

# Pieces of the Past, Maya Treasure Hunt

A Virtual Reality Game Experience

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## ABSTRACT

We present an educational virtual reality (VR) puzzle game set in an archaeological context. We digitally documented the site architecture and a selection of excavated artefact using structure from motion (SfM) mapping, reconstructed the site during Classic Period (AD 250-900) based on the current state and archaeological findings, and created the natural environment using procedural modeling. With this collection of resources, we created a holistic landscape of the Mayan site of Cahal Pech. The player can link the Mayan ruin between its current state and the past through collecting artefact and evidence, and discover the architectural beauty and historical richness of this site.

## CCS CONCEPTS

• **Applied computing** → **Education; Interactive learning environments;**

## KEYWORDS

Digital humanities, photogrammetry, 3D modeling, educational games, serious games, virtual reality, cultural heritage

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## 1 INTRODUCTION

Cahal Pech is a hilltop Maya city located in the Belize River Valley of west-central Belize. Excavations have identified settlement dating to the Early Preclassic Period (1200-900 BC) [Awe 1992; Ebert et al. 2017]. During the Classic Period (AD 250-900), the site was the seat of an important regional kingdom governed by a dynastic lineage. Our educational game sets stage on this mysterious land that is full of treasures and gateways to the past.

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## 2 METHOD

### 2.1 Data Capturing and Modeling

To balance accuracy and aesthetics, we utilized photogrammetry data to create the architecture of the site (sketchfab link <https://sketchfab.com/chorophronesis>); hand modeling with commercial 3D modeling software to create the historical Cahal Pech model, and procedural modeling to create the natural environment (Figure 1).

*2.1.1 High Resolution SfM of Site Architecture and Artefact.* SfM is a technique that allows for the construction of photorealistic 3D models based on parallax imaging using photogrammetric techniques. In large scale site or site with complex or high structures, unmanned Aerial Vehicles (UAVs) is generally the best choice. However, the use of UAV is subjected to local regulations. In our situation, Cahal Pech prohibits UAV. Although the workflow of SfM is mature and widely-used, we demonstrate the possibility to document an archaeological site by using a single hand-held DSLR camera and sometimes with a help of a mounting pole (27'). Cahal Pech is consisted of 8 plazas, a palace, and two ballcourts. Several large temples also housed elaborate royal tombs. We established a SfM workflow that is efficient, cost effective and versatile. We scanned each structure individually which is not only suitable for hand-held cameras, but also higher in resolution compared to scanning the entire site altogether with UAV. This is important for VR content creation since players have close-up, embodied experience with the site. It is also efficient because in our experience, it usually takes one person about 30 minutes to 1 hour, and 100-300 images to scan a complete structure (20 meter by 20 meter), including both exterior and interior. If the structure is multistory or large in scale, the amount of time and photos needed will increase, but still is feasible. We reconstructed most of the structures in Cahal Pech and some of the artefact to serve as the basis of the VR environment, models concentrated on documenting consolidated and unconsolidated Late Classic (AD 600-900) architecture in the monumental civic-ceremonial core of Cahal Pech. The models were scaled and geo-referenced after generation.

*2.1.2 Hand Modeling in SketchUp and Procedural Vegetation modeling in Unreal Engine.* We hand modeled historical Cahal Pech based on their current states, as well as archaeological findings and documents using SketchUp. We used the foliage tool in the Unreal Engine to procedurally generate trees, understories, leaves and grass.

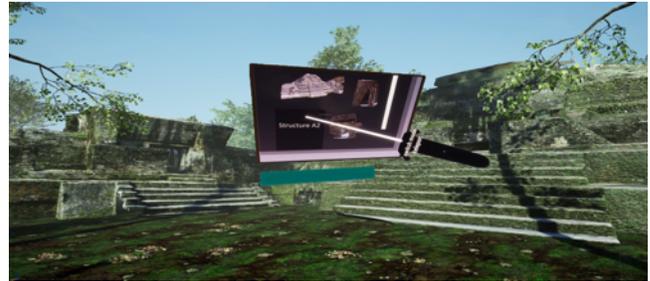


**Figure 1: Structure A2 (front) as seen from Plaza B at the Mayan site of Cahal Pech.**

## 2.2 Game Design in VR

We targeted our game for HTC Vive and Oculus Rift as they allow for whole-body experiences. SfM models usually have excessive polygons, therefore we reduced over 90% of polygon count to maintain frame rate in VR, while still remaining the quality by using high quality texture maps (Figure 1 and 2). Players can physically walk around or teleport, perceive the simulated space using a 1:1 body scale. The player plays as an archeology student in 1950s (before Cahal Pech was discovered), after a long, moist jungle walk, the player finds the site. The player tries to disentangle what happened here by collecting artefact and other evidence that scattered around on site and buried underground. Once the player collects enough evidence, he/she unlocks a story to the past and a piece of structure of Cahal Pech in classic period. Each time the player gets such a structure of the past, he/she needs to match it with the current structure (Figure 2), until the player reconstructs the entire site, and discovers the full story of the hidden secrets. The menu interface was created using a game asset called VR integrator <https://www.unrealengine.com/marketplace/zh-CN/slug/vr-integrator-radial-and-dockable-menus>. Our goal is not to create an archaeology training tool, but rather to create an educational experience where the player can become familiar with the architecture of this particular site and the stories behind the stone walls, through linking the site between its current state and the past state. While we have scaled our architecture and artefact models to be as precisely as possible, we acknowledge the discrepancies, such as in the game story, the player finds the site before it is excavated, however, at that time the site did not look like its current state which is mostly excavated; further, the game storyline is mostly artistic creation based on historical event. We try to avoid possible misunderstandings caused to the player by acknowledging this in our game.

In summary, there are three highlights of the project: 1. We created an educational game with scientifically-constructed and geo-referenced 3D models using structure from motion (SfM) mapping, in combination with models created from archaeological archive. 2. We demonstrate the possibility to document an archaeological site with a single hand-held DSLR camera and sometimes with a help of a mounting pole (27' long). 3. We developed xR (virtual reality, augmented reality, and mixed reality) visualizations, interaction



**Figure 2: The player matches the historical structure A2 to the current structure; left: structure A2 back; right: structure A1 front.**

techniques, and guidelines to realize an immersive workbench to provide interested lay people with a remote site visit and exploration framework, and researchers with a tool for simply analysis. We have elaborated on 2 and 3 in other papers [Wallgrün et al. 2017a,b]. In this abstract, we are focusing on the first aspects, which is to develop an educational game using the combination of SfM, procedural modeling and hand modeling.

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