Virtual and Augmented Reality for Understanding Changing Ice Sheets

Sofía Sánchez-Zárate*
Columbia University

Manxueying Li†
Columbia University

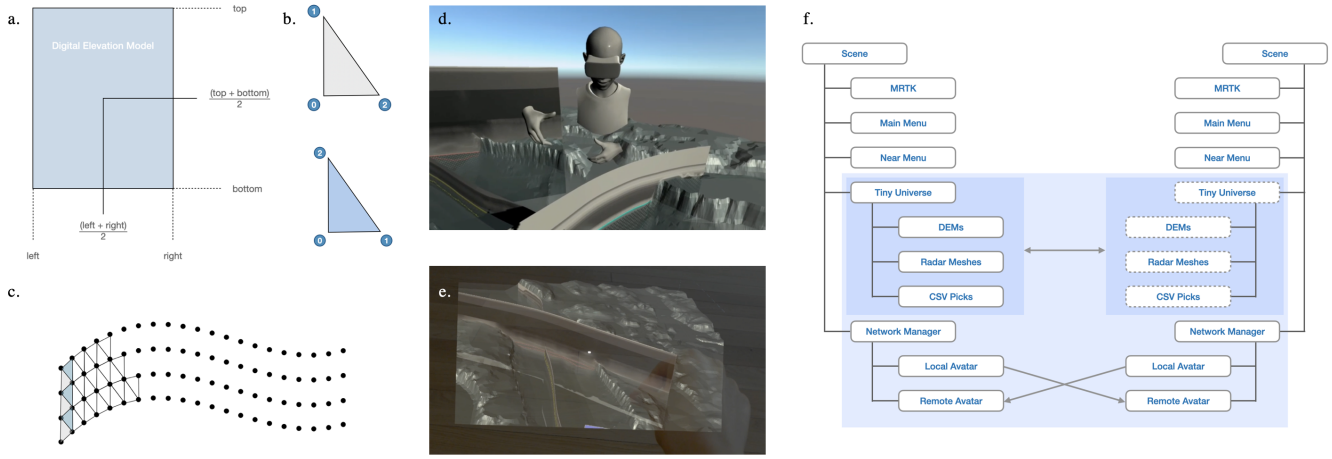

Figure 1: a. Positioning the DEMs by calculating the centroid, b. Inverting trigangle direction for both sides of the radar mesh, c. Visualizing the creation of the radar mesh given flight-path coordinates, d. View of an avatar, DEMs, and radar in VR, e. Bird's eye view of the DEMs and radar in AR, f. Scene hierarchy

Abstract

Ice shelves are an important part of the ice sheet system, as they restrain the flow of ice out to the ocean, and therefore modulate sea level change. One major challenge for geologists is identifying internal structures of the ice on two-dimensional ice-penetrating radar images without further context. This system provides a flexible, three-dimensional method for visualizing radar data on the Ryder Ice Shelf in Greenland using virtual and augmented reality on the Microsoft HoloLens and Oculus Quest.

Index Terms: Augmented Reality, Virtual Reality, User Interface, Microsoft HoloLens, Oculus Quest, Unity [Game Engine], Digital Elevation Model, Radar, Ice Shelf, Ice Sheet

1 Introduction and Prior Work

This project uses virtual reality (VR) and augmented reality (AR) to build an environment for analyzing data collected on the Ryder Ice Shelf in Greenland. This visualization system could help glaciologists understand the ice shelf's structure and the subsequent response of ice shelf surface hydrology.

Prior work was done developing an AR application for the Ross Ice Shelf in Antarctica. "Inside the Ice Shelf" by Boghosian et al.[2] utilized a HoloLens to visualize radar and lidar data. This project builds on Boghosian et al.'s work by displaying radar images on curved meshes rather than flat ones to more closely represent the flight path taken by the plane collecting the radar data as shown in Figure 1.b. and c.

*e-mail: sofia.sanchez@columbia.edu
†e-mail:manxueying.li@columbia.edu

Additionally, "The Antarctica Series"[4] by the New York Times is a collection of VR films of ice shelves over the continent, one of which is called "A Shifting Continent." It provides a virtual experience of flying over the Ross Ice Shelf alongside scientists, making remote locations more accessible through immersive science journalism.

2 System

This application was developed on Unity 2019.4.15f1 utilizing Microsoft's Mixed Reality Toolkit (MRTK), Photon Unity Networking (PUN2), and the Oculus Avatar SDK. It was created specifically for the Microsoft Hololens, an AR Head-Worn Display (HWD), and the Oculus Quest, a VR HWD.

