December 23, 2016; Clark’s comments

Lucas

This version is a substantial improvement and near excellent. Some minor issues that I found can be addressed later. You do not have to revise now.

You will receive an “A” on the Final Project.

Clark

**Lucas Tai-MacArthur**

**Visualizing the Past/Peopling the Past**

**Final Project**

**December 19th, 2016**

**Causeway and Canal Modelling in the Bolivian Amazon**

**Introduction**

The visual presentation of the past is an essential activity in understanding other cultures. From enlightenment era paintings depicting Roman life to modern films showcasing the worlds of yesterday, visual media has always provided a window to other time. In the modern day, the power of digital technology has opened an entirely new set of possibilities in displaying the past to present-day audiences. Digital 3D modelling and interactive 3D engines create a more real, reactive world and the birth of widespread virtual reality has given historians more immersive tools than ever.

In the northern reaches of the Bolivian Amazon, native peoples built a hydraulic transportation system which spans hundreds of miles of desolate savanna. In its prime, it was used by the inhabitants of the region to travel on foot and on canoe between centers of population. During seasons of inundation it allowed traversal of floodplains, and in the dry season, the canals kept enough water to allow canoe passage when it was impossible anywhere else. It also served a larger purpose of supply management in the region; these works stored water and fish year-round, in effect stabilizing the native stockpile of resources (Erickson et al. 2009).

A recreation of these earthworks and canals would be congruent with this class as a final project for several reasons. First, it builds on research undertaken in large part at the University of Pennsylvania. Second, I have been personally interested in the process by which societies come together to build infrastructure and being able to take advantage of this final project to explore and delve into this process would be of great benefit.

**Goals**

After discussions with the course staff, I thought about what I wanted to build and then planned the project backwards from that. In the final deliverable, I wanted to be able to showcase the canal and causeway system not in isolation, but in the way in which it appears in the wild. I wanted to build a kilometer scale savanna model with several canals and causeways connecting dispersed forest islands all within a vegetated and accurate landscape. These models are to be placed in the Unity game engine to showcase the construction in a living, interactive way. With this final goal in mind, I decomposed the work into sub-problems which would be independent and easy to tackle. They are detailed below and represent the individual sub-goals of the final project.

1. Create a modular canal and causeway terrain 3D model of terrain. Using this building block, individual sections of a straight canal and causeway can be tiled to arbitrary length across a landscape.
2. Create 3D models of Amazonian forest islands using photographs, archeological investigations, and satellite imagery.
3. Vegetate the above two previous models in a way which is consistent to how actual vegetation populated the area.
4. Create 3D models of relevant objects which were used in the process of creation and maintenance of the earthworks. Ensure that these objects are accurate in shape and size, as well as possessing the correct texture and material.

**Pre-Columbian Causeways and Canals**

Every model in this project is supposed to be situated in the Bolivian Amazon, specifically, in the north of Bolivia. This is a region of seasonally inundated grassland and savanna. Essentially, this region is not the typically tropical jungle that one imagines when they hear the description amazon, but a large flat plain of tall grasses and scrub bush which is periodically interrupted by raised landforms called “forest islands.” The climate is also two seasoned, with an alternating dry and rainy portion of the year (Hasse and Beck, 1989).

To properly model these earthworks, it was necessary to gain a background understanding of all the features, their geographic distribution, their different types, and what they represented for the peoples that constructed them. To begin, consider the canal and causeway. These are the primary methods of transportation between the forest islands. They are long, straight landforms. The causeway is a raised, level path which is high enough to remain dry even in the wet seasons. The canals are long straight ditches with a similar connective feature. In the rainy season, they provide paths by which canoes can move goods from one area to another. In the dry season, their shape and depth trap enough water to allow for transportation by boat where otherwise it would be impossible (Erickson et al. 2009). Canals and causeways were heavily vegetated due to both their year-round dry causeways and their year-round water in the canals.

