Recreating Pre-Columbian Life in the Baures Region of the Bolivian Amazon

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Fig. 1. Modeled inhabitants of Baure in traditional dress. (Clothing by Ikuromor Mabel Ogiriki; basket by Emiliya Al Yafei)

***Abstract*—In an effort to "people the everyday past" using Virtual Reality, we chose the Baures region of modern-day Bolivia in the Amazon basin. The indigenous pre-Columbian inhabitants converted vast wetlands and savanna into a highly productive anthropogenic landscape. We created a digital reconstruction of typical Baures topography, vegetation, earthworks, seasonal changes, and authentic 3D objects to produce a real-time virtual experience for introducing the region, its inhabitants, their material culture, and daily activities. Our emphasis has been on interdisciplinary pedagogy, public engagement, user immersion, scientific accuracy, and cultural relevance.**

***Keywords*—Computer Graphics, Anthropology, Human animation, Cultural Heritage, Archaeology, Visualization, Amazonia, Earthworks**

I. Introduction and Background

Archaeology and Anthropology have relied on the use of a wide variety of traditional visual media such as technical drawings, artist's reconstructions, photography, documentary film, graphs, profiles, and maps to illustrate and engage professional, sponsor, student, public, descendant communities, and other audiences. These disciplines, however, have been slower to embrace newer 3D modeling, virtual reality, lighting simulation, digital games, and human animation due to the perception of high costs, steep learning curves, and a generally conservative attitude toward new technology.

In an effort to "people the everyday past" using contemporary digital technologies, we chose the Baures region of modern-day Bolivia in the Amazon basin. Before the arrival of Europeans the indigenous inhabitants converted vast wetlands, savanna, and forest islands into a highly productive anthropogenic landscape by constructing canals and causeways for transportation and communication, raised fields for farming, and fish weirs and ponds for year round protein which supported large populations for millennia. We created a digital reconstruction of typical Baures topography, landforms, vegetation, earthworks, and seasonal changes based on the archaeological, historical, and ethnographic record combined with contemporary remote sensing, aerial imagery, and GIS. Ethnographic and archaeological museum artifacts inspired the creation of authentic 3D objects and motion capture illustrated the object's probable use. As the landscape was reformed by the activities of humans, its historical ecology was recreated through study of on-site indigenous domestic architecture, earthworks, crops, vegetation, animals, and soils. We produced a real-time "people populated" virtual experience for introducing the region, its inhabitants, their cultural artifacts, and daily activities (Fig. 1, Fig. 2). Our emphasis has been on scientifically-grounded, interdisciplinary pedagogy to support the accuracy and cultural relevance of the enterprise. Recreating a virtual experience of a bygone society is a holistic enterprise. The geographical, ecological, archaeological, historical, and ethnographic context inform the artifacts, processes, and daily life of its human inhabitants. Consequently, in a virtual reconstruction, these considerations must be taken as seriously as the computational development of the representative 3D models comprising the visual experience [1], [2], [3], [4], [5], [6].

Fig. 2. Modeled Baures vegetation with canoes. (Canoes by Emiliya Al Yafei; vegetation by Josh Nadel)

Pre-historic everyday life often left few tangible activity, architectural, or landscape signatures and are difficult to imagine from disparate written accounts or from hand-drawn sketches, often produced with cultural bias, from memory, or from secondhand lore. Examples of pre-Columbian cultures of the Americas often have few remaining architectural structures, and those that remain are mostly exemplified by the monumental architecture of Mexico and the Yucatan and Inca in South America. Beyond monumental mounds in North America, adobe structures in the Southwest, and scattered pre-Columbian village sites, little structural evidence remains of the everyday life of indigenous people before Europeans arrived. Most everyday life of the past occurred outside of the traditional site and within the surrounding cultural landscape of fields, forests, paths, roads, quarries, rivers, and lakes.

Baures in modern-day Bolivia is a pre-Columbian Amazonia region where the indigenous population, the Baure, created thriving communities on forest islands within vast savannas and wetlands [7]. Alternating floods for half the year and drought the rest of the year presented an environmental challenge to the past Baure. They exploited these extremes by creating extensive terrain modifications that included earthen causeways connecting forest islands, canals for water transport, raised fields for crops, and fish ponds and weirs to secure protein. We became interested in reconstructing life digitally to emphasize human creation, transformation, and management of resources, in addition to its monumental scale landscape modification in the Amazon.

