Digital Imaging of Artefacts: Developments in Methods and Aims

edited by

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Prehistoric stone sculptures at the Gregorio Aguilar Barea Museum, Nicaragua: photogrammetry practices and Digital Immersive Virtual Environment applications for archaeology

Alexander Geurds, Juan Aguilar, and Fiona McKendrick

Abstract

During the summer of 2016, photogrammetric acquisition was completed on a corpus of more than fifty pre-Columbian stone sculptures idols on display at the Gregorio Aguilar Barea Archaeological Museum (MAGAB) in Juigalpa, Nicaragua in order to create digital three-dimensional copies. Using computer vision, the goal is to analyse and compare these monumental objects and come to new observations on indigenous clothing, body adornment, weaponry, and possible post-funerary customs, in combination with an increased understanding of sculpting technology. This particular practice of sculpting large stone human and animal-like figures represents a unique case in the pre-Hispanic Americas, in light of the presumed absence of institutional political hierarchy in this region and the high volume of sculpture production. The MAGAB houses the single largest collection representative of this tradition. However, hardly any data on the context of these igneous rock sculptures was available until recently. These lacunae provided impetus for some of the research questions of the Central Nicaragua Archaeological Project (PACEN), initiated in 2007 and directed by Dr. Alexander Geurds. This chapter reports on the particular methodological challenges of creating a photogrammetric record of large worked monoliths in a closely spaced exhibit setting, as part of the ongoing PACEN investigations in stone sculpture production and use. We also provide details of efforts to generate a digital museum reimagining of MAGAB, presenting the needed steps from data collection to data presentation, and argue for the potential of Virtual Reality for engaging with existing and new audiences worldwide. To build a digital rendering of the original stone sculpture collection to be enjoyed and fully explored online, all 3D models were imported into the freely available Unreal Engine 4 Editor, a computer game engine tool to design virtual walkable worlds and tell new stories. In keeping with Aguilar Barea's collaborative vision, this archaeological imaging research works together with the MAGAB for purposes of knowledge exchange and exhibit improvement: the digital possibility to be able to freely rearrange massive and anchored sculptures, and redesign the museum to improve object lighting and overall visibility enables new ways to disseminate this unique but rarely exposed collection and its particular history of collecting.

> ‘When the idol was perfect, its mouth was open, into which the blowing of the wind made a mournful, whistling sound, exciting suspicions that it was the incarnation of one of those ancient ‘demonios’ of the Indians. The pious priests demolished it in consequence.’
>
> —Ephraim Squier, 1852

Introduction

In this chapter, we discuss the use of digital photogrammetric recording of a corpus of more than fifty prehistoric stone sculptures on display at the Museo Arqueológico Gregorio Aguilar Barea (MAGAB) located in the city of Juigalpa, central Nicaragua (Figure 1), completed in the summer of 2016. Using computer vision, the goal set was to re-analyse and compare these monumental monoliths and come to new observations regarding prehistoric indigenous clothing, body adornment, weaponry, and possible post-funerary customs, in combination with an increased understanding of technologies involved in sculpting the objects. The large volume of sculptural production combined with the presumed absence of institutional political hierarchy in this Central American region make this particular practice of creating large stone human and animal-like figures an extraordinary case for the pre-Hispanic Americas. Alongside improving archaeological understanding, our digital archaeological project also aims to actively support and advance MAGAB’s efforts in preserving their collection, as well as promoting local cultural heritage valorisation in Nicaragua—a country marked by economic challenges and cultural divisions as a result of a modern history defined by authoritarian regimes and civil war during the 20th century.

In this contribution, the particular methodological challenges of collecting data and creating a digital photogrammetric record of large worked monoliths in a closely spaced exhibit setting are outlined. We also provide insights into efforts to generate a digital sculpture museum reimagining MAGAB, and make a case for the potential of using Digital Immersive Virtual Environments (DIVE) for engaging with existing and new museum audiences worldwide. Finally, we also want to put forth ideas concerning how this digital museum project can benefit existing local and national heritage narratives. In doing so, this archaeological digital imaging research works with the MAGAB for purposes of knowledge exchange and exhibit improvement: the digital possibility to redesign the museum enables new ways to disseminate this unique but rarely exposed collection and its particular history of collection.

Before discussing digital photogrammetry in archaeology and highlighting DIVE´s manifold possibilities for cultural heritage management and museology, we set out how the MAGAB is at the centre of our on-going research. The intrinsic motivation behind the digital stone sculpture collection project flows from how the project relates to this small family-run museum and its founder’s vision of caring for the past.

