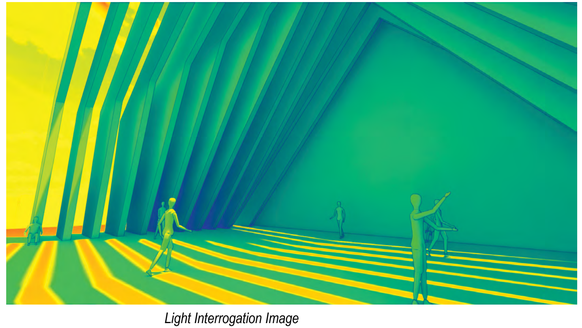
Nighttime Cool Colors Model



Nighttime Warm Colors Model



Spatial Interrogation Image

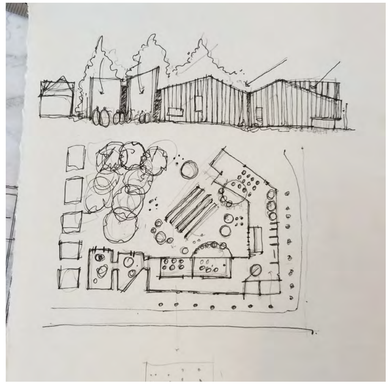


Light Interrogation Image

6.2_NORTH AVENUE: FROM CHAOS TO CALM

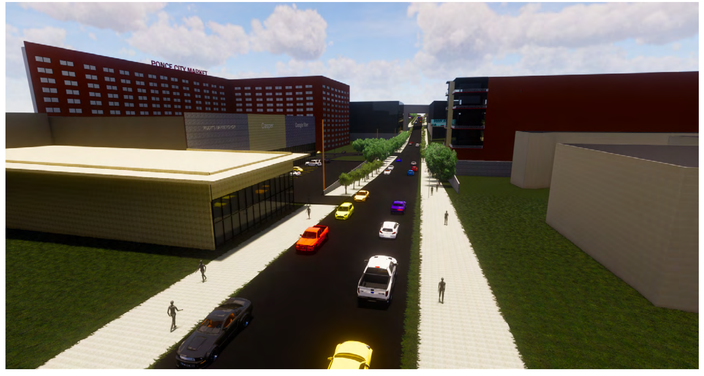
To prove that Hailey's models were adding calm to the chaotic environment that is North Avenue, I first had to model North Avenue in detail with all of its chaotic elements. This included traffic, both pedestrian and vehicular, the layers of visual barriers, the hilly terrain, and the sounds of the city. After all of this detail was input into a model almost a square kilometer in area, I then began adding her detailed interventions to the site.