Fig. 3. Part of the Baure village with thatched roof houses and traditional construction. (Procedural houses by Youssef Victor; village layout by Emiliya Al Yafei)

Visualizing everyday life in pre-Columbian Baures involves, at the minimum:

- understanding the terrain, seasons, climate, flora, fauna, and how water was controlled and managed through hydraulic engineering.
- researching primary textual, artistic and visual sources of Europeans about the indigenous people that they encountered (and affected), and
- reconstructing possible realizations of daily life from actual pre-Columbian artifacts, earthworks, and archaeological, historical, and ethnographic records.

Cultural reconstruction is an ambitious undertaking to understand what the Baure did to survive and flourish through their social organization, built landscape, and resource management. This holistic view leads to multimedia, immersive, and non-traditional narratives [8]. Our approach is human-centric and lends itself readily to as the creation of a Virtual Reality experience.

The goals of the VR experience include representative 3D models, virtual human animations, and agency:

- A village of typical houses, plaza, gardens, and orchards on a forest island;
- Human inhabitants, spanning gender and age;
- Daily activities, skills, indigenous materials, tools, and artifacts;
- Terrain including native wild, managed, and domesticated vegetation;
- Seasonal hydrology cycles (wet period with inundation, and dry period with flood recession);
- Cultural behavior (oral history, communication, social interaction, entertainment, motivation for activities);
- Movement of humans throughout their aquatic and terrestrial landscape.

Our 3D interactive VR experience intends the user “back in time” as a child observing and learning about the ways and customs of her people in the Baures region. The child gains experience by interacting with people (starting with her family unit); and as experience grows, new options open up. This game-like motivation drives the experience forward in a way that mere curiosity cannot. For example, “what do we eat?” is a question that can open experiences of farming and fishing. At first the user can only watch, but after observing the process she can become a more active participant (e.g., by trying to catch a fish from an inverted basket). These become skills in one's repertoire of everyday life. Needs beget artifacts, which must either be created or bartered; for example, a carrying basket, clothing, a backpack, or a bow and arrow. As experiences accumulate, new options open up, and eventually the user has a broad enough base of knowledge to become an adult. That ends the experience for now; however, a future iteration could expand to include other activities involving finding a partner, raising a family, balancing survival, religion, and community needs, and communicating across family groups and beyond.

Fig. 4. Humans changed the Baure landscape: constructed causeway between forest islands and canals with people fishing and canoeing. (Terrain and vegetation by Josh Nadel and Emiliya Al Yafei)

Achieving these goals requires developing a narrative consisting of short “real-time” vignettes based on everyday life. Since hours of VR immersion are unreasonable, the user's child avatar learns about her world by asking and observing the critical and informative components of her cultural experience. Visual flashbacks which accompanying the narration of a parent or elder can illuminate the annual seasonal changes imposed on the region: floods in the wet season and dry the rest of the year. This annual cycle led to crucial responses, such as aquatic and terrestrial movement through canals and causeways connecting forest island communities, raised fields for farming, and weirs and ponds for trapping and maintaining fish during the dry season. Thus, the child learns about its environment through seeing the formative events and her people’s responses, problem solving, inventions, and innovations.

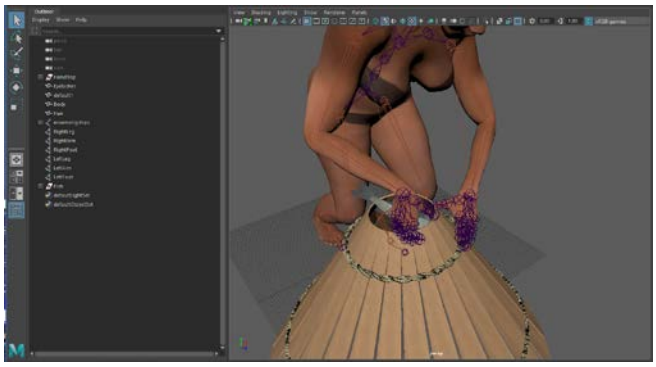

Fig. 5. Using a conical fish trap of wooden slats bound with cord to catch fish by hand. Autodesk Maya screen capture showing articulated hands for animation by motion capture. (Model by Lucien Wang)

The virtual Baure environment is created using Autodesk Maya© for 3D modeling and the UnReal© game engine supports body and object animations and the VR experience. All reconstructions reference original source materials as much as possible, including authentic museum artifacts and personal source material collected on site. Models must respect anthropological issues such as the authenticity and provenance of material culture, the ecology of the landscape, and the human activities that enabled this population to flourish in Pre-Columbian times.

