A 3D Virtual Environment for Storm Surge Flooding Animation

Maria E. Presa Reyes and Shu-Ching Chen
School of Computing and Information Sciences
Florida International University
Miami, FL, 33199, USA
{*mpres029,chens*}*@cs.fiu.edu*

***Abstract*—In this paper, we present a storm surge flooding animation system using Three-Dimensional (3D) visualization of real life Geographic Information System (GIS) data. Putting together ground elevation with building information provided by Open Street Maps (OSM), we can recreate real life cities (e.g., South Miami Beach in this paper) in a 3D environment. The 3D terrain development and visualization are done with the aid of the game engine Unity. With this tool, learning about storm surge and hurricanes can be an interactive experience. Moreover, since the system more closely portrays a real life environment, visualizing the effects of storm surge can help users study past hurricane disasters as well as possible forecasted hurricane events. For an immersive experience, we connect the system with an Integrated Computer Augmented Virtual Environment (I-CAVE) to give users the capability of navigation through the terrain in a human-scale view.**

***Keywords*-Unity; GIS; storm surge modeling; 3D visualization; digital elevation models; augmented reality**

I. Introduction

A storm surge occurs when the wind produced by a coastal storm, such as a hurricane, pushes water towards the land. The effects of a storm surge are detrimental to the infrastructure, roads, and the lives of the people who reside in the exposed areas. Officials use storm surge to determine who needs to evacuate [1].

Florida is especially susceptible to storm surge due to being the state with most of its major cities close to the coast and low-lying areas. The state has not been directly affected by a hurricane since hurricanes Katrina and Rita struck in 2005. However, Florida has withstood more direct hurricane hits than other states. The higher the population grows in the coastal areas of Florida, the higher is the risk of a hurricane affecting thousands of lives.

Current systems usually rely upon two-dimensional (2D) visualization when trying to show the areas that may be affected or were already affected by a hurricane. A frequent type of presentation that is implemented is a map of the region which makes use of a color-coded system to display which areas are most vulnerable and which areas are safe, such as [2]. Users who are not familiar with the geography of the current region they are residing or the dangers of storm surge might not be aware of their level of risk and make a decision that might be harmful to their lives.

Adding a third dimension gives us a representation that closely resembles the world we live in. The system can be advantageous for educational purposes, as well as spreading awareness to residents who have little to no experience dealing with hurricane-surge flooding [3].

In this paper, we focus on a virtual terrain created by 5h GIS data that covers the southern area of Miami Beach, Florida. Miami Beach is a city that lies about four to five feet above sea level, which makes it particularly vulnerable to surging waves. The Great Miami Hurricane that took place in 1926 caused a lot of devastation and many individuals lost their lives because of their lack of knowledge towards hurricanes. After applying a storm surge animation to the virtual terrain, we can observe how various theoretical hurricanes would affect the city of Miami Beach if they were to happen in real life.

II. System Architecture

The proposed system is built using Unity 3D, a powerful cross-platform game engine useful for creating high-end 3D experiences [4]. While using Unity, we can take advantage of a lot of already pre-built components so that there is no need to build from scratch. The Unity Terrain Engine, for example, is highly praised for being very optimized and easy to customize. To produce a terrain that mirrors the Miami Beach area, we first collect Light Detection and Ranging (LiDAR) data provided by The National Oceanic and Atmospheric Administration (NOAA) website [5]. LiDAR is a remote sensing technology which emits lasers and measures the time it takes for the sensor to detect the reflected light. The benefits of using LiDAR as a method for measuring the elevation are its high-accuracy and cost-effectiveness when compared to some other methods. Now that LiDAR data becomes easier to find, we can take advantage of this technology to build accurate and interactive 3D maps. We import the LiDAR data into Blender, and with the help of the BlenderGIS module, we can create a 3D mesh surface using the Delaunay triangulation algorithm [6]. We import the mesh of the surface into Unity. Then after creating a new terrain, we use the Object2Terrain module such that the terrain can obtain the same shape as the mesh [7]. Now that the terrain represents the different elevation areas from Miami Beach, vegetation and texture are added to the terrain to make it more closely resemble the real life environment. For developing the buildings as well as the roads, we use the information provided by Open Street Maps (OSM). From the OSM website, we first select our area of interest (e.g.,South Miami Beach) and download the file that contains all information (e.g., building footprint, building height, roads, etc.) regarding that area. Then using OSM2World [8], we create 3D buildings and the roads and export them together into Unity. Both terrain and buildings are put together in the Unity environment where we add the components that simulate the storm. A water module from the Unity's standard assets is added to the terrain to simulate the ocean and surging waves. This module is highly customizable. It provides many parameters such as wave frequency, wave steepness, wave speed, and wave direction, which can be easily changed to fit the needs for a storm surge animation. Hurricanes are often accompanied by high winds and heavy rains. Therefore, our model presents a rain animation as well as the movement of the trees through the winds to make the simulation feel more realistic.

III. Demonstration

We demonstrate the process of the storm surge as it affects different areas of South Miami Beach. During a hurricane, we show how the wind pushes the sea water towards the city, causing the streets to flood.

The user has two choices for navigation. The bird's-eye view (as shown in Figure 1) shows an overworld perspective. Having a top level view of the overall scene gives the user a broad sense of how the storm surge is affecting the city. As can be seen in the figure, waves are surging towards the land and mainly affecting the buildings that sit closer to the coast.

Another form of navigation is the human-scale point of view (as shown in Figure 2), where the user can walk around and observe more specific affected areas. The human-scale point-of-view is integrated with I-CAVE for an immersive experience. Integrated Computer Augmented Virtual Environment (I-CAVE) is a visualization and research facility, ideal for presenting 3D virtual environments to a group of people [9].

At the moment, the system presents the visualization of a hypothetical storm surge. Nonetheless, there is potential to connect the system with real data and present a visualization of either a historical hurricane or predicted hurricane in a virtual environment.

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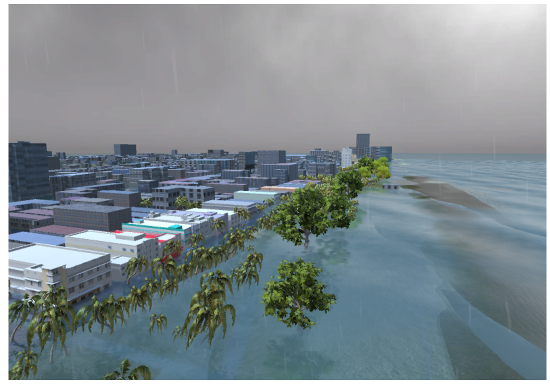

Figure 1. The South Beach 3D model during a storm surge as shown in a bird's-eye view.

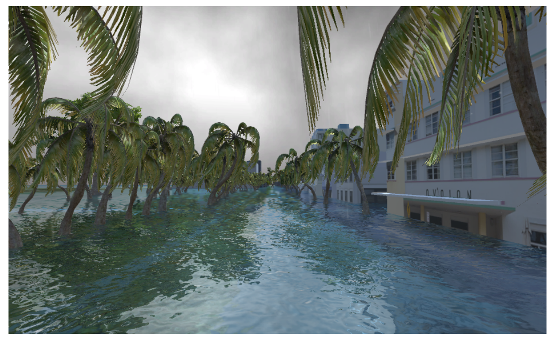

Figure 2. A human-scale level view of the flooded Ocean Drive in Miami.

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