= *SITE FOR URBAN INTERVENTION*

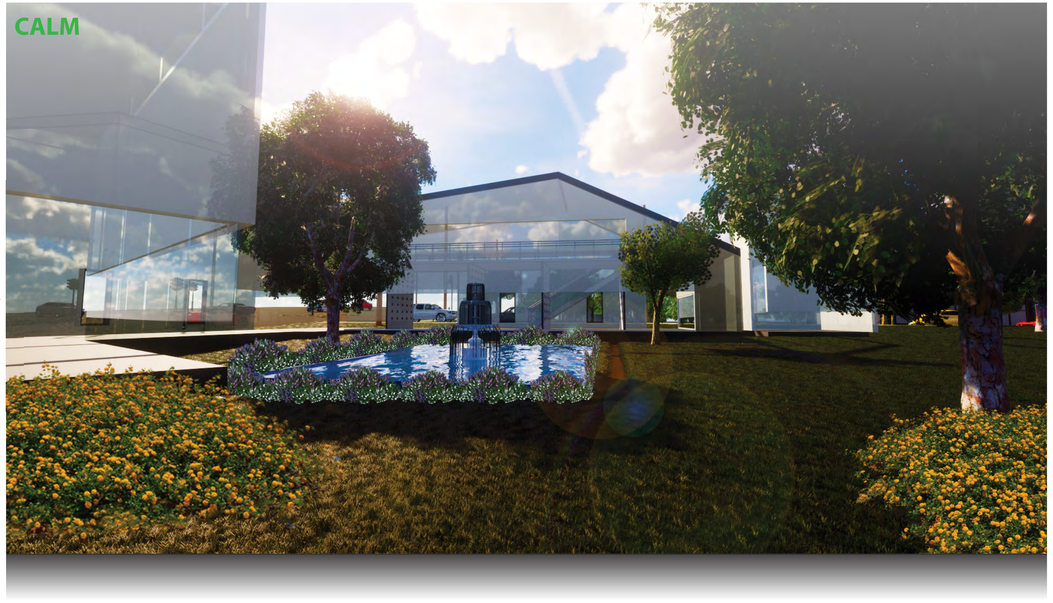


SITE MODEL OF NORTH AVENUE

North Avenue has a lot to offer. It starts near Freedom Parkways as a residential area, then slowly moves to a commercially zoned area. We then cross the Beltline Trail, which is the old rail systems converted to a walking trail and community. Then we hit Old Fourth Ward Park, the Masquerade, and Ponce City Market, all huge tourist attractions and large crowds at pretty much all times of the day. Then we move further down and hit more residences and a few more strip shopping centers, finally ending at Grady Hospital. All in all, a pretty chaotic setup. It's also pretty chaotic on my computer's processor as well, since the model is so large with so much information, and nearly cause my powerful computer to crash many times!