II. Related work

Modeling past architecture is now a popular enterprise for 3D computer graphics [9]. Populating ancient sites with appropriately attired people is desirable but more difficult. Problems to be addressed include accurate human scale and physique, proper clothing, likely accessories, societal roles, population density, interactions, and movement. Achieving these requirements in a real-time interactive experience of a multi-person populated arena demands significant computer graphics resources to drive VR displays.

Some of the earliest attempts include recreations of Pompeii in ancient Rome [10], [11], [12]. These efforts included differentiated people by attire and social class, carried objects, and crowd motions. A reconstructed Uruk village and its inhabitant's daily activities have been modeled in SecondLife and later in Unity© [13], [14]. Everyday population flows were modeled for a small village in Rio Grande do Norte, Brazil [15]. Using the Unreal game engine and existing game assets, Ubisoft created virtual tours of ancient Egypt [16]. Experiencing crowds in a VR environment where one's avatar was perceived and avoided by the virtual inhabitants enhanced the subject's feeling of presence [17]. More general issues in game-like cultural experiences have been explored [18], [19].

III. Methodology

To reconstruct defining elements of the Baure culture, we made it the focus of a highly interdisciplinary undergraduate studio-seminar course that approaches fundamental issues in Anthropology and Computer Graphics. The anthropological perspective focuses on the history, theory, and methods of how archaeology and visualizations of the past are created, presented and used (or misused) in scholarly media (e.g., traditional publications, conference papers, and project databases), and popular culture (e.g., artist’s reconstructions, movies, TV documentaries, museum exhibits, games, the internet, and art). The computer graphics perspective addresses contemporary methodologies (e.g., 3D modeling, animation, VR, simulation, and agent-based modeling) and the challenge to best transform known and often incomplete information into engaging digital realizations. Students with no prior computing, programming, or graphics backgrounds learned to use Autodesk Maya for 3D modeling, MotionBuilder to process motion captures, and the Unreal Game Engine for animation.

In a series of in-class labs and working sessions run by undergraduate teaching assistants, the students first modeled a textured rug, a 3D symmetric pottery object based on a photograph and cross-section, added asymmetric elements such as handles, and then proceeded to model a 3D dugout canoe. Issues of texture choice, lighting, and material appearance were explored both in lecture and in Maya. After gaining enough Maya experience, students began the customized development of their individual project choices. These included stone axes, bows and arrows, hammocks, food preparation tools, musical pipes, baskets, fishing implements, wood and thatch houses, manioc, maize, raised fields, canals, causeways, fish weirs, and fish ponds. The 3D modeling component was mediated by carefully selected background readings, primary and secondary textual and image reference materials, first-hand examination and photography of original artifacts at the Penn Museum, and step-by-step blog entries to document the entire reconstruction process.

We believe that this careful attention to the details of artifact construction yielded substantial pedagogical benefits. First, anthropological accuracy, the provenance, and verifiable sources were paramount to cultural authenticity. These sources included on-site archaeology; ethnographic photographs, technical drawings, and videos; Google Earth for accurate placement of terrain and landscape features; and hands-on manipulation of actual Penn Museum artifacts. Second, the construction process for the physical object came into sharp focus during modeling. Twisted ropes, knotting, holes, weaving, and plant materials became a crucial and detailed part of the 3D process. The importance of this step was initially underestimated. digitally scanned artifacts in 3D do not reveal the thought and skill that went into their actual construction. There were no shortcuts!

We obtained 3D articulated male and female body models from Turbosquid [20], and then modified them to better match the cultural and personal features of the Baure people. Hair, skin tone, faces and clothing were all customized based on primary source material. Clothing, although mostly simple, was produced in DC Suite [21].

Fig. 6. Terrain with modeled fish weir earthworks constructed by the Baure. There is a fish trap basket at the neck of the weir. (Vegetation by Josh Nadel; terrain by Emiliya Al Yafei)

The particular usage characteristics of the artifacts led to student exploration of Maya modeling and animation features well beyond the introductory material. For example, the physics engine was used to model the essential interaction between a human model and the hammock, to behave appropriately when being used or exited. Likewise, physics was used to model aspects of food grinding and processing. Key-frame animation was used to model a woman reaching into an inverted cone fishing basket to catch fish. 3D motion capture of an archer's movements were added to a rigged model of a bow and arrow for accurate hunting motions. Similarly, poling and oaring motion captures were applied to male and female characters navigating the canals in a canoe. Modeling a pan pipe led to investigating the automatic generation of the tones directly from the 3D model. Modeling the extensive raised fields of the Baures region led to the automated procedural generation of the terrain and the cultivated plants (manioc and maize) based on Google Earth imagery.

