

Augmented Reality Sandbox Project Archive

June 4, 2021

Prepared For
CS 461 Spring Term

Prepared By
Group 7
Zach Bishop, Tyler Rivas, and Andrew White

Abstract

This paper discusses everything there is to know about the Augmented Reality Sandbox project. It shares where to find all other documents related to this project and gives enough information to allow another group to continue development. This document serves as a master guide and reference for what has been accomplished and what there is left to do.

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1. Introduction

Three years ago, Joseph Louis, a civil engineering professor here at Oregon State, saw something somewhat unique online. He came across something called an Augmented Reality Sandbox. He saw this sandbox as an opportunity to better educate the students in the college of civil engineering. Being our project partner, Joseph Louis requested to lead this project with the main goal being to educate and help the civil engineering students learn and see how different terrain data affects the terrain.

As previously stated, our project partner was Joseph Louis. The members of the team were Andrew White, Zachary Bishop, and Tyler Rivas. Zach had the role of being the team lead. He acted as the primary source of communication with our project partner, and he was responsible for setting up meeting times, organizing project work, and keeping the team on track. Aside from that, Zach also was a part of every aspect of the project, including development. Andrew, although not the team lead, contributed to every part of the project. This included research, development, implementation, scheduling, and team participation. Tyler Rivas acted as the lead developer for the implementation of the core features assigned to us from the start. Aside from this, Tyler contributed to every aspect of the project and the team. This included research, development, implementation, scheduling, and team participation. Our project partner's role was supervision and guidance. He had a vision of where he wanted the project to go and what features he wanted to be added to the project. Aside from that, he had no role in development; he was solely responsible for checking our progress and telling us what he wanted us to implement with the sandbox.

Our team specifically had a lot of issues with Covid-19 and the pandemic. The problem was that due to the restrictions placed on Oregon and the campus being closed, we could not access the actual sandbox and the hardware for the project until late winter term. This was a considerable issue because, without the sandbox, all we could do was research; we couldn't do any implementation or testing, which was extremely detrimental. This put us exceptionally behind on the project, and the code deliverables that we were supposed to have were not able to get done. With all of that being said, we did finish one core feature, and we got another core feature working in more of a beta version. Overall, we were handed some terrible cards this term, but we ended up completing a lot with the time frame we were given.

When our group came into the project, there was a lack of documentation. We made it a point that we were going to document thoroughly. We provided extensive documentation on what the next group should work on and how they should start the project. We suggest that they go through all of the documentation and start from the first step that we recommend that they do. This will lead them to have the best success this upcoming year.

2. Copy of the Vision & Scope Paper

A copy of the Vision & Scope paper (otherwise known as milestone 2) can be found in the Box drive for this project within the archive folder.

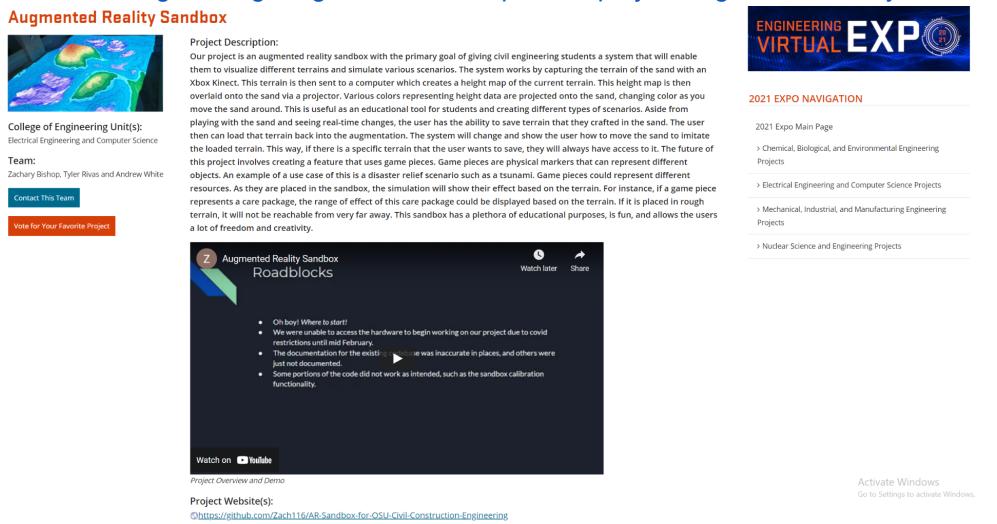
3. Copy of the Winter Term Retrospective

A copy of the Winter term Retrospective paper can be found in the Box drive for this project within the archive folder.