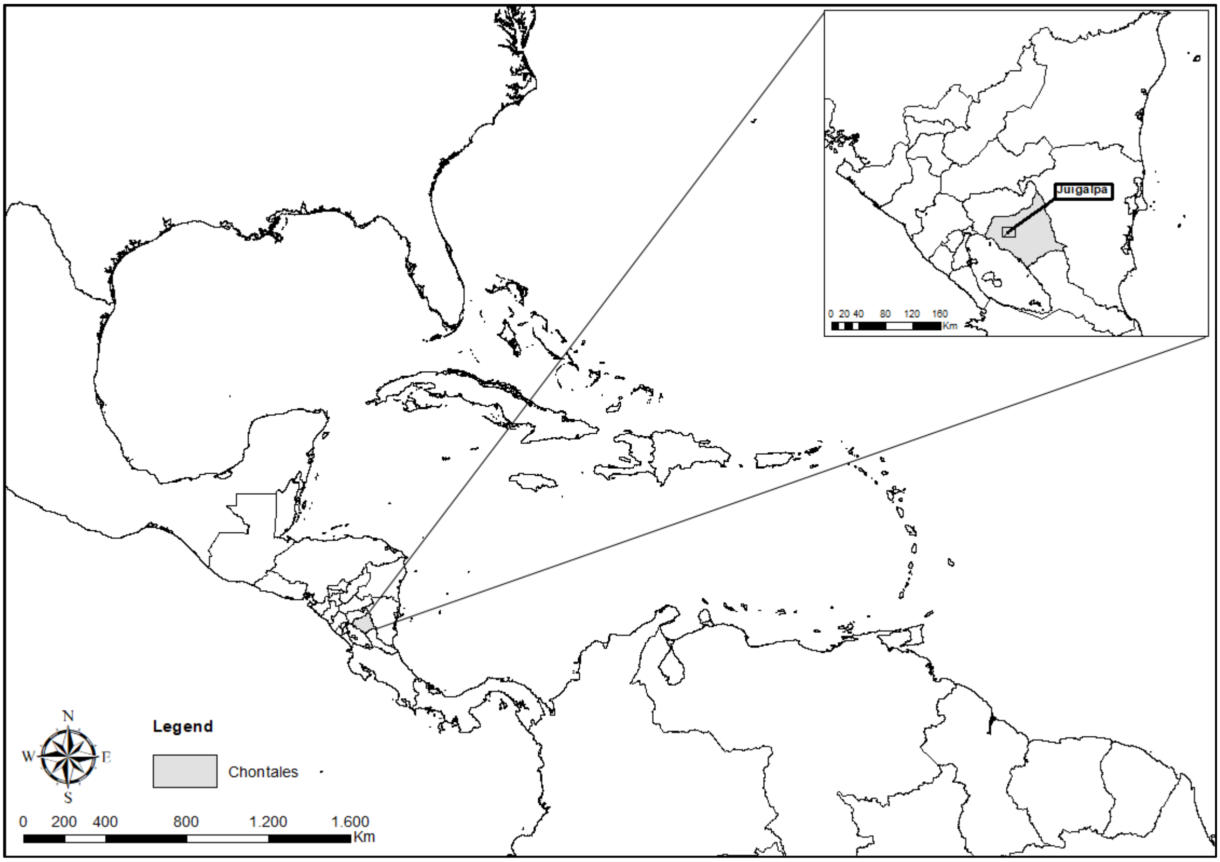

Figure 1. General map of Middle America, indicating Nicaragua, the Chontales region and its capital Juigalpa (map courtesy of Simone Casale).

The MAGAB and its prehistoric stone sculpture collection

The pedigree of the collection is centred around Gregorio 'Goyo' Aguilar Barea. Born in Juigalpa in 1933, Aguilar Barea became one of the protagonists of a remarkable push in promoting local heritage in the Nicaraguan province of Chontales from the 1950s onwards. He is considered the driving force behind the founding of multiple local public cultural institutions in Juigalpa including a zoo, an orchestra, a public library, numerous other cultural organisations, a local history circle or 'intellectual clan', and, most importantly perhaps, a museum devoted to local material culture, whether pre-Hispanic, colonial, or contemporary. He acquired objects for the museum collection from near and far. These donations include dozens of stone sculptures, some of which are several metres in height. Many were donated by ranchers who found them in their lands around Juigalpa. In this way, and through subsequent donations, Aguilar Barea amassed a significant collection of archaeological artefacts alongside the stone sculptures.

After more than a decade of planning and building, bringing together funds and building materials through a form of local crowdfunding *avant la lettre*, the museum opened its doors in January 1967, attracting national attention as well as the presence of several foreign archaeologists, an unprecedented feat at the time. The collection of sculptures was already sizeable and gradually expanded in the years thereafter. However, the majority of the stone sculptures were anchored in the ground in what was originally designed as an outdoor patio in front of the main museum building (Figure 2). The placement of the sculptures was largely in service of the building architecture with three rows of seven or eight sculptures parallel to either side of a stone-paved path leading from the street to the museum entrance, and six larger sculptures facing the street. The spatial result of this is a highly linear 'chessboard' setup (Figure 3), while overall impressive on the beholder, it makes individual appreciation of sculptures challenging.

Figure 2. Photograph showing initial outdoor patio layout. SItuation c. 1970 (photo: courtesy MAGAB).

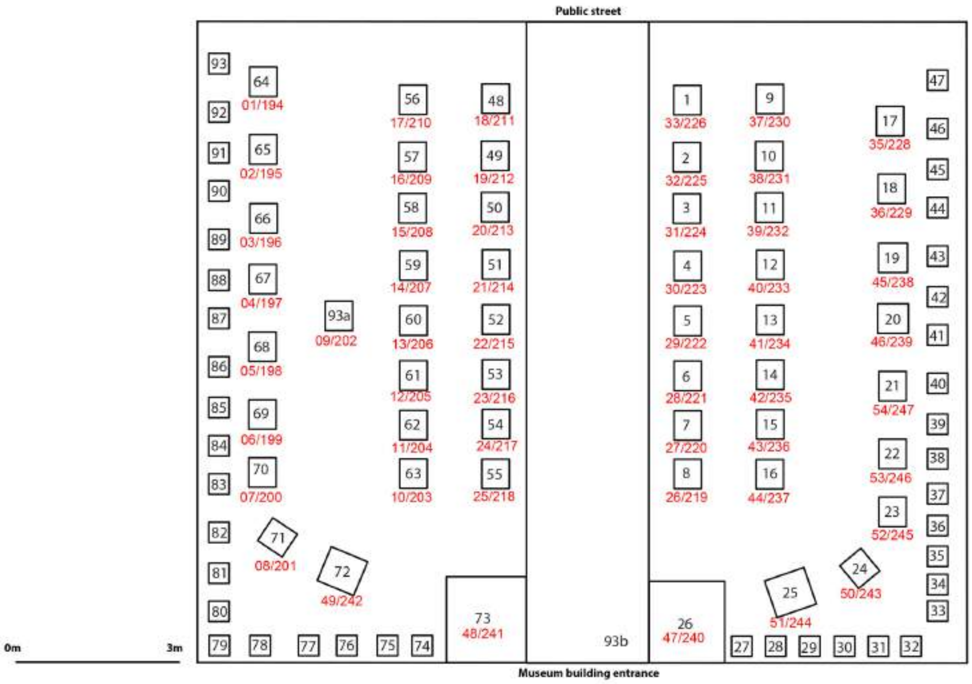

Figure 3. Schematic plan drawing of current patio space, indicating individual sculptures and reference numbers (drawing: Alexander Geurds).

Regrettably, Aguilar Barea prematurely died in a tragic car accident in 1970, abruptly leaving behind a local cultural legacy exceeding that of many national figures in Nicaraguan history. To this day, he remains an iconic figure revered in Juigalpa. The museum, posthumously named the *Museo Arqueológico Gregorio Aguilar Barea*, is visited by all primary and secondary schoolchildren of Juigalpa, visitors from outside of Chontales, as well as a steady trickle of national and international tourists. Since Aguilar Barea's death, the day-to-day management of the museum has been the almost uninterrupted responsibility of Gustavo Villanueva, one of his staunchest collaborators. Since the onset of the 21st century, Villaneuva has gradually transferred this task to a legally recognised friends association. The vacuum left by Aguilar Barea's death led to a power struggle, with the museum becoming a bone of contention in the 1970s and multiple stakeholders bitterly arguing over ownership and authority of the collection, the museum building, and adjoining lots of land. For now, this conflict remains in want of a mutually agreeable solution, and the emotions and legal battles that have made up this conflict perhaps speak to the local importance of this museum and, central in this, its collection of stone sculptures.

Since its inception, the MAGAB has witnessed several modifications to the entrance space where the sculptures are placed. This has included filling up the grassy spaces in between sculptures, roofing the patio area (effectively making it an indoor space), and modifying the original iron fencing separating the patio from the public street (Figure 4). Whilst closing the space negates some threats posed to exposed sculptures, these adjustments have in turn also generated new issues to do with lighting, cement dust, and climate control. Overall, the condition of the stone sculpture collection is continually threatened, and although the museum staff are ambitious and caring, funding for improving the collection's preservation is limited - a stark contrast to the vision and initial community push demonstrated during its founding period.