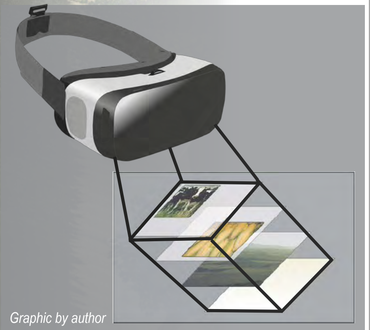
FROM CHAOS TO CALM



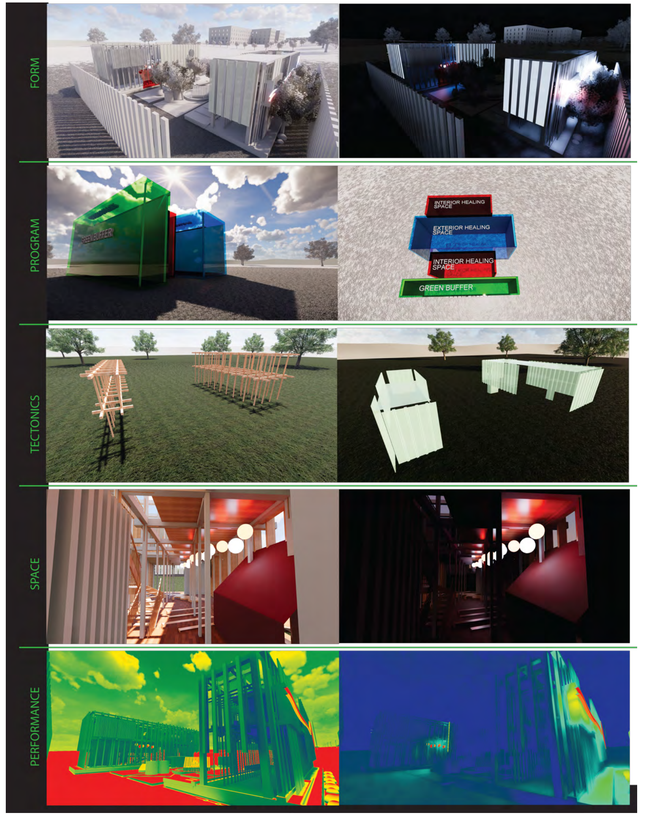
FROM CHAOS TO CALM

Intervention at Night

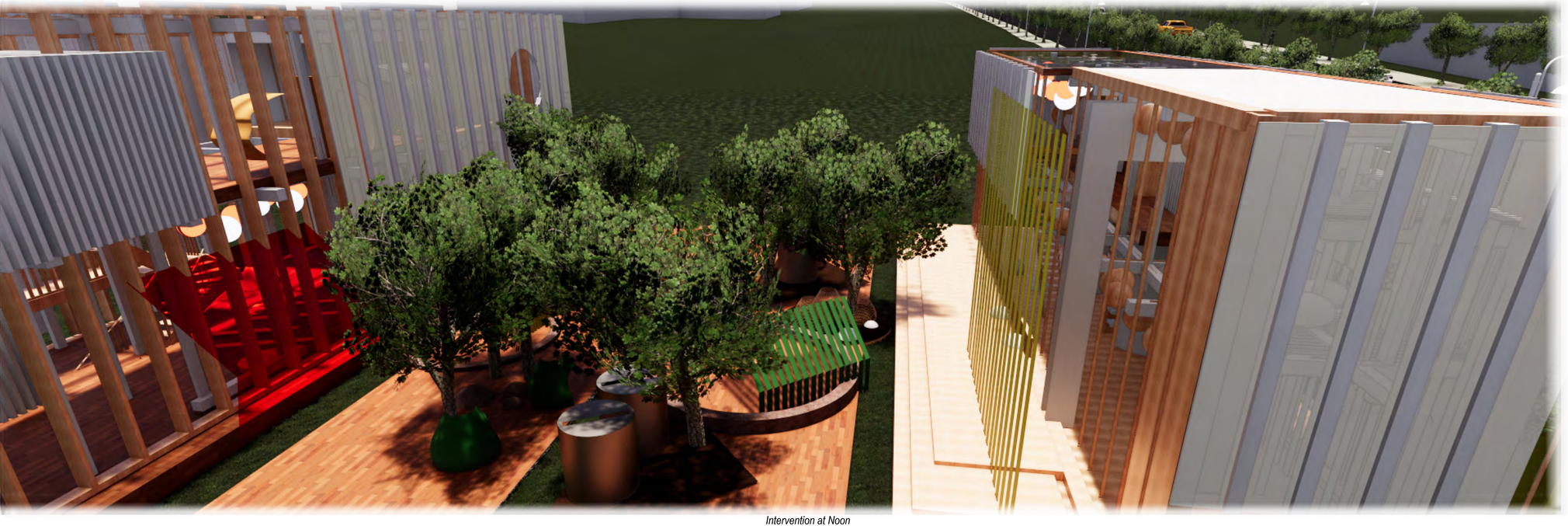
So this is Hailey's intervention. The design is not mine, and this is an important thing to know when critiquing this thesis. Remember I am not focusing on design, but representation of design. So, using the model shown to the left, I looked at it through the 5 lenses previously talked about at day and night, shown to the right. This allowed me to approach Hailey with a series of investigations based on real factors that she could then use to further develop her own model. There were a few structural members that got in the way of the walkthrough, and this helped her see those obstructions so she could edit her design before further review. All in all, a very useful tool for making design decisions.



Graphic by author



6.3_FINDINGS AND TAKE-AWAYS



Intervention at Noon

Findings and Take-Aways:

This project has taught me a lot, not just about virtual reality and its capabilities, but also about the way we use Revit and other BIM software packages in general. So many firms use Revit as a production tool, not as a design tool, and they are limiting its potential because for some, it is just too time consuming to learn how to use Revit “outside the norm”. However, if we spend the time to use it to question our design moves earlier in the design process, we can push designs further and make them better all together.

1 - To use VR as an architectural tool, we must use it alongside our current BIM practices.

2 - We must accurately BIM model, without taking shortcuts, to get the full potential of VR within design. This is not currently the case with most firms, but is worth the extra time put in.

3 - VR is not great for representing abstract ideas. However, it is a good tool to push those abstract ideas further, questioning things such as materiality, form, and function.

4 - VR is a tool. Like a screen is for AutoCAD or Revit, it is a representational tool, spitting out as an output the information you input. If you are not getting what you want, it is likely you need to change what you input.

5 - To further its potential, VR can be used through the 5 lenses defined in this book (Performance, Program, Tectonics, Form, and Space) to further break down complex information into easily understandable layers to make design decisions.

6 - As VR is more widely adopted, it can be an additional billable item for an architect to produce a walkthrough, and a faster way to produce already implemented renderings. Until its full adoption, it is a very useful competitive edge for a firm selling immersion to a client.

7 - If you don’t wish to mess up your hair with a VR headset, please get over yourself. Odds are, it doesn’t look as nice as you think it does, and you are really missing out on the beauty this device has to offer. It just can’t be fully captured by a rendering.