4. Screenshots of Virtual Expo Page and Link

Link to the virtual expo page for this project:

<https://events.engineering.oregonstate.edu/expo2021/project/augmented-reality-sandbox>



Screenshot of the virtual expo page

5. Project Documentation

For a full guide of how to use this project, read the README on the github page:
<https://github.com/jlouis2k4/AR-Sandbox-for-OSU-Civil-Construction-Engineering>

6. List of Recommended Technical Resources

The following videos and articles cover how to use Unity, how to import a terrain through a script, and how to use Vuforia.

[How to make a game in Unity](#)

[Using scripts to import terrain from raw data](#)

[Vuforia example within Unity](#)

7. Conclusion and Reflections

Zach Bishop:

- What technical information did you learn?
 - Throughout this project I have mostly learned how to use Unity. I learned how to create game objects and make different objects interact with each other. I also learned more about writing code in C#. These two things were the main tools that I used for this project. I also learned a

little about using Vuforia, but we never got to the part of the project that needed it so I only gained a very basic understanding.

- What non-technical information did you learn?
 - As team lead, I quickly learned how to effectively communicate and delegate work. My role mostly consisted of assigning tasks to different team members and following up to ensure that they were completed on time. I also learned how to communicate with our project partner to figure out exactly what he wanted out of this project. Taking what he said and translating it into technical features was difficult at times, but ultimately a great life skill to learn.
- What have you learned about project work?
 - I've learned that scheduling is key when it comes to project work. Laying out a road map that accounts for possible problems while also being flexible is extremely important. We started later than intended because of roadblocks, so it became increasingly important to learn how to manage the little time we had effectively.
- What have you learned about project management?
 - I realized how important it is to delegate work to other team members instead of trying to do it all yourself. I am often a controlling person who likes things to be done in a specific way. This often leads me to try and handle most tasks on my own. However, with a project like this, that is more than improbable. I quickly learned how to assign tasks to different team members. Not only that, but also giving tasks to the people who are best suited to handle them according to their specific skills.
- What have you learned about working in teams?
 - I learned that communication is extremely important. Making sure everyone is aware of which assignments are coming up, when they are due, and any new information that arises is key to making sure everyone is contributing and all tasks are completed. There were many times that information would be told directly to me and I would need to make sure to pass it on to everyone else. If I forgot to do so, we would then have to scramble to complete assignments at the last minute instead of spreading the work out over a few days.
- If you could do it all over, what would you do differently?
 - I would try to push to get the basic equipment earlier. We were unable to get access to the sandbox, but we did end up getting the Kinect and projector. With these tools alone we were able to test out some of the existing features. However, we realized that we could do this fairly late and it ended up being not much help. If we had communicated more often and clearly with our project partner earlier on, we may have gotten the equipment earlier which would've translated into more time to work on the project.

Andrew White:

- What technical information did you learn?
 - I learned a lot of different things. I learned how to work with Unity, and I also learned a little bit about Vuforia, the built-in SDK. In general, working with augmented reality programs was something that I added to my tool

belt. Also I've never used C#, so learning a little C# was something that I learned as well.

- What non-technical information did you learn?
 - I learned how to work with a team, and how to properly communicate with each member. Teamwork was something that I already was good at, but effectively communicating with my teammates and our project partner was a different ballgame during this project, and adjusting my style was something that I added to my workflow.
 - I also learned how to work in a scrum environment. Having sprints each term, and meeting with our TA, and project partner felt like a good introduction to how things may run at an actual company, so doing that was extremely helpful.
- What have you learned about project work?
 - I've learned that project work has a lot of working parts. Working with a team on a big project can get complex. I learned that it can be fun, and it can also be challenging and time consuming. Like I stated earlier I learned that communication is really the most important thing when it comes to the success of a project/team.
- What have you learned about project management?
 - I've learned that managing a project can be pretty unorganized and can get scattered easily. Maintaining great communication and organization throughout the entire project makes life WAY easier. Effective documentation also is a must when it comes to managing a project.
- What have you learned about working in teams?
 - I've learned that communication is probably the most important factor while working on a team. Zach was our team lead and he had great communication and always made sure that Tyler and I knew what was going on and reminded us of things that were due and meeting times. Without our team's great communication we probably wouldn't have gotten half of what we accomplished with the time that we had.
- If you could do it all over, what would you do differently?
 - I can't really think of anything that I would do differently. I would say that I would make it so that we had access to the sandbox/hardware at an earlier date, but most of that was out of our control.