Finally, we turn to the forest islands. These raised platforms of earth were heavily vegetated because they remained dry in all seasons. It was this stability that led to the peoples of the amazon choosing these areas to build their settlements. The forest islands provide central hubs from which the canals and causeways emanate. The earthworks are primarily connective in nature and connective of population centers (Erickson et al. 2009). Thus, the forest islands are an integral part of the transportation network that the canals and causeways provide.

**Process: Overview**

In general, the process for creating the eventual Unity game objects worked as follows. Firstly, after research and finding some form of basis for the model. Maya 2017 was used to create a digital representation and to texture it accurately. Then, Maya 2017’s pipelining suite created a Unity object and texture which could then be imported into the scene.

**Process: Accurately Creating Modular Terrain**

The first step towards creating a living model of the causeways and canals of the Bolivian Amazon is to accurately model the physical and visual characteristics of transportation networks themselves. That is, to create a basic model of various canal and causeway types which can be used as a building block in a larger system.

The first distinction that is made in the text is between major and minor causeways and canals. Major versions of these works were described as “highly visible as tree- lined features flanked on one or both sides by canals filled with dark aquatic vegetation, which stands out against the grass- covered savanna.” (Erickson, 2009:p.212) It was only major canals which I decided to attempt to create in this project. The second distinction made in the text was about the dimensions of the earthworks. In Landscapes of Movement, Erickson describes the physical form of the causeway and canal is described: “Major Causeways range in width from 1 to 10 m and elevations vary from 0.5 to 3 m tall; Major Canals are comparable in dimensions.” (Erickson, 2009:p.212) As such, I attempted to follow these rough guidelines while using a few images from that text as a guide towards what both the savanna, road surface, and canal interior would look like. (Figures 1 and 2)

My first attempt at a causeway and canal building block produced the following. A trapezoidal road surface and smaller, round bottomed canal (Figure 4). I built a terrain texture based of a photo of the savanna and of a road surface (Figures 2 and 3). I selected a grass texture for the savanna, a dirt texture for the road, and a mud texture for the canal, all off a free textures website (www.texturelib.com) then stitched them together to create one contiguous texture to cover the model. (Figures 5 and 6)

After showing Dr. Erickson these attempts, there were a few pieces of constructive feedback that I used to improve the models to their final form. These were twofold. First, I had placed rocks in the Unity model to simulate rocks buried in the soil. These were removed as no rocks are found in the soil of the region in question. Second, that the original causeway model had far too much distance to transition into the canal, and that the slope between causeway edge and canal wall should be much sharper. This was achieved by shortening the transitional zone and lessening the distance between the two features on the Maya model. (Figure 7)

Finally, I learned that there were two other earthwork types that I should attempt to model. Firstly, a double-wide causeway adjacent to two canals (Figure 8), and secondly, a canoe path without a causeway which was simply a small straight canal which held just enough water to let a canoe glide by. (Figure 9).

**Process: Modelling of Forest Islands**

In this context, the forest islands connect and give purpose to each canal and causeway. The earthworks exist because the forest islands exist and require connection (Erickson et al. 2009). Therefore, they provide an important grounding for the rest of the project. To develop a modular forest island that could be placed in the landscape, I first took a set of aerial photographs from Google Earth (Figures 21 and 22) and traced them in Maya 2017 to generate a polygonal representation of a forest island in unity. Then, using the grass texture from the savanna, texture it. Finally, put it into unity and place it alongside a canal or causeway to figure out the correct scale. (Figures 23 and 24).

**Process: Vegetation**

Accurate vegetation of the models is a key goal for this project. It remains this way because one of the most defining features of the canals and causeways of the Bolivian amazon is the heavy forestation present around these earthworks. In aerial photos, these constructions can be pinpointed because of their thick cover in palm trees and other high growths (Figures 10 and 11). To create this without having vegetation which accurately depicted this would be inaccurate. The information about how the Bolivian savanna is vegetated comes from a survey made by the New York Botanical Garden (Hasse and Beck, 1989). This report focuses on the type of flora found in different subdivisions of the region and can be used to justify the sort of plant models I place on the causeways and canals.