Figure 4. The patio interior, c. 2010. Note the concrete foundations of sculptures and raised wall facing the public street (photo: Alexander Geurds).

Another issue affecting the stone sculpture, however, originates from the time before the building of the museum. In accordance with amateur collecting practices of the time when the sculptures were transported to Juigalpa by Aguilar Barea and his collaborators (Figure 5), little attention was awarded to physical and wider landscape contexts of these monoliths. In combination with a lack of subsequent archaeological research in the area, hardly any data on the context of these igneous rock sculptures was available until recently. These lacunae provided impetus for some of the research questions of the *Proyecto Arqueológico Centro de Nicaragua* (PACEN), initiated in 2007 by Alexander Geurds. In this sense, the digital imaging work presented here is part of a larger endeavour to investigate how the sculptures were created and preserved. We ask how raw materials were carved, including from where and how these materials were quarried, and the nature of the technologies involved in shaping them. The project also investigates the sculptures' monumental contextual settings: how do the surrounding anthropogenic mounds relate to the sculptures, and can the individuals depicted be linked to those settings?

Figure 5. Photograph showing Aguilar Barea (at centre, with cap) and a group of his young explorers with a sculpture found at the Copelito farmstead (photo: courtesy MAGAB).

The Chontales stone sculptures from an archaeological perspective

Ancient Nicaragua was a diverse cultural landscape. It was a key transition zone in Central America between the Mesoamerican and Isthmo-Colombian cultural areas (Baudez 1970; Drennan 1995; Healy 1980; Hoopes and Fonseca 2003; Lange 1992; Lange and Stone 1984; McCafferty and Steinbrenner 2005). Linguistically, it was a patchwork of speakers of many languages, pertaining to multiple language families (Constenla 1991; Lehmann 1920; Van Broekhoven 2002). When we speak of prehistoric Nicaraguan cultural identities, therefore, these are mostly known through references to ethnicities in 16th-century Spanish written accounts.[1]

In different regions of Nicaragua, stone sculptures were typically set in monumental environments defined by a planned arrangement of stone and earthen mounds serving a communal function. Such monumental sites emerged in several regions of Central America during the last millennium BC and lasted up to the period of the Spanish Conquest in the early 16th century. In the material world of prehistoric Central America monumental stone sculpture played a visible and connecting role in and between communities. In Nicaragua specifically, the use of monumental stone sculpture flourished perhaps from AD 600 up to the Spanish Conquest, but its development and link to monumental

[1] These identities remain complicated to attest archaeologically, as research in Pacific Nicaragua has repeatedly demonstrated (McCafferty and Dennett 2013; Steinbrenner 2010) through the study of 'foreign' pottery decorative motifs and more recently through analysis of pottery technology.

architecture is hardly known. We are unable to evaluate what role sculptures played in these complexes and it remains obscure how these monumental centres figured in regional settings.[2]

The regional investigative focus of PACEN is in the geographically diverse area of central Nicaragua, where the stone sculptures were procured, fashioned, and placed in communal ceremonial settings. Given the transitional geography in this region, it is thought that societies here were culturally related to both the Caribbean tropical forest lowlands towards the east, as well as the drier and volcanically active region around Lake Nicaragua and the Pacific coast to the west. Geographically, central Nicaragua is best described as a bridging zone between on the one hand the fertile soils and freshwater lakes of the Pacific coastal areas, while the other side is defined by the remnants of volcanic ridges separating central Nicaragua from the wide lowland expanses of the Caribbean to the east and northeast (Figure 6). Central Nicaragua itself is geomorphologically marked by Tertiary volcanic rock (Ehrenborg 1996) featuring abundant basalt and andesite outcrops used in the production of these sculptures.

Accordingly, the archaeological record shows significant differences to the Pacific in terms of settlement pattern across the landscape, domestic structures, as well as public architecture. Until recently, the prehistory of central Nicaragua lacked chronological precision and relied upon a rather crude categorisation by the Western explorers who travelled the region in the second half of the 19th century (e.g. Belt 1874; Boyle 1868; Pim and Seemann 1869; Squier 1852). Entire archaeological periods still remain undetected, including the initial peopling during Paleoindian times (2000–500 BC) as well as the transitional period at the onset of the Spanish colonization (*c.* 1522–1600 AD). For now, the earliest pottery types in central Nicaragua have been associated to materials from the second half of the last millennium BC and ranging up to the early part of the 16th century AD (Gorin 1989). What little we know of the prehistory of central Nicaragua points to hunter-gatherer and horticulturist societies gradually spreading across the geographically diverse landscape and subsequently developing monumental practices including earthworks and anthropomorphically-carved monoliths, as documented by the Spanish when they arrived in the region in the early 1520s. By then, the use of stone sculpture in combination with monumental public architecture was vibrant and probably widely dispersed across central Nicaragua and neighbouring regions. This we can conclude on the basis of the presence of stone sculpture preserved in museum collections throughout Nicaragua. This pervasive use demonstrates that these objects formed an integral part of the indigenous social world. Anthropomorphic sculpture occurred along the Pacific coast, on the interior lake islands, and in the tropical lowland Caribbean region (for an overview see Haberland 1973). This indicates that those who commissioned the sculptures not only used them to increase community coherence, but also to proverbially ‘fix’ particular regional memories and histories by means of the hardness of the sculptures’ basalt.

[2] Some of these questions have led to pioneering work worldwide on the relationship between settlement context and stone sculpture in prehistoric Western Europe (Robb 2009), the Greek Neolithic (Nanoglou 2008), and parts of prehistoric Mexico and Costa Rica (e.g. Cyphers 1999; Holmberg 2005).