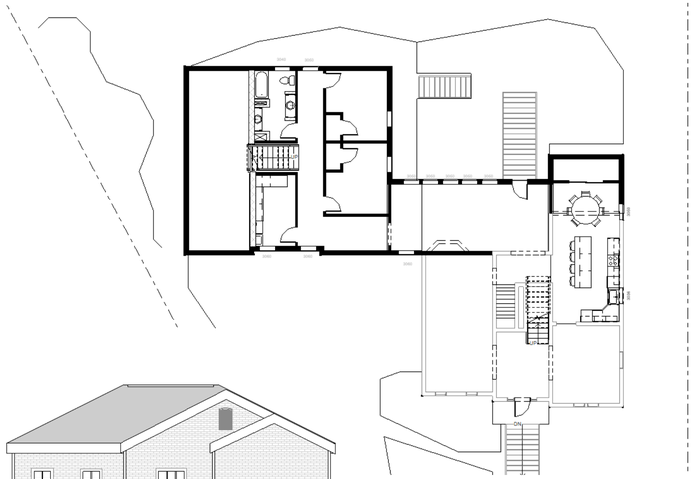
R.1_TESTIMONIES AND APPLICATION

The Forrest Residence

While writing this thesis, as all students find, money became tight. To give myself a little more pocket money, I took a residential renovation job in Rex, Ga, just south of Atlanta. In doing so, I met with the client, took measurements, and began designing for him. He had such a vision of the space he wanted, and I thought it would be a wonderful test case to interrogate the validity of VR presentations within architectural practice. In short, the client wanted a space larger than his existing house, plus he wanted some of the house renovated with the addition. Seeing as this was a big wish list, after getting a preliminary design, I handed him an xbox controller, showed him the controls, and said, “Walk the entire place and tell me what you like or don’t like, and we will flush out all the details right here.”

So, how did the client take this?

Both he and his wife loved it. He could read a plan, but she could not. Yet that didn’t stop either of them from using the Virtual Reality walkthrough from enhancing their understanding. I spent more time driving to meet them than I did meeting with them. It’s that good at making quick decisions.



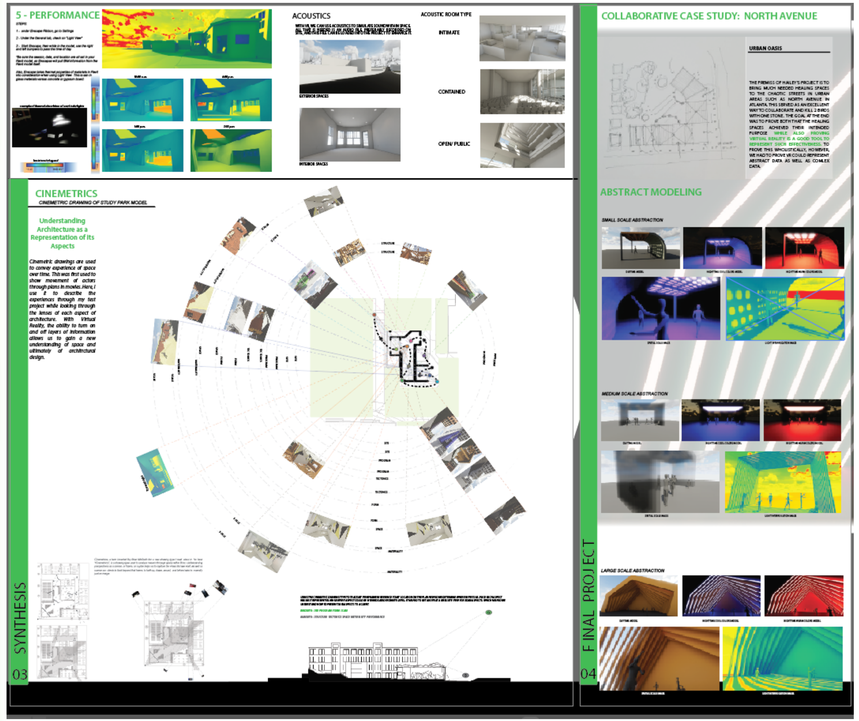
2nd Floor Plan of Forrest Residence *COPYRIGHT HZHDESIGNS*