These sources, in addition to a discussion with Dr. Erickson detailed two primary plants that I should focus on. Firstly, *Mauritia Flexuosa*, the Royal Palm would have been grown and encouraged on the year-round dry surfaces of the causeways. I located a free model of this tree in the Unity Store which looked about correct and scaled it based off university arboreal data (UF IFAS, 2014) (Figure 12).

Secondly, between the water and the palms, would be small grasses and scrub brush which dominated the savanna region. A World Wildlife Fund report on the region classifies several plant species which would be found in the region (World Wildlife Fund, 1997). Working off this, I used the Unity Store to locate tall grass and small scrub models which look like those detailed in the report and scaled them based off relevant photographs. (Balee and Erickson, 2006) (Figures 10,11 and 13).

**Process: Tools of Construction**

As recommended by Dr. Erickson, I modelled two tools that were used by the native peoples of the region as basic construction equipment for building earthen causeways and canals, the woven basket and the digging stick. Both were modelled in Maya 2017 and then exported into the Unity game engine. For both items, it was difficult to find real reference photographs of objects in the Bolivian Amazon. Instead, I took educated guesses in both items which allowed me to create accurate models in Maya 2017.

I could not find any digging sticks from the Amazon in the Collections Database of the Penn Museum, but found a wealth of information and photographs of similar items from other areas which helped me create something accurate. Firstly, a literary description of a digging stick (Smith 2015) gave me not only dimensions but a reference to the kind material used (Figure 14). From here, I found a model of an Australian aborigine digging tool (Google Images, 2016) which I used as a reference for a Maya model (Figures 15 and 16). From the description by Smith, I knew that the item would have been made of palm wood, and so I located a palm wood texture (www.texturelib.com) and used it to texture the model before exporting it to Unity. (Figures 17).

For the basket, I found a relevant object which was from the same Amazonian area as the earthworks in the Collections Database of the Penn Museum. I used this as the reference with which to create a model in Maya (Figures 18 and 19). The museum description simply says “Plant Fiber” as the material, with this generic information I located the most similar plant fiber texture that I could find and textured the model with it (www.texturelib.com). I also used Unity’s scaling tools to create baskets of different sizes and shapes (Figure 20).

**Results & Conclusions**

The recreation of historical artifacts, landforms, and systems is a difficult but rewarding process. It takes a keen eye and care for the details of history. From considerations of materials and plant life, to the specifics of how massive infrastructure projects would link together in the landscape, there is much to take account of before we in the present can make an accurate model of the past.

I created three canal and causeway models. The causeway with single parallel canal (Figure 6). The doubly wide causeway with two parallel canals, one on either side (Figure 8), and the single canal canoe path (Figure 9). Second, I selected vegetation for the canal and causeway models with botanically accurate plants in the correct ecological zones (Figure 12 and 13). Third, I created 3D models which are correct representations of two important tools used to constructed the earthworks we have described, the digging stick (Figure 17) and the woven basket (Figure 20). Finally, we create forest islands from accurate space-based imagery of the actual landscape of the Bolivian Amazon to provide a sense of scale and purpose for the rest of the project (Figures 23 and 24).

Time constraints prevent further work this semester on combining the above displays into a larger model of a subsection of the Bolivian Amazon which displays how all the parts individually work together to form a transportation system. Similarly, animation of a human model using the tools was not possible due to deadlines. However, included in this submission is what amounts to a first attempt to assemble the forest islands and causeways together into one coherent scene (Figure 25). To improve the models in the future, one would have to have a better sense of the large-scale connectivity in the region. Showing how people travelled on the canals and causeways by use of foot and canoe would give the viewer a human sense of how these individual parts fit together.

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