Final Summary Report

CSE486: CS Capstone Project II

Construction Management (PhD student) - HoloLens 2-based Construction Scheduling Simulator

A construction simulation application in which users can simulate correctly installing building components using augmented reality and the Microsoft Hololens

Table of Contents

Project Description

The objective of the Construction Scheduling Simulator is to create an alternative method for teaching construction management students proper procedures for installation. The motivation is that by creating an augmented-reality based alternative, the program will be able to replace physical models currently used. Using this replacement has multiple benefits for both the users. In the case of this project there are two users: the stakeholder, and his students. This creates substantial benefits for the stakeholder due to the increase in efficiency across cost, space and time. By replacing the physical models with holographic alternatives, the simulations significantly lower cost by no longer requiring the purchase of physical materials. For simple projects like the pipe installations demonstrated in our version of the project, this may seem negligible, but upon expanding to larger and more complicated models such as a house or a playground, the savings become more evident. This cost also extends beyond the one time cost though, as many materials in construction are not reusable. Overall, the purchase of a few HoloLenses is much cheaper than the continuous purchase of construction materials. It is also more versatile, as one HoloLens can be used to simulate an infinite number of constructions, which materials have to be purchased independently for each project.

In addition to the cost aspect, using HoloLenses instead of physical materials can save space. Not only do materials take up space to store, but when using them, materials obviously cannot overlap in real space. On the other hand, the HoloLenses can run multiple simulations in the same space, since the holograms can only be seen by the person with the HoloLens. Finally, using a HoloLens saves time in multiple places. When ordering physical materials, the instructor has to wait for them to arrive, while holograms are always available. The instructor also doesn't have to worry about the time needed to set up and tear down any physical materials that would be used.

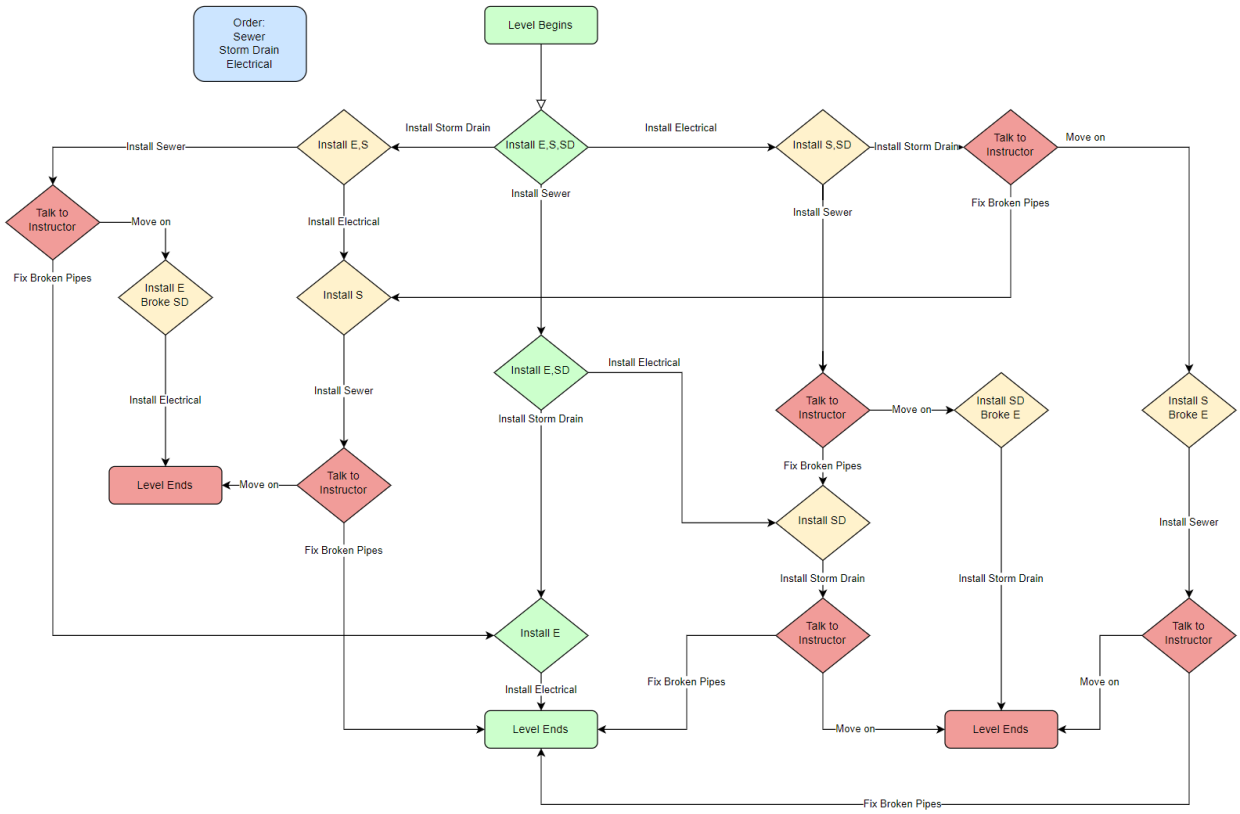
Overall, the project had numerous requirements to ensure that, as a program, it would serve as an accurate replacement for physical construction simulation. One of the most important requirements was that the project must be realistic. This was one of the hardest ones to tackle as not only is realism a scale, but it is extremely difficult to replicate with holograms because of how hard it is to mesh them with the real world. In the case of our project, implementing realism meant that the project had to be accurate, rather than realistic. Models and textures could look simulated, but animations and sounds had to be as realistic as possible. Another important aspect