IV. Results

As objects were completed in Maya, the students had to transfer them to Unreal as part of an extensive culturally and ecologically accurate project context. Most of the models and animations found their way into a complete fly-though of the landscape. The associated video highlights the terrain features: the forest islands connected by human-made causeways and canals; fish weirs and ponds necessary for retaining fish after the wet season; a small village of houses around a plaza (Fig. 3); and the dense vegetation of the Amazon basin. As the camera moves over the landscape one sees the Baure appear, engaged in everyday tasks such as walking on the causeways (Fig. 4), using fishing baskets (Fig. 5) in the canals and weirs (Fig. 6), paddling a canoe in the canal, sitting around a fire (Fig. 1), using a bow and arrow (Fig. 7) and preparing food.

Because all objects are modeled by hand or through procedural methods rather than scanning, much greater attention to material, form, scale, and construction of the material culture of past societies is possible, such as the careful consideration of attaching the bowstring to the bow with a wrapped cord (Fig. 8).

The video was presented to large audiences at two professional conferences in Archaeology in 2017 with positive response (in one case, we were asked to show it twice).

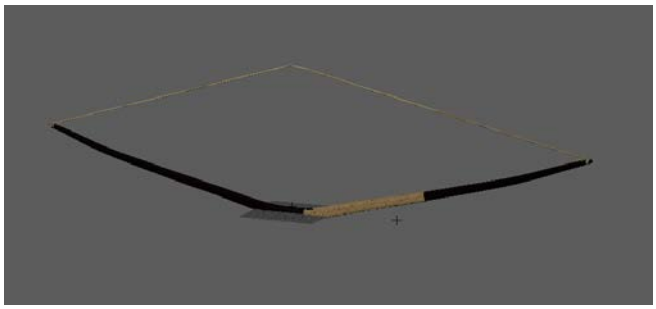

Fig. 7. Modeled bow after an exemplar in the Penn University Museum. The bow is rigged to allow it to bend realistically. (Model by Angel Fan)

Fig. 8. Detail of modeled bow showing the cord windings used to attach the bowstring. (Model by Angel Fan)

V. Future

As Villani notes, “Cultural Presence is the feeling of being and making sense there together” [22]. To establish cultural presence, the experience should present [23] an inhabited space with appropriate and distinctive cultural traits, portraying daily activities independent of the observer, and modeled with scientific authenticity. We have independently, but in parallel, adhered to these principles in the development of the cultural reconstruction of Baures within the context of the local landscape. We endeavored to model cultural artifacts, terrain, activities and human appearance as close as possible to the extant knowledge and anthropological and archaeological assessment of pre-Columbian life.

The next phase of our investigation embeds the VR user as a participant in this culture as a child, observing and questioning the everyday activities she perceives around her. During 2018, work on this interactive and immersive VR component focuses on creating animated Baure characters

with everyday life stories to tell. A voice-activated interface offers hands-free dialogue interaction. User orientation from the VR display guides navigation through the village space. A robust system suitable for pedagogical experimentation and evaluation is anticipated by early 2019.

ACKNOWLEDGMENTS

Many of our students have been involved in this and earlier versions of this work, and in supplying 3D models and animations to the video, including Angel Fan, Sacha Best, Chloe Snyder, Estee Ellis, Jack Gindi, Greg Howard, Sangeun Lee, Tunika Onnekikami, James Prell, Siyona Ravi, Lucien Wang, and Lucas Tai-Macarthur. The VR work in progress is being done by Yanfei Li, Seyoung An, Spencer Webster-Bass, Eli Bogomolny, and Daniel Pitt. This project and others are documented in greater detail on the website http://visualizingthepast.net, designed by Alexis Ward. We gratefully acknowledge support for this work during summer 2017 and 2018 through PURM and SURGG grants from Ann Vernon-Grey at the Center for Undergraduate Research (CURF) and from Yolanda Essoka and the LSAMP program at the University of Pennsylvania.

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