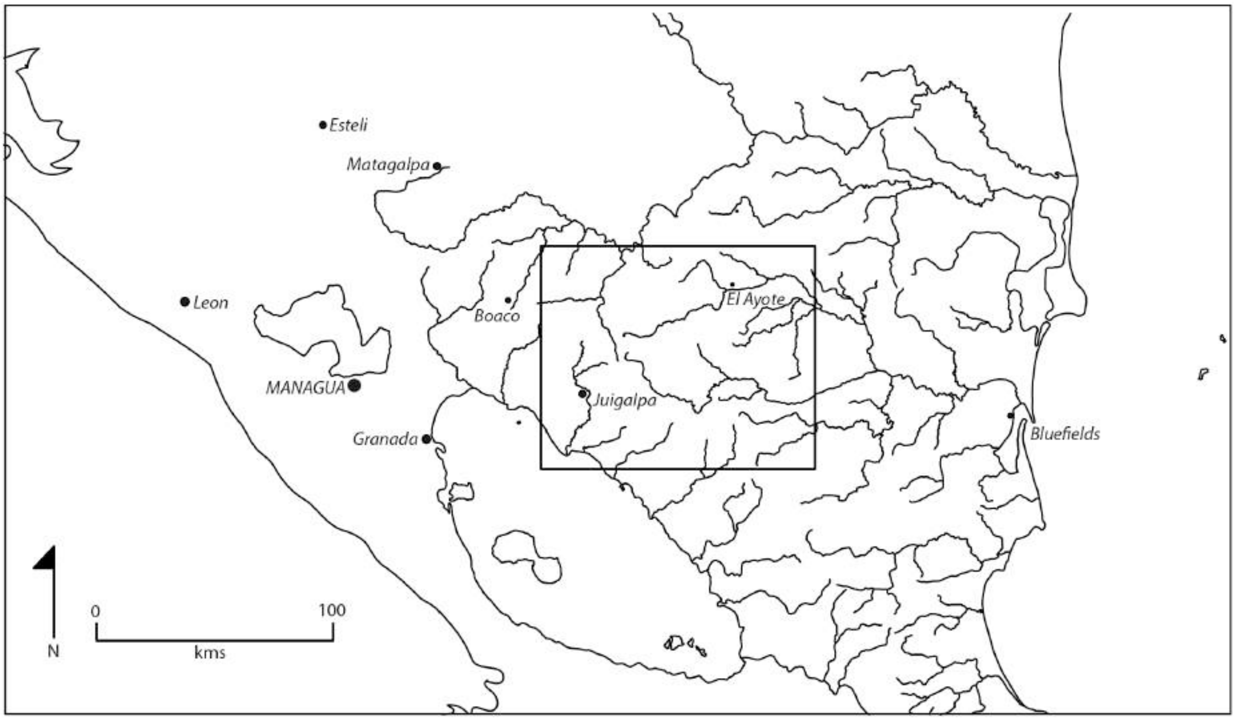

Figure 6. Map showing central Nicaragua depicted by the indicative rectangle. Note watershed division between Lake Cocibolca and the Caribbean Sea (map: Alexander Geurds).

Two principal focus areas are traditionally defined for Nicaragua: the Chontales region, and a second region in Pacific Nicaragua that includes the islands of Ometepe and Zapatera. Historically, the Zapatera island sculptures have received most attention, likely due to the proximity of the island to the Colonial period capital city of Granada. From the 19th century onwards, a mix of clergy, adventurers, and early scholars reported on, sketched, published, and removed many of these Zapatera sculptures. More recently, archaeology has taken a renewed interest in the island context of these sculptures.

Overall, the sculpting of large figures in bas relief on monoliths adheres to a wider shared preference for a style that can be characterized as ambiguous. Certainly present is an emphasis on the human body combined with renderings of animals and supernatural creatures, albeit in forms that are often hard to interpret. This combination of sculpting the human body in conjunction with the (super)natural world may index stages of transformation. The technology involved in quarrying the monoliths varies from heat-induced fracturing of individual polygonal columns from extrusive basalt outcrops to the extraction of entire monoliths from exposed sections of andesite. Some level of labour organisation is presumed in the extraction and transport due to the considerable mass of most monoliths, measuring up to five metres in height and weighing several tons each.

Despite their significance, the monumental stone sculptures have stood silent in much of the regional scholarly analysis, generally relegated to a separate treatment from a classificatory or iconographic perspective. Partly responsible for this was the scarcity of their systematic archaeological documentation (but see work by Navarro Genie 2005, 2007), a condition that has for example led to museum panels devoid of any specific contextual information for the sculptures on display. Within this limiting setting, stone sculptures in Nicaragua were used to construct public memories through the formation of local museum collections (Whisnant 1995). On the basis of these collections, existing studies on sculptures have focused on stylistic descriptions, emphasizing style coherence and outlining iconographic aspects such as clothing, weapons, and animals (Baudez 1970; Falk and Friberg 1999; Haberland 1973; Richardson 1940; Rigat 1992; Thieck 1971; Zelaya-Hidalgo et al. 1974).

In response to this scarcity of sculpture data, PACEN designed exploratory research to detect and record sculptures and fragments thereof in close context, leading the documentation of several dozen previously unknown sculptures (Geurds 2010; in press), to add to the existing body of knowledge on this sculptural tradition unique to the archaeological landscape of Nicaragua.

Scanning the museum's stone sculpture collection

Digital documentation of the known stone sculptures on site at the museum was, however, complicated by a number of challenges. As a method to generate digital 3D models by taking well-framed photographs from various angles, digital photogrammetry by definition heavily relies on the liberty to freely position the photo camera anywhere inside the given space. MAGAB's interior architecture, however, imposed several restrictions on photogrammetric data acquisition. On one hand, the mentioned 'chessboard' setup of the stone sculptures with very limited space in between, combined with the fact that all sculptures were anchored in the ground, called for new Structure from Motion (SfM) strategies. With little space to move the camera between the sculptures and without being able to move the sculptures or the museum wall, in order to capture the maximum extent of a sculpture's geometric structure, every possible camera angle had to be used to assure sufficient overlap during the posterior processing of the photogrammetric data (Figure 7). On average, 60 high resolution photographs including a scale bar were taken with a 21.1-megapixel Canon 5D Mark II on a Manfrotto tripod.

Figure 7. The photogrammetry work process, showing Juan Aguilar. Note the limited room for positioning (photo: Alexander Geurds).

Alongside the spatial factor, we also had to account for particular lighting conditions. The roofing of the patio had significantly reduced the amount of natural light inside the museum building. Consequently, a mobile lighting system was installed and all photographs had to be taken with long exposure times to compensate for the scarcity of available light as well as the almost closed camera lens iris required to guarantee full depth of field. A CamRanger remote control and image preview system in combination with an Apple iPad were used to remotely trigger the camera to avoid vibration and shaking during the long exposure times as well as to immediately check photograph quality on the larger computer tablet screen. Raising the ISO number to make images brighter and/or shorten exposure time would not have been favourable because so-called colour noise, a visual distortion, in the photographs would have diminished the overall quality. In general, the camera settings revolved around an aperture value of 22 (f/22), an ISO number of 200–400, and an exposure time around 1 second.

Despite these challenges imposed by the museum's interior architecture and the arrangement of the collection, all steps of the photogrammetric capturing process could be carried out by one person with the aforementioned adjustments in place. However, all data collection had to be completed in one month. Strict time management as well as occasional assistance from other PACEN members helped complete the photo scanning of 52 stone sculptures within the available four weeks. Especially with regards to the time-consuming repositioning of lights and camera for each photograph, the time saved by working in a team raised the quality of the 3D models since more time could be invested to meet the best possible photographic quality standards and thus later allow the production of high resolution textures without shadows or blurriness.

In an effort to reduce long computation times later, a telescopic background system was used to create a large white backdrop behind each sculpture (Figure 8). In doing so, a stone sculpture could be visually isolated from all neighbouring sculptures, which in turn made placing a digital mask on each photograph in Adobe Photoshop significantly easier (Figure 9). This way, the photogrammetry software would only concentrate on a particular stone sculpture and avoid unwanted rendering of other sculptures.

Figure 8. Use of telescopic background system (photo: Roosmarie Vasclamp).