was that the simulation had to require a decent level of interaction with the user. Rather than just pressing buttons, the user has to expressly vocalize the actions that will occur, whether that be installing a specific pipe, fixing a pipe, or viewing how well they did at the end of the level. Furthermore, the project had to be reusable, both in regards to being able to rerun the level and being able to create multiple levels. We were able to successfully implement the former, and while we didn't have time to implement a second level, the framework exists to do so.

Over the course of the semester, our group successfully implemented all of the required functionalities for the stakeholder. Our specific level was designed to simulate installing underground pipes. All of the models provided by the stakeholder were properly implemented and aligned so they showed up to scale and in the proper place in the real world. This was a large hassle due to the numerous models that needed to be implemented, and the inconsistency between them. We had to be extremely careful to make sure everything lined up properly, or model swapping would be a jarring experience for the user. A proper ordering system was also implemented to ensure that pipes are installed in the proper order, and that the user has the chance to fix any mistakes they might make. This was the most difficult part, as the logic and ordering behind it changed multiple times throughout the semester. Animations were implemented for trench digging, pipe installation, pipe breaking, pipe fixing, and trench filling. These assisted with realism of the project and with the flow of the level. Without animations, the project felt clunky and choppy, and as a user it was hard to keep track of what was going on. Audio cues were implemented to assist the user in knowing when trenches are dug or pipes are broken during installation. Additional props are also added around the scene to assist in adding a level of realism.

One thing that makes this project unique is how interactive it is. Out of the capstone project, there were two main categories: projects and research. Out of the projects, most were implemented in the form of a monitor based computer program, and while they are interactive, they are still limited in the freedom the user can have. Our project lets the user "physically" interact with the project in a way that is not possible without augmented reality or virtual reality. Another aspect that makes it cool is that the project will immediately be used in education. The stakeholder for our project came up with this project to assist in his Ph.D research in teaching construction management. It is incredible to know that something we developed as a capstone will be used to help teach others in a college program.