2.1 Geographical Data

The data in this project falls into three categories: Digital Elevation Models (DEMs) of the ice bed and surface, radar images collected over different portions of the ice shelf in 2011, 2014, 2015, as well as the "picks" selected as the bed and surface lines stored as comma separated values (CSVs). The DEMs are 3D graphical representations of elevation data over a portion of Greenland created with ArcGIS. The radar images show cross-sections through the ice shelves aerially collected in the aforementioned years.

2.2 Displaying the Data

The CSV selections are plotted using the CSVReader script[5] which iterates through the values, creating a sphere at each coordinate. The lines created by the spheres are shown alongside the radar images within the scene in order to help the user see the general location of the surface and base on the radar as shown in figure 2. This data was also used to accurately place the DEMs within the scene since they did not retain positional data. Rather, the cen-

troid of the DEM was calculated (as seen in figure 1.a) in order to position the object within the scene.

The radar images were added as materials and placed onto their respective mesh as components. The meshes were created using CSV coordinates from the flight path taken by the plane which collected the radar data. These coordinates became the corners of the triangles that composed the mesh[3] in order to capture the curvature of the flight path as seen in figure 1.b. and c.

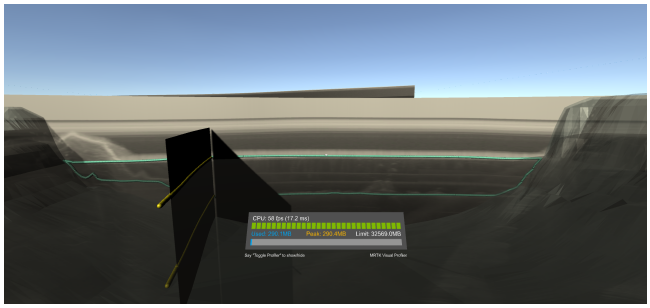

Figure 2: Radar image and CSV picks plotting

2.3 User Interface

The user interface for this application consists of two menus and direct manipulation of the ice sheet. The main menu, shown in figure 3.a contains check boxes which toggle the view of the different objects in the scene (DEMs, radar images, CSV picks), as well as a slider to change their vertical exaggeration. The near menu, seen in figure 3.b, is used for "teleportation" to different view points and can show a dynamic measurement tool. This menu can be pinned to one spot or follow the user's gaze.

2.3.1 Visualization

Direct manipulation can be used to move, rotate, and scale all of the components within the 'Tiny Universe' (figure 1.f) through the use of MRTK's BoundingBox, NearInteractionGrabbable, and ObjectManipulator C scripts. The main menu can also show and hide each object individually, as well as expand and contract the y-axis of all of the objects with the vertical exaggeration slider. The system also "teleports" the user to different vantage points by moving the entire 'Tiny Universe' parent object in relation to the user. All manipulation of this parent object is shown to all users within the same scene through networking, further explained in section 2.4.

2.3.2 Measurement Tool

A dynamic ruler was created to measure the straight line distance between two points in kilometers. The user can grab on to either of the two handles, created using spheres, and a LineRenderer script connects them with a colored poly-line. The Euclidean distance between the centers of the spheres is calculated and displayed on

(a) Main Menu (b) Near Menu

Figure 3: Main Menu and Near Menu

Figure 4: Dynamic measurement tool – "AR Ruler"

both ends with TextMeshPro. Since all of the objects are scaled down, the true distance is restored before being displayed.

2.4 Player Networking

Player networking is developed using PUN2 framework. Upon entering the scene, users are automatically connected to the server and placed in a room. If the user is the first to connect, a new room is created, otherwise the user is placed in a prexisting one. PhotonView and PhotonTransform scripts are attached to the 'Tiny Universe' parent object to enable synchronized movement of the data for all users as demonstrated in figure 1.f. Ownership is transferred between the users to allow everyone to manipulate the object.

The Oculus Avatar SDK was utilized to allow users to see the head, lip, and hand movements of other people in the room. All avatar-related input events are serialized into a list of byte-arrays and sent across the network to synchronize avatar actions[1].. Incoming packets are deserialized and recreated on the Remote Avatar object, also shown in figure 1.f.

3 Conclusion and Future Work

This AR/VR application displays ice-penetrating radar data collected over the Ryder Ice Shelf in an immersive and interactive manner, allowing for a better understanding of the internal structures of the shelf. It can be used by several users to simultaneously analyze data as interactions are synchronized over the network. This system can be used both for glaciology research and as a manner of immersing people into remote environments, otherwise difficult to see.

Going forward, improvements include adding an annotation tool, improving the alignment between the DEMs and radar images, changing the measurement tool from directly manipulating the handles to tap-to-place for more convenience and precision, and making the project adaptable to any DEMs and any radar images.

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