Tyler Rivas:

- What technical information did you learn?
 - I learned how to use the xbox kinect sensors with unity as well as how to use the vuforia framework. Although we didn't end up using the vuforia framework as we ran out of time due to covid restrictions.
- What non-technical information did you learn?
 - I learned a lot about working in sprints and scrum environments. Working in a team like this gave me a good indication of how a real company may run a project.
- What have you learned about project work?
 - There is often too much work to do alone and that the team mates should be relied on for things that they are good at individually.
- What have you learned about project management?
 - Documentation and communication can make or break a project.

- What have you learned about working in teams?
 - Communication is really important
- If you could do it all over, what would you do differently?
 - I would have tried to get access to the equipment earlier than we did. Either by pushing the project partner or by requesting the sensor and projector. As it stands, we didn't have access to the equipment until very late in the project.

8. Future Direction

The future teams working on this project should aim to improve the existing systems, such as the calibration system, and the loading system. Currently the sandbox needs to be calibrated before each use, and this can be time consuming to get the system properly calibrated. The loading system also needs the user to adjust the calibration so that the bounds of the loaded heightmap match the bounds of the sandbox. If the calibration system could be automated by combining similar technologies found in the Handheld AR device project then users trying to use the sandbox could spend far more of their time learning about their loaded terrain environment then setting up the sandbox for use. Another thing to consider is the use of game pieces. These game pieces could represent many different things, such as disaster relief equipment. A user could use the sandbox to simulate earthquakes where debris blocks roads and cities, and with the game pieces they could determine where best to place such equipment so that it is most effectively used given the local geography. Such simulations could be very beneficial to civil engineering students as they are learning about how to most effectively use the tools at their disposal.

User Stories

1. As a user I need to be able to use game pieces to test different scenarios so that I can gain a better understanding of the effects of different decisions.
2. As a user I need to be able to quickly set up the physical system and easily use the software interface so that I can focus more time on learning valuable information by simulating different scenarios.
3. As a user I need to be able to load terrain heightmaps using common GIS formats so that I can more easily gain a perspective of a particular piece of geography.

9. Appendices

Appendix 1: Essential Code Listings

The following code is within the `terrain_load_save.cs` script. This script contains most of the code used to implement the saving and loading features.

```
public void Update()
{
    if (SaveTerrainPanel.gameObject.activeSelf == false &&
LoadTerrainPanel.gameObject.activeSelf == false) {
        if (Input.GetKeyDown(KeyCode.S))
            terrainSave();
        if (Input.GetKeyDown(KeyCode.L))
```

```

        gen.loadTerrain = true;
    if (Input.GetKeyDown(KeyCode.Q))
        gen.loadTerrain = false;
    }
}

public void terrainSave()
{
    // Save
    string filename = "output";

    // Get filename from user
    if (saveInputField.GetComponent<Text>().text != "") {
        filename = saveInputField.GetComponent<Text>().text;
    }

    Texture2D output = gen.heightmapFromSensor;
    byte[] b = output.EncodeToPNG();
    File.WriteAllBytes(Application.dataPath + "/Output/" + filename +
".png", b);

    Debug.Log("Saved the heightmap to a file called " + filename + " at: " + Application.dataPath + "/Output!");
}

// User needs to input:
// The file path
// The fileType (raw or png)
// The resolution (height and width) of the heightmap. If bigger than the terrain, it will be cut off
// The mode (8-bit or 16-bit)
public void terrainLoad()
{
    // Load
    string filePath = Application.dataPath + "/Output/" +
"output.png";
    string fileType = "PNG";
    string mode = "16-bit";
    // height and width of the heightmap. Needs to be less than the heightmap resolution of the terrrain
    int h = 212;
    int w = 256;

    float[,] heightData = new float[h, w];
}