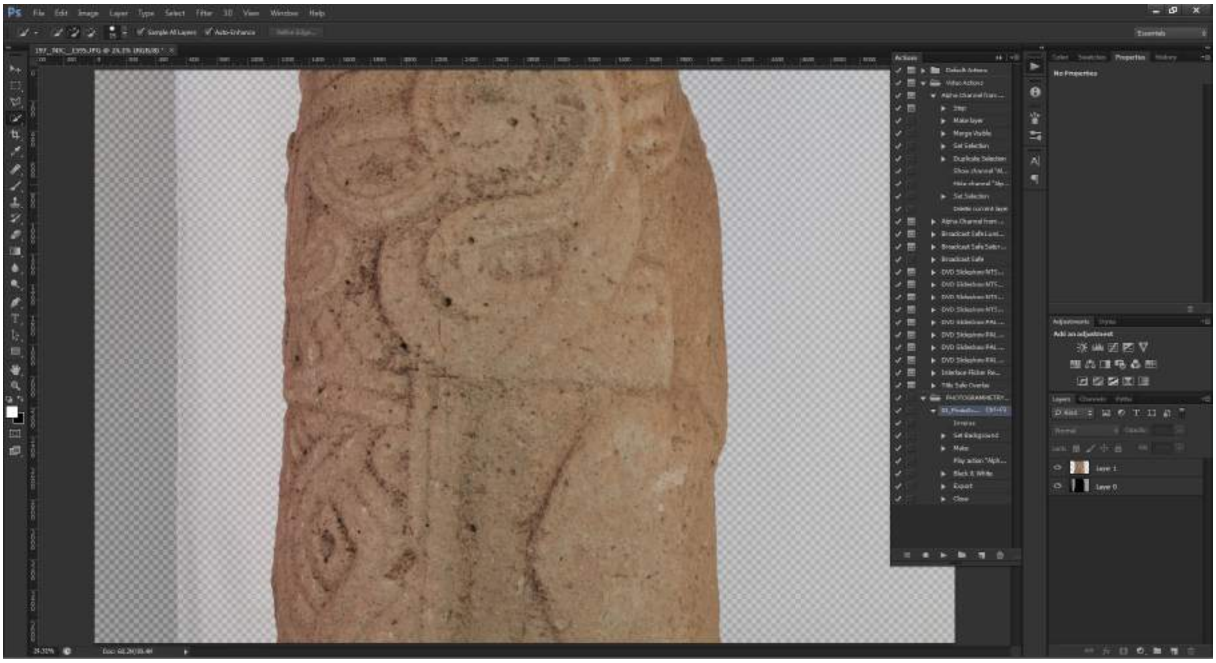

Figure 9. Screenshot taken by Juan Aguilar showing isolation from background in Adobe Photoshop.

As a precautionary measure, photogrammetric data of selected stone sculptures was sent via the remote desktop software Teamviewer from an iPad to a PC in Europe with larger computer resources. This step of performing a quick rendering of a complete model was necessary to detect errors in camera alignment or potential gaps in the geometric structure due to the possibility of insufficient overlap between photographs. After this error analysis, new photos could be taken on site in Juigalpa to fill the gaps (Figure 10).

Figure 10. Recording the sculptures from particularly cramped positions (photo: Alexander Geurds).

Towards the end of the four-week data collection phase in Nicaragua, the idea to rebuild the stone sculpture collection in digital space came forth out of on-site discussions. In Agisoft's digital photogrammetry software Photoscan Pro, all 52 digital 3D models were generated (Figure 11), producing around 34.84 million faces per sculpture and 1.812 billion faces for the entire collection.[3] The high number of faces is necessary to maximize the accuracy of the digital copy and to digitally preserve the details of the sculptures' carvings.

The most promising results were achieved by importing all 3D models into the freely available 3D post-processing software Meshlab. Its *radiance scaling shader* adds a high contrast filter to the 3D mesh, which makes even minute depressions on the geometric surfaces clearly visible (Figure 12). In combination with the high face number, and without the distraction of the current stone-coloured texture, all carvings on the sculptures became easily identifiable, which is of particular interest for iconographic analysis (Figure 13). The ability to reposition a virtual light and to capture and export snapshots taken from any angle provides iconographic analysis with the ability to produce high-resolution images for study and publication.

In the absence of physical weight and dimensions, and without the disadvantageous circumstance of museum artefacts being completely immobile, the stone sculptures in their digital form enable new kinds of scientific observations and measurements. Furthermore, the way to conduct these analyses changes by the simple fact that archaeologists do not need to be on site in the field. Pressure to complete archaeological documentation in a certain period of time is partially removed and digital photogrammetry presents itself as a complementary method to analyse artefacts remotely.

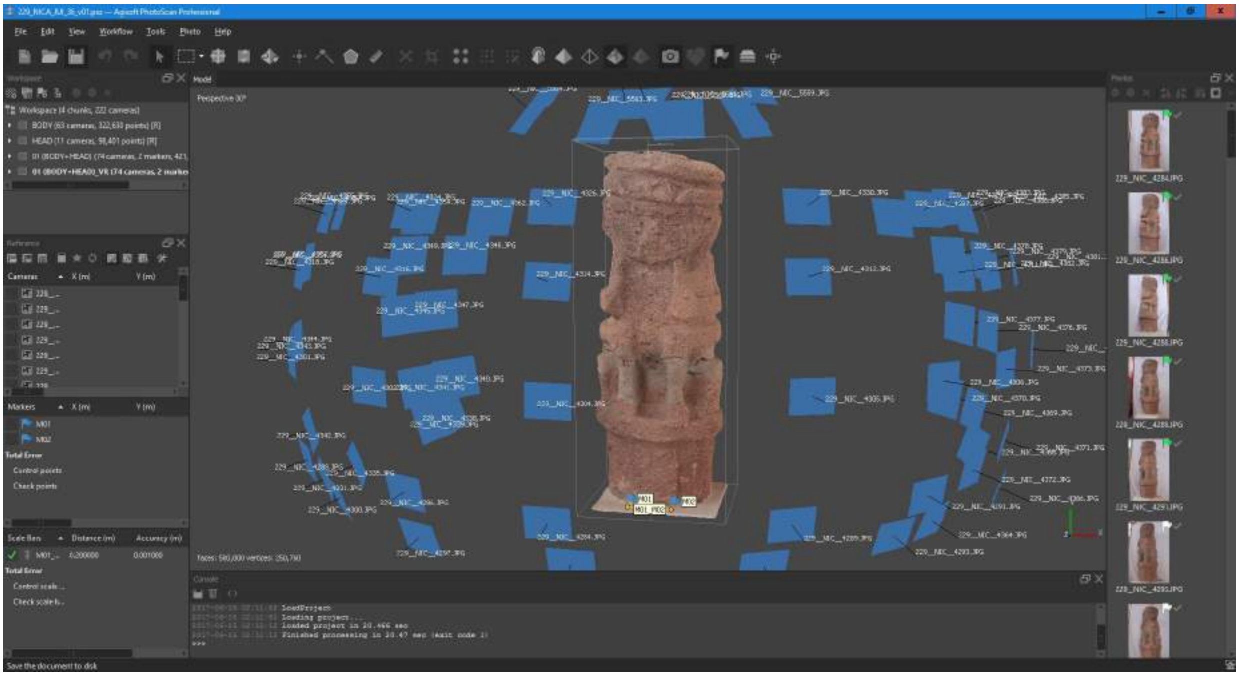

Figure 11. Screenshot taken by Juan Aguilar showing the work process in Agisoft Photoscan Pro.