Front Elevation of Forrest Residence *COPYRIGHT HZHDESIGNS*

R.2_FINAL BOARDS

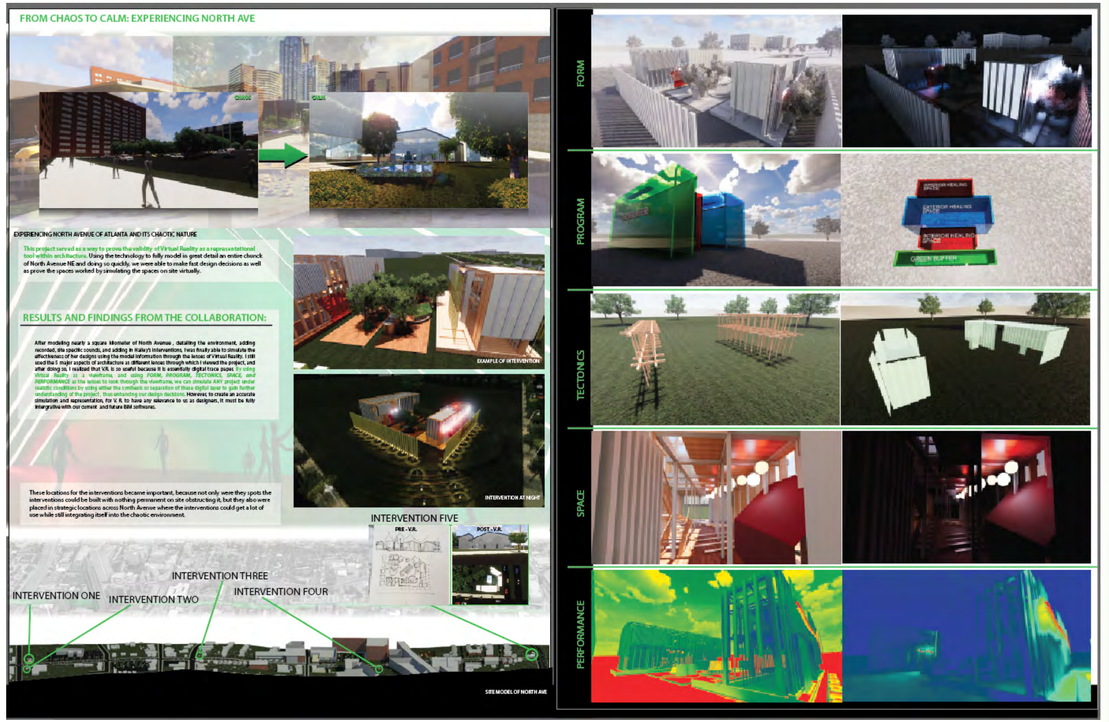
^ Above are my final boards for this project. Along with these 6 boards, there was a VR setup so any spectator could walk through North Avenue and experience the chaos within it.

To the right, you will see the closeup of boards 1 and 2. Board 1 was all about research and precedent studies. Board 2 begins to look at the defining “5 lenses of Architecture” outlined earlier in this book. >



< To the left, you will see boards 3 and 4. Board 3 focuses on the last of the 5 lenses and the summary drawing called cinemetrics. Board 4 started to outline the collaborative project with Hailey.

To the right, you will see boards 5 and 6. Both boards focused on the collaborative intervention and looking at it through the 5 lenses of Architecture. >



R.3_ANNOTATED BIBLIOGRAPHY

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In this article, a researcher takes virtual reality and uses it to simulate escape from an airport from a pedestrian point of view to help aid him in his design process and his signage.

“AN EXAMPLE OF VIRTUAL REALITY IN ARCHITECTURE”, WEB ARTICLE. HTTP://WWW. BLUEMARBLE3D.COM/TECHNOLOGIC/TABID/117/POST/AN-EXAMPLE-OF-VIRTUAL-REALITY-IN- ARCHITECTURE/DEFAULT.ASPX

This article gives an example of the practical use of VR to build a Chick-fil-a quickly and without errors. The client could review the design in full before it was built and voice any concerns quickly.

CURTIS, WILLIAM J. R., “MODERN ARCHITECTURE SINCE 1900”

A study of modern architecture, this book aims to define what started a shift in architectural style, and I am using it to specifically look at the work of Charles and Ray Eames and their use of film in architectural practice.

SASS, LAWRENCE, “DIGITALLY FABRICATED: BUILDING DELIVERY THROUGH KITS”, MIT LECTURE (2008)

This lecture by an MIT professor is used to show how we can use the digital realm to design houses and make them easier to understand from the perspectives of both the architect and the contractor.

DIMANLIG, DOM, “THE VIRTUAL HANDS OF THE ARCHITECT” MASTER’S THESIS (OCTOBER 2016)

Here the project is about using Virtual Reality as a design tool, and how effective it can be for the designer to use. This will help with my thesis for both his precedents and his ideology. He uses VR as an evolution of current drawing techniques.