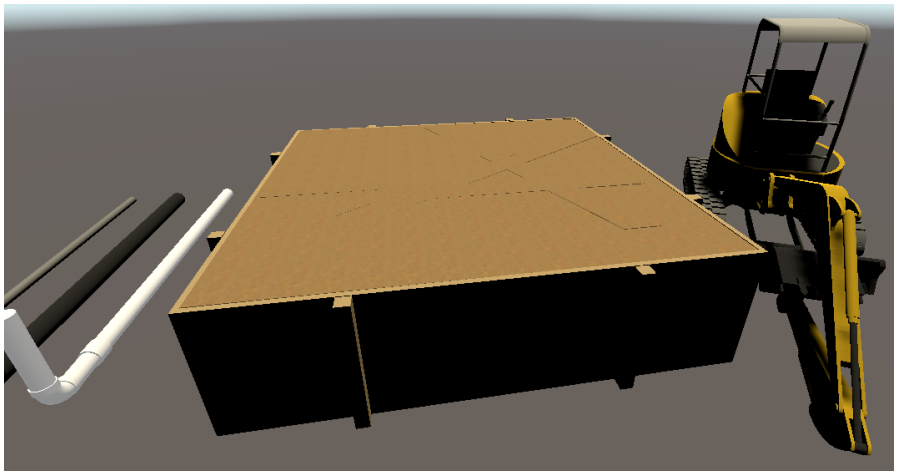
System Diagram:

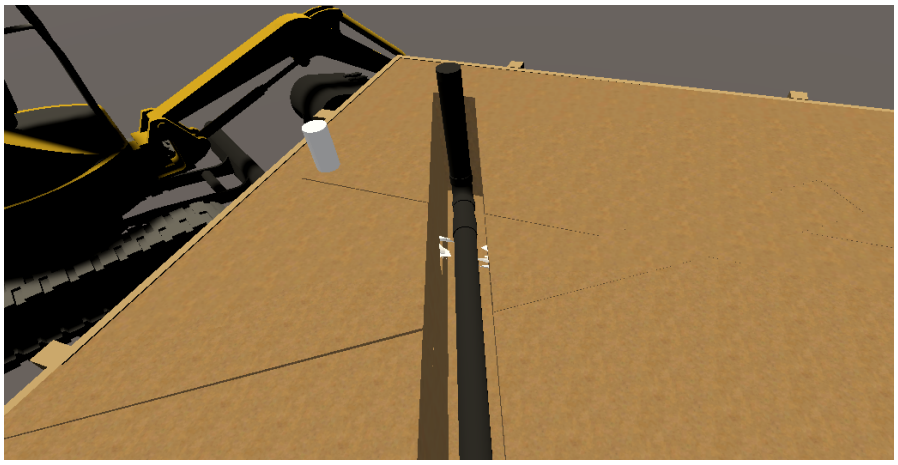


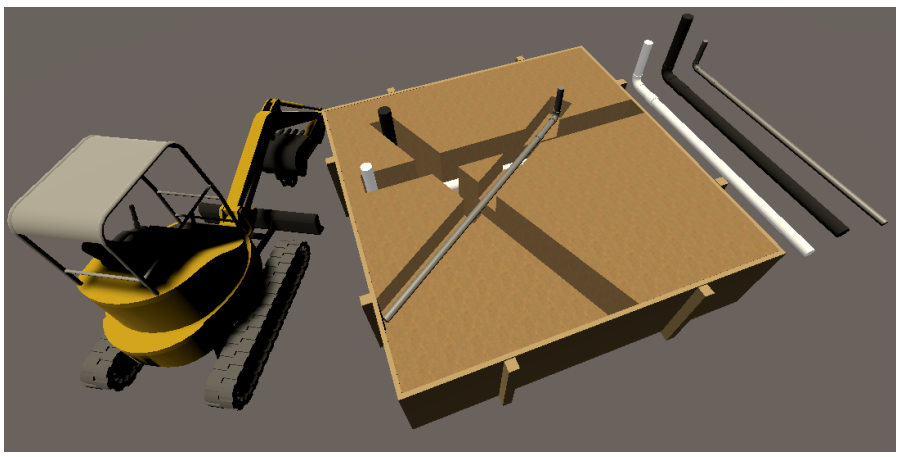
User Stories:

- As a user, I should be able to use voice commands to install each of the pipes so I can interact with the holograms.
- As a user, I should be able to install pipes in an incorrect order to allow me to make mistakes.
- As a user, I should be able to fix pipes at the time I break them so I have the chance to realize and correct mistakes.
- As a user, I should be able to move on when a pipe breaks so the error remains if I don't realize my mistake.
- As a user, I should see animations and hear audio clips that support the installation process so that the simulations are more realistic.
- As a user, I should be able to remove the trench backfills after the level is over so that I can see how accurate my installation was.