[3] Another term for 'face' can be 'triangle' which is the smallest two-dimensional unit of any 3D mesh, consisting of at least three connected vertices.

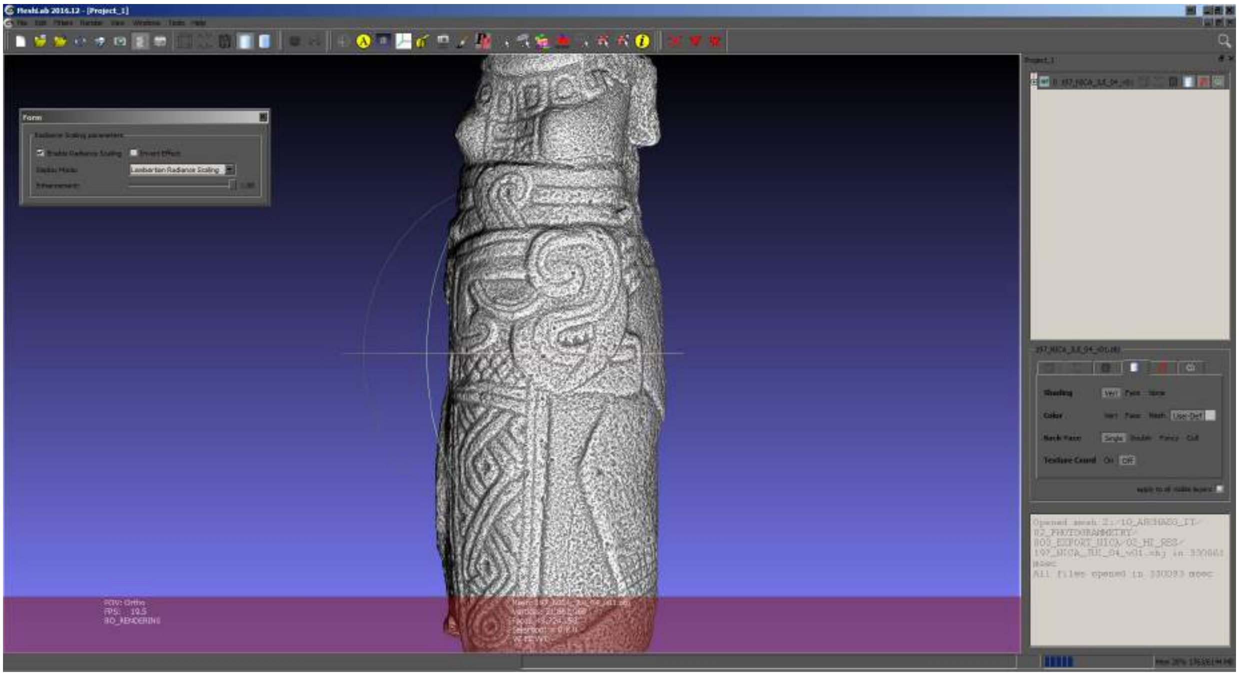

Figure 12. Screenshot taken by Juan Aguilar illustrating the possibilities of object radiance scaling using the Meshlab software package.

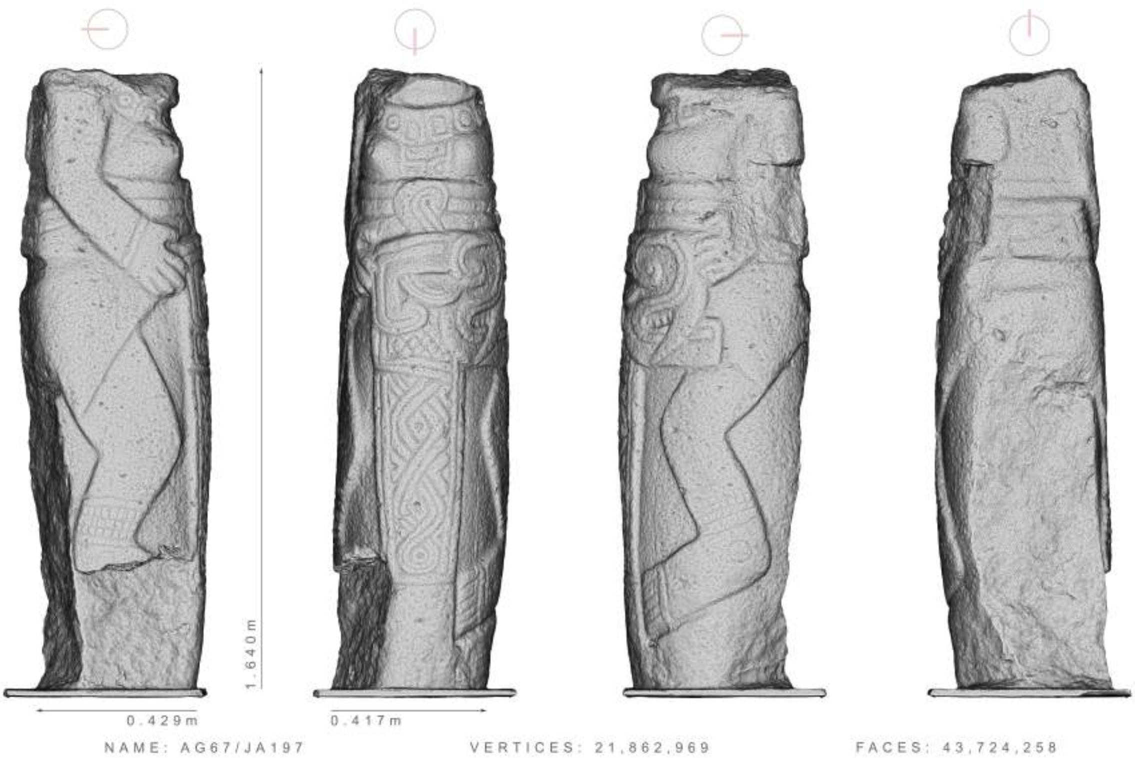

Figure 13. Example of rendering of sculpture. Note the high degree of detail. Rendering by Juan Aguilar.