MCGRATH, BRIAN, AND JEAN GARDNER. “CINEMETRICS: ARCHITECTURAL DRAWING TODAY” CHICHESTER, ENGLAND:WILEY-ACADEMY, 2007

Focuses on a new type of drawing: cinemetrics. The drawing is a plan/ perspective hybrid mostly used to track movement through scenes within movies. I used this information to distill what the computer does while moving through rendered, virtual space.

R.4_LIST OF FIGURES

FIG. 1.3.1 - https://www.trekk.com/insights/augmented-or-virtual-how-do-you-your-reality Last accessed 10/24/17

FIG. 1.3.2 - https://www.wareable.com/news/what-mark-zuckerberg-gets-right-about-the-future-of-wearables-707 Last accessed 11/12/17

FIG. 1.3.3 - https://www.wareable.com/news/what-mark-zuckerberg-gets-right-about-the-future-of-wearables-707 Last accessed 11/12/17

FIG. 1.3.4 - http://brainyandnerdy.com/microsoft-hololens/ Last accessed 3/18/18

FIG. 1.3.5 - http://brainyandnerdy.com/microsoft-hololens/ Last accessed 3/18/18

FIG. 1.3.6 - http://brainyandnerdy.com/microsoft-hololens/ Last accessed 3/18/18

FIG. 1.3.7 - https://www.trekk.com/insights/augmented-or-virtual-how-do-you-your-reality Last accessed 10/24/17

FIG. 1.3.8 - https://www.youtube.com/watch?v=0GL9bScesOg Last accessed 10/25/17

FIG. 1.3.9 - https://www.youtube.com/watch?v=o7zh0tDzK2A Last accessed 10/25/17

FIG. 1.3.10 - https://www.youtube.com/watch?v=o7zh0tDzK2A Last accessed 10/25/17

FIG. 1.3.11 - https://www.youtube.com/watch?v=0GL9bScesOg Last accessed 10/25/17

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FIG. 1.4.2 - https://forums.oculusvr.com/community/discussion/26785/enscape-for-autodesk-revit Last accessed 10/13/17

FIG. 1.4.3 - https://forums.oculusvr.com/community/discussion/26785/enscape-for-autodesk-revit Last accessed 10/13/17

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FIG. 2.1.3.1 - http://theconversation.com/how-to-build-a-virtual-reality-system-in-your-living-room-28598 Last accessed 10/13/17

FIG. 2.1.4.1 - https://enscape3d.com/architectural-visualization/ Last accessed 10/14/17

FIG. 2.1.4.2 - http://wrw.is/learn-completely-revolutionize-revit-presentation-capability-enscape-review/ Last accessed 10/13/17

FIG. 2.1.4.3 - https://www.youtube.com/watch?v=0GL9bScesOg Last accessed 10/25/17

FIG. 2.1.4.4 - https://www.youtube.com/watch?v=0GL9bScesOg Last accessed 10/25/17

FIG. 2.3.3.1 - https://www.gensler.com/projects/erwin-penland-headquarters?l=all Last accessed 9/18/17

FIG. 2.3.4.1 - https://www.youtube.com/watch?v=o7zh0tDzK2A Last accessed 10/25/17

FIG. 2.3.4.2 - https://www.youtube.com/watch?v=o7zh0tDzK2A Last accessed 10/25/17

FIG. 2.3.4.3 - https://www.youtube.com/watch?v=o7zh0tDzK2A Last accessed 10/25/17

FIG. 2.3.4.4 - https://www.youtube.com/watch?v=o7zh0tDzK2A Last accessed 10/25/17

FIG. 2.3.4.5 - https://www.youtube.com/watch?v=o7zh0tDzK2A Last accessed 10/25/17

FIG. 2.3.5.1 - https://futurumresearch.com/how-microsoft-hololens-is-changing-medicine-and-surgery/ Last accessed 10/03/17