Additional Project Images:







Summary of Contributions

When it comes to presentations, although there weren't many, I was in charge of collecting the base information. This means coming up with an outline, answering any basic questions, and agglomerating all of the information onto the slides. Most of the styling and examples were left to my group mates who are more artistically talented than I am. When presenting, I would generally cover the parts I programmed, as well as background information as I was generally the person in charge of research. I would also generally be the person to answer questions outside of my group members' respective technical expertise, as I have the most background knowledge in augmented reality and virtual reality from prior experience.

I also worked on multiple reports throughout the projects. For the sprint retrospectives, I was responsible for the week 8 report. I also worked with Samantha on the test report, and with David on the final poster. In the report, I was in charge of the test cases that allowed the user to install the pipes, both correctly and incorrectly. I was also responsible for testing those requirements, both of which passed. On the poster, I was responsible for collecting the basic information for each category.

For the project, I was responsible for many of the technical aspects that weren't coding heavy. One of the main components I designed was the logic diagram for the project. Although not necessary, it made testing the program significantly easier. I was also in charge of setting up all of the models. While this sounds simple, it was probably one of the more time consuming parts of the projects. For all of the models, I had to scale, move, align and group according to purpose. Most of the Dirtbox and the trenches could be done at the same time, but the pipes were not as convenient. Since each form of each model was modeled individually, I had to realign and reshape so each form of the same pipe matched. If I didn't take this step, swapping between forms could be potentially jarring for the user to watch. I also did various other smaller tasks like coloring components, readjusting sizes and positions, and adding logos to props. This allowed the main coders to focus on their tasks.

When it came to team management, I served as a kind of technical head for our group. Within our project, there existed a very large gap in technical knowledge between our stakeholder and us students. I served as the main explainer, and took the position of explaining what was and wasn't technically possible for us to implement and why. Our sponsor also frequently changed his mind when it came to what he wanted, so I was in charge of negotiating

and creating cutoffs for changes to make sure everything could get done on time. Within the team, there wasn't much management that needed to be done. Most of the group members were on top of our work, and all worked to remind each other to make sure we were on pace.

Reflection of Personal Work

Overall, I believe I did a solid job on my work. Even so there were still some things that I could have improved on as I developed them. One of the largest issues that I ran into throughout my work was model issues. There were multiple times when I would receive a model that only had a few minor issues. Due to my lack of modeling experience, I was unable to fix them myself and had to request a new model be made, which wasted time. If I had spent the time earlier in the project to learn the modeling software the sponsor used, I could have saved that time, but due to the development processes, there were more model changes needed than I anticipated. Another part of my work that could have been better was the logic diagram. It took me three weeks and multiple versions to develop a flowchart that was close to what we wanted. A different type of diagram like a UML would have been better for our purpose, but by the time I realized that I had already started and didn't want to change it.

All in all, I learned a lot of solid skills that will assist me in the future. My skills in Unity grew by leaps and bounds, and I am now much more confident about model manipulation in Unity. Surprisingly, this is not as niche of a skill as it seems. Unity skills are relevant not only in simulations, but also in game design, animations, and general front end design. Many of the precise changes I had to make can be compared to minute changes needed in production builds. The project also helped develop my logic and planning skills. While the flowchart is an obvious example, helping implement the logic in Unity was a great help in showing how the same logic can be represented in different forms. Aside from technical knowhow, I also gained skills that will be useful in the workforce. Teamwork, as always, is a helpful skill to develop, as the teams and people you work with constantly change. Working with limited information was another big skill, as a constantly evolving goal meant there was little predictability in what would be the final decision, so we had to design our project in a more general way that we could quickly modify it to fit the needs of the stakeholder.

Throughout development of the product, I learned a lot about what works when and why, and this statement is applicable to a variety of different ideas. I learned that knowing how to plan

ahead is a valuable skill that can save time, but planning too far ahead makes you rigid and wastes time. Instead, it is better to have a solid outline, and be prepared to adapt when necessary. I also learned that it is best to set boundaries and be open about what is reasonable to prevent false expectations for the product. Overall, these new learnings provided me with a great framework for both how to plan future projects and how to best help when working on a team.