Public engagement

These preliminary results seem primarily to benefit an academic audience, by providing resources for further research. However, since the first generation of a 3D model, the question arose if there was potential to do more with the data. Not only had PACEN the means to re-analyse the sculptures, but the detailed digital copies represented an opportunity to engage project members with questions of cultural heritage preservation and promotion. Should our role as archaeologists merely be limited to scientific analysis? Perhaps in using the sculptures to ask questions about prehistoric regional identity, we were at risk of neglecting their social context and meaning to current populations. The special case of Nicaragua's history and how heritage is seen and negotiated impelled the project to rethink both how results might be presented, and with which audiences in mind. Engaging public audiences with these materials is underpinned by an understanding of national as well as local recent history.

Since the middle of the 20th century, Nicaraguan history has been marked by political fragmentation and various forms of economic and cultural exploitation (cf. Babb 2001; Chavez 2015). As part of this traumatising process, multiple efforts of cultural negotiation and policy making have transformed historical awareness, and repeated efforts to redefine priorities and values in culture have thereby increased the potential to engage audiences with indigenous archaeological heritage (Whisnant 1995). These cultural policies build on the legacies of the colonial epoch and its relationship to the indigenous presence. The 16th century brought formal Spanish and informal British colonisation and the decimation of indigenous demographics. After independence in 1821, there followed a period of westernisation that reinforced colonial structures but were based on US cultural ideals, which culminated in the 20th-century cultural repression of the Somoza regime. After the Sandinist Revolution of 1979 and its ensuing Contra War, a period of destructive civil conflict took place that still resonates strongly in civic society. Each of these periods announced yet another programme of cultural reforms.

In such a national history, realisation of indigenous identity does not equate to national or regional identity. With important regional exceptions, most people do not self-identify as indigenous in Nicaragua. Similarly, people place intrinsic value on archaeological sites and have local knowledge of ruins in a practical sense: as a source of building materials, yet as something of a delicate nature that they would not want damaged or destroyed. As a result of this ambiguity and the twists and turns of Nicaraguan history, knowledge about prehistory is difficult to access, often not valorised, and considered alien to many.

This historical context, while destructive in many ways, makes Nicaragua a pressing case study for studying the role of indigenous archaeological heritage at both governmental and local levels. Throughout the many national programmes and policies, its prehistoric material culture continues to take up a central place. At the same time and paradoxically, local valorisation of precolonial heritage research remains poorly defined.

In focusing on public engagement in archaeology, we make reference to a growing body of work that is concerned with the role of the past in the present and which reports on archaeologists embracing collaborative approaches in their discipline (e.g. Richardson 2013; Skeates et al. 2012; and the journal *Public Archaeology*). Such initiatives focus on stakeholders who maintain ties with the archaeological heritage being studied. Examples of such collaborative work ranges from increasing research communication and involving stakeholders, to outright co-design of research projects. In designing this project, we ask how can such approaches take form in countries with a recent history of repression and internal armed conflict? Which methods might generate lasting impact on archaeological research in societal settings where national heritage priorities are repeatedly redefined? Lastly, we are also interested in examining whether digital imaging innovations in archaeological knowledge production can contribute to sustainable heritage valorisation in such culturally fragmented surroundings.

Digital Immersive Virtual Environments

One way to define a possibly successful strategy for public outreach is to look for ways to meet the public on platforms already used by general audiences. In recent years, we have seen digital immersive virtual environments technologies, or to put it in more general terms, technologies that reproduce 'a sense of 3D', gradually becoming part of daily life and increasingly familiar to wider audiences. It can be argued that the latest consumer product release to help usher in shared familiarity with DIVE and visual immersion is the computer game Pokémon Go. Released in 2016 on mobile devices, Pokémon Go aims to combine the physical world with 3D digital gaming content, thus creating a so-called augmented reality experience.

In contrast to 3D films, where the 3D experience is limited to constantly staring in the direction of a fixed rectangular screen, Pokémon Go and also Google's 2014 release entitled Cardboard, grant the spectator several kinds of freedom to change perspective at any time. Google Cardboard, for instance, allows a mobile device to constantly analyse a viewer's head rotation and tilt movements, which contributes to a fluent and physically correct viewing experience when watching 360-degree photos or videos. This sensory experience increases a person's level of 'presence', an accepted calibrating factor in the evaluation of digital virtual environments (Smolentzev et al. 2017).

In other words, photographs and videos no longer have to be defined by conventional 2D reproduction techniques and a person is free to experience more than just a rectangular-shaped part of reality. However, the point of view (POV) will always be defined by the position of the recording omnidirectional camera. This issue of bodily movement is addressed in augmented environments such as Pokémon Go, which uses a GPS signal and the mobile device's built-in camera to blend computer game elements with the image of real locations on the device's display. These examples show the increased potential for interaction between the physical and any given virtual environment. This is made possible by hardware and software tracking a viewer's movements and position, and using this data as a reference to correctly display digital content from a specific viewing angle.

Archaeological recording and use of digital 3D

For the past fifteen years or so, these developments in the entertainment industry have increasingly informed object-focused disciplines such as archaeology, art history, and museology on the integration of virtual reality. Since the advent of various 3D data recording techniques at the turn of the millennium, many archaeological sites, excavation trenches, architectural elements and structures, sculptures, and small finds around the world have been 3D-scanned either by using a laser scanner, structured light scanner, or digital camera, whether in the air, on the ground, or underwater (see discussion in Sapirstein and Murray 2017).

After the 3D recording stage is complete, the subsequent activities also need specification. The required methods and techniques to visualise, improve, or expand analysis and disseminate digital archaeological content are therefore also increasingly under consideration (Kersten and Lindstaedt 2012). In most cases, satisfactory solutions revolve around the two-dimensional representation of three-dimensional data on a computer screen, given the worldwide presence of flat displays and traditional one-dimensional viewing habits. This flattening of 3D data in combination with both a viewer and a (mostly immobile) visualisation system, however, dramatically reduces the possibility of gaining more information about a specific 3D-scanned archaeological object or context. With the sole option on the computer screen of rotating and/or zooming in on an object with a mouse to get 'a sense of 3D', the paradox of current digital 3D representation becomes obvious.

In our project in Nicaragua, we wanted to move beyond the discussed 2D representation of 3D and use or adapt the technology and concepts first widely distributed through Google Cardboard or augmented reality computer games like Pokémon Go.[4] Therefore, the creation of a fully walkable DIVE museum with the help of the freely available video game creation software Unreal Engine 4 Editor, by video game developer Epic Games, allowed new options for museum design, cultural heritage management and interaction between archaeology and the public in digital space to be explored (Remondino and Campana 2014). In this way, we propose that using a popular video game design software as a new medium constitutes a practical solution to present 3D archaeological data in more appealing and immersive ways than traditional audiovisual productions or printed articles.

Building a walkable MAGAB virtual museum

A virtual museum would be an opportunity to nullify some of the limitations imposed by the architecture of the current museum building. How the stone sculpture collection at the MAGAB is presented to the public is currently marked by two major problems: the narrow spaces between individual sculptures, and, depending on the time of the day and weather, the scarcity of light. In Unreal Editor, the rearranging and lighting of the massive anchored sculptures in a circular setup within a Guggenheim Museum-inspired setting was accomplished without much effort and in a timespan of hours (Figure 14).