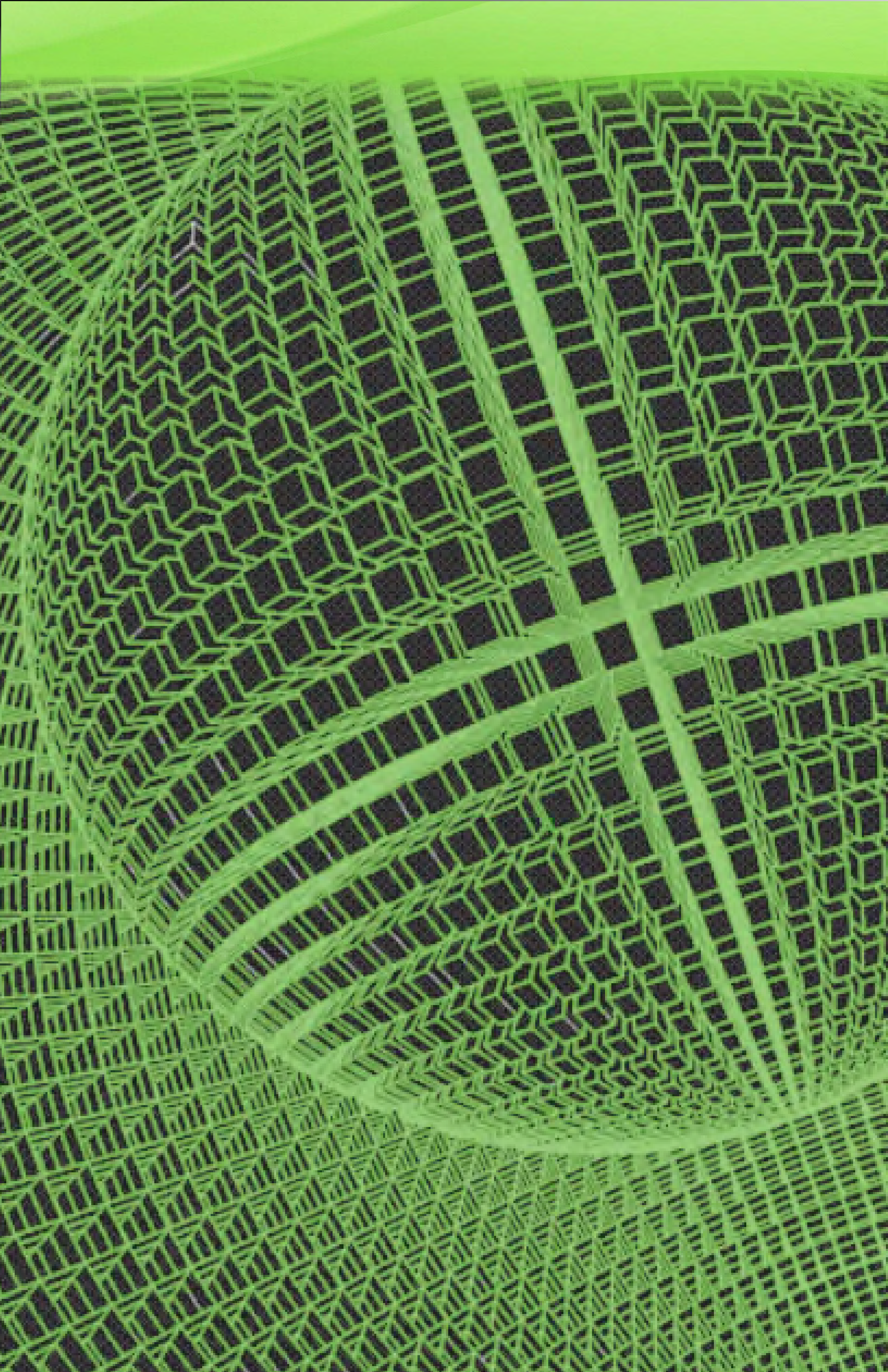
FIG. 2.3.5 2 - https://www.xpereal.com/ Last accessed 10/03/17

FIG. 2.3.5.3 - https://www.theverge.com/2015/1/5/7487653/hp-zvr-3d-virtual-reality-display-with-stylus-ces-2015 Last accessed 10/25/17

FIG. 2.3.5.4 - https://www.roadtovr.com/world-of-comenius-virtual-reality-education-biology-lesson-leap-motion-oculus-rift-dk2/ Last accessed 11/13/17

FIG. 5.2.1 - https://www.immersive-display.com/en/p/257-samsung-gear-vr-virtual-reality-headset.html Last accessed 2/22/18

BEYOND FLAT SPACE

HOLDEN HOLLEY

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