```

```

// Grab user data from UI
if (loadFileName.GetComponent<Text>().text != "") {
    filePath = Application.dataPath + "/Output/" +
loadFileName.GetComponent<Text>().text;
}
fileType = loadFileType.options[loadFileType.value].text;
mode = loadMode.options[loadMode.value].text;
if (loadHeight.GetComponent<Text>().text != "") {
    h = int.Parse(loadHeight.GetComponent<Text>().text);
}
if (loadWidth.GetComponent<Text>().text != "") {
    w = int.Parse(loadWidth.GetComponent<Text>().text);
}

if (fileType == "PNG")
{
    byte[] fileData = System.IO.File.ReadAllBytes(filePath);
    var tex = new Texture2D(h, w);
    tex.LoadImage(fileData);

    //Use this if doing terrain, but we are doing heightmaps
and textures now
/*
for (int y = 0; y < h; y++)
{
    for (int x = 0; x < w; x++)
    {
        heightData[y, x] = tex.GetPixel(y, x).r;
    }
}
*/
gen.loadedHeightmap = tex;

gen.loadTerrain = true;
}

//This currently does not work because we are using textures
now
//To use this feature, there needs to be a way to color the
sand by comparing the loadedTerrain and current terrain
/*
if (fileType == "raw")

```

```

{
    using (var file = System.IO.File.OpenRead(filePath))
    using (var reader = new System.IO.BinaryReader(file))
    {
        for (int y = 0; y < h; y++)
        {
            for (int x = 0; x < w; x++)
            {
                float currHeight;

                // Perform correct conversion based on bit
                type
                if (mode == "16-bit")
                {
                    currHeight = (float)reader.ReadUInt16() /
                    0xFFFF;
                }
                else
                {
                    currHeight = (float)reader.ReadByte() /
                    0xFF;
                }

                heightData[y, x] = currHeight;
            }
        }
    }

    loadedTerrain.terrainData.SetHeights(0, 0, heightData);
    gen.loadTerrain = true;
    */
}
}

```

The code which follows from here can be found within the TerrainGenerator.cs script. This piece of code is what performs the color changes when loading a terrain. This code needs to be altered to normalize the heights within the loaded heightmap so the max and min heights match the max and min heights of the sandbox calibration.

```

// If we are loading terrain
if (loadTerrain)
{
    // if current height is higher than the heightmap.