Real World Value

Economic benefit is the most obvious category where this project benefits the stakeholder. As discussed earlier, implementing this program can save time, cost, and space. Time can be saved by eliminating setup and teardown times, as well as the wait for physical materials to arrive. Cost is saved through converting repeated large purchases of various materials into a single HoloLens purchase. Space can be saved by eliminating both the space needed to store materials, and by allowing multiple HoloLenses to operate in the same space. All three of these combined allow the construction management students to operate on a smaller budget, and allow more students to practice at the same time. There are some downsides to this though. Although time was saved, time also needs to be spent developing the levels, and while we did establish a framework with our work from this semester, it is also true that it took a team of us a whole semester to develop a level from scratch. Cost is also not negligible, as each HoloLens 2 costs $3500, which is a relatively steep initial cost if they were purchased in bulk.

Health and Safety is another category in which this project has some interesting implications. One side effect of replacing physical materials with holograms is just that: there are no physical materials. This significantly increases safely in simulation by preventing various injuries that can occur, such as cuts, splinters, or more serious accidents. Even so, the HoloLens approach is not without its flaws. While physical materials can no longer cause injuries, false perceptions still can. The reason the HoloLens works so well is it convinces the user that the holograms it shows exist in the real world. Sometimes it does this job too well, and the user may try to use a hologram as support and injure themselves in the process. Another issue is that the HoloLens is ultimately still a simulation, and is going to be a less accurate experience than performing construction management in the real world. Scattered tools and misplaced parts are real hazards that the HoloLens can’t simulate.

Team Reflection

For the most part, the project was successful, and the team worked together extremely well. Most of the team members were more than willing to do their part to make the project the best it could be. David did a fantastic job coding the backend objects we used for the proper installation order, Joseph's animations tied perfectly into the objects David wrote, and Samantha's textures and constant testing made the whole process progress smoothly. In the final version we submitted to the sponsor, the code was fully functional and contained few, if any bugs. One thing I feel we did well as a team was closing out the project. Although the original list of bugs was in the twenties, we were able to clear them out in just two weeks.

Although the project was a success, there was a lot we could have improved on as a team. One of the big points was communication. As a group, we would meet once a week to give a progress update and decide the priorities for the next half-sprint. Each team member would then go their own way, and the only time anything was discussed outside those meetings was if we needed something for a sponsor or for a sprint retrospective. As the semester progressed, our communication did improve, but was still relatively limited. I believe that if we communicated more about our progress, group members who are unable to finish their parts on time will be able to inform the rest of the team ahead of the weekly check in. That way, someone else may have the chance to help out so we don't fall behind. Aside from this, one of the big issues with our project is that we only have two HoloLenses and five students, meaning that we had to cycle the HoloLenses between us. Obviously we needed to communicate to set up the meetings, but sometimes a group member would fail to respond for a few days or even during the meeting, causing delays to the handoff, and as a result, the project. Constant communication during important meetings was something that we lacked, but would have been extremely helpful.

Another thing we could have improved on was planning. Every week, we met to give an update and decide what the next week's focus would be, and that worked, but it also meant there was little to no foresight. We never planned more than that week out. Multiple times throughout the semester, this led to us redoing previous components due to changes in the final goal. The animation design and timing was re-coded four times to match the final specifications. If we had taken the time at the beginning of the semester to get a concrete goal, the project would have gone much more smoothly.

Conclusion

As a project, the HoloLens 2-based Construction Scheduling Simulator was a success. Students who use it are able to successfully simulate the process of installing multiple utility pipes, and solve any issues that may occur during the process. At the end, they can review their work and learn from any mistakes they made. All in all, this project was a great success, and a great learning experience. I got to learn more about Unity, experiment with the HoloLens, and help develop a solid program that did its intended purpose. While there were certainly some struggles with the project, teammates, and the sponsor, all's well that ends well, and I believe that this ended about as well as it could have. In the future, I'd love to have the opportunity to experiment more with the HoloLens. It is such a unique tool, and is only just now starting to become applicable in a lot of industries.