```

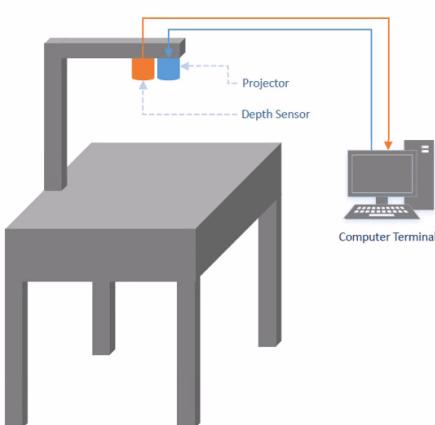
```

        if      (heightmapFromSensor.GetPixel(j,i).r      >
loadedHeightmap.GetPixel(j,i).r)
{
    // show red to lower.
    yNorm -= 1.0f;
}
// if current height is lower than the heightmap.
else    if      (heightmapFromSensor.GetPixel(j,    i).r     <
loadedHeightmap.GetPixel(j, i).r)
{
    // show blue to raise.
    yNorm += 1.0f;
}
// if the current height is the same as the heightmap.
}
vertices [j + frameWidth / downsampleSize * i] = new Vector3 (j * spacing, yNorm * magnitude, i * spacing);

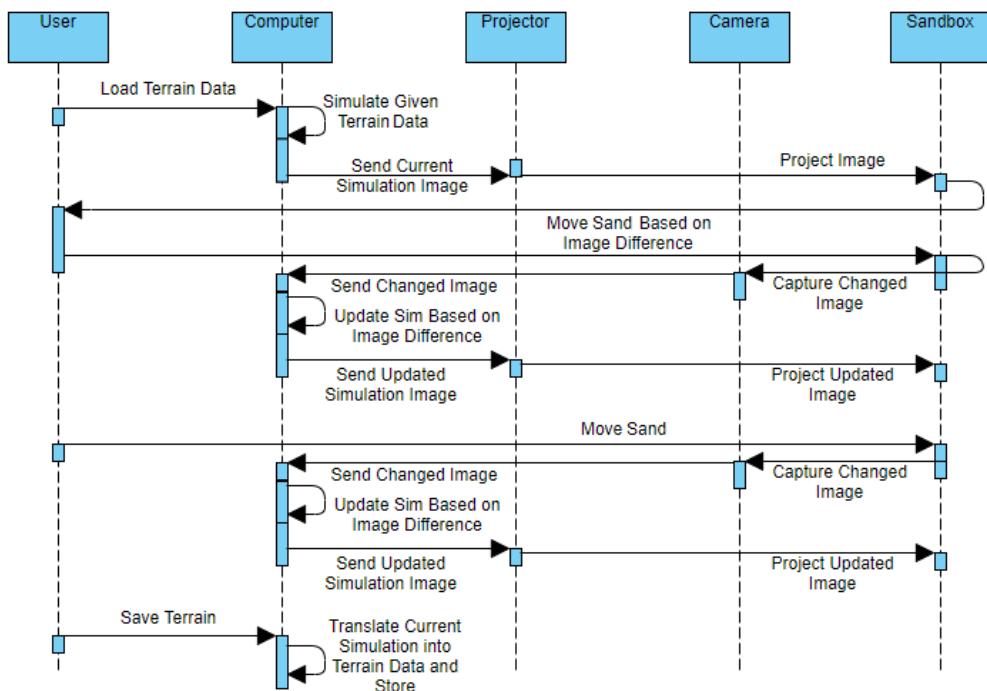
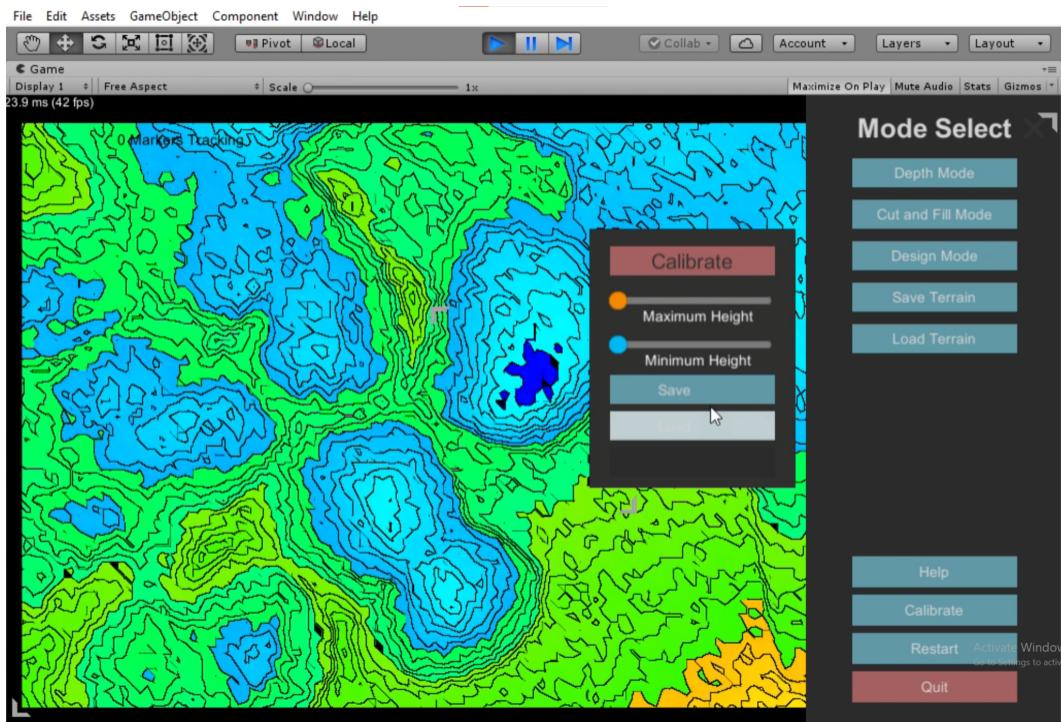
```

Appendix 2: Photos and Diagrams

Portable Sandbox Design



Initial design and the final built sandbox



Functional diagram of the features our team implemented

Appendix 3: Code Reviews and Responses

A copy of the code reviews, a summary of the most common suggestions, and a response to the reviews can be found in the Box drive for this project within the archive folder and in a subfolder called peer reviews.