[4] Some opinions would argue that there is a significant difference between 2.5D (three-quarter perspective) and true 3D like in computer games, yet the final representation happens on a stationary two-dimensional computer screen which eventually would also render true 3D as 2.5D.

Figure 14 . Screenshot taken by Juan Aguilar of a possible virtual museum, rendered in the Unreal Editor software package. The robot-like figure is not relevant, but a standard feature of Unreal Editor.

An initial compromise that had to be accepted was one of drastically reducing the number of faces for each sculpture model to avoid computer instabilities and allow better render results. As discussed above, a digital stone sculpture model counts a high face number which, in combination with the simultaneous rendering of other sculptures, is not suitable for any DIVE application because of the immense number of computations. Plans to show high-detailed 3D models had to be abandoned, and subsequently the high-resolution textures without shadows played a vital role in adding realism again to the virtual museum (Figure 15). In this regard, computer rendering capabilities define the complexity of the virtual museum.

Figure 15. Screenshot taken by Juan Aguilar showing a possibility for rendering a virtual museum, note increased spacing and alternative 'ceiling' illumination.

A second compromise was the decision to include 3D models with occasional gaps. As described above, some parts of a stone sculpture were difficult to reach and, as a consequence, were hard to photgraph, which resulted in insufficient photogrammetric material for digital reconstruction. These 3D models are incomplete and gaps can only be filled with the help of special algorithms in Meshlab, which can only estimate how the missing structure of the original might look.

Both compromises were needed in order to create a functioning and stable running DIVE experience. As a consequence, the DIVE comes with significant reductions concerning the overall 3D model quality and accuracy. However, the ability for archaeologists to create this DIVE themselves, using freely available software, helps avoid other possible forms of distortion. The rebirth of the stone sculptures as 3D models gives archaeologists the agency to communicate directly and immediately to wider audiences instead of indirectly and with limited decision-making in consultancy roles for film production companies or video game developers.[5] In these latter cases, producers request consultation from archaeologists, resulting in non-specialists deciding which content needs to be enriched with scientific facts and to what degree. In our case, we believe we do not have to lend the Juigalpa sculptures to third parties to see them come to life, for example, as part of the decoration in an entertaining audio-visual product. However, to bypass the unintentional restrictions imposed by the video game design tool Unreal Editor and avoid the situation that the stone sculptures can only be experienced as part of a video game, having a look at what the entertainment industry has produced since the release of Google Cardboard and Pokémon Go helps find solutions.

[5] The subfield of archaeogaming analyses the representation of archaeology in gaming, alongside attempting to conduct archaeological research of video games themselves. One of the initial aims was to analyse and question how archaeological data was portrayed in games (Reinhard 2017). Archaeogaming also takes part in debates on audiences of archaeological heritage (Mol et al. 2017).

An adequate solution to simultaneously combine head-tracking as well as the ability to freely move around in a DIVE through ambulation in the real world (in contrast to a so-called point and click solution) was offered through the Bridge headset, released in late 2016 by US-based technology company Occipital Inc. This head mount is similar to Google Cardboard, but with the significant difference that it is equipped with a laser scanning device, the Structure Sensor (Figure 16). In combination with a mobile device that serves to render and display any 3D content, the Bridge headset allows positional head-tracking and 3D image rendering to be calculated by the mobile device itself. As a consequence, Bridge is not connected by wires to any external rendering computer, which allows for greater autonomy than other positional tracking headset devices. With the possibility to define a viewer's position in physical space and the direction in which they are looking—or, put simply, change the POV at any time—the virtual experience or 'presence' in a DIVE is significantly increased.[6]

Figure 16. The Structure Sensor (photograph: Juan Aguilar).

As a consequence, the liberty to experience a DIVE museum without any physical restrictions not only makes the existing virtual MAGAB museum more real, but it also allows the rethinking and perhaps redefinition of the idea of a museum itself: With so much autonomy in virtual reality, the established idea of putting objects on display in one single place may no longer be the only option when stone sculptures are able to leave the museum building and virtually 'go back to' their place of origin.

Embedding a DIVE museum in the landscape of central Nicaragua

In applications of digital technology for public engagement purposes in archaeology, the goal of method advancement conferred by the new technology must be matched by the aims of improving access and designing outreach strategies. We believe that a series of tailored VR, AR and Mixed Reality experiences using the digital sculptures can enrich the abovementioned needed discussion on contextual information in archaeology as well as address the briefly discussed notion of 'presence'. Ultimately, our aim of outreach should benefit specific audiences of the museum, promote the iconic prehistoric monolithic sculptures, and give archaeological heritage in Nicaragua, including museum collection and sites, greater exposure to aid in their sustainable valorisation.

[6] 'Presence' in relation to 3D virtual environments can be defined as a human sensory reaction to immersion in such environments, leading to virtual objects being experienced as actual ones and having educational and enjoyment purposes (Lee 2004).

When the sculptures were reborn as 3D meshes and visuals, and were freed from the restraints of their museum environment, real or virtual, we decided to display the sculptures in a way that could go beyond the limitations of their current space and position them in an environment that in itself acts a teaching resource, implying or replicating the landscape and sense of space within which the megaliths originally stood (most sculptures used have approximate provenience data). Digital reconstructions allow for the return of sculptures to their original context as part of prehistoric indigenous communities, without fear for the preservation or conservation of the stone originals.

In relation to the potential of outreach to national and international tourism, a few days camping, visiting beaches, climbing a volcano, hiking, or following nature trails can be interspersed with the introduction of an AR experience. In destination tourism dynamics, there is a need for experiences that are natural, 'authentic', and remarkable. Such a demand for location-specific points of interest can motivate the designs of in situ digital reconstructions.

Virtually engaging audiences

We aim to expand the experiential possibilities of the sculpture in the MAGAB through the use of VR and AR, with a series of solutions tailored to the numbers, mobility, and technology of a spectrum of forms of alternative tourism, ranging from adventure and ecological tourism to leisure and educational tourism.

Backpacker tourism characteristically is characteristically travelling in small groups with an above-average preference for mobility and technology (access to mobile devices). In this case, a VR installation within the museum, composed of a headset and relay screen, could act as a primer for nature walking or hiking in the area. A VR experience that integrates the sculptures into a digital landscape would leave viewers excited to find these places and make those connections themselves through landscape exploration. This might further be achieved with an AR component triggered at the original location of one of the museum's sculptures, converting the contemporary natural surroundings into a VR enhanced archaeological landscape, a museum in and of itself.

Local visitors in smaller numbers would also benefit from the VR headset and relay screen installation within the museum. Their local knowledge and familiarity with the landscape might make AR 'place-finding' unnecessary, but since they bring particular knowledge and familiarity with archaeological sites in the vicinity, they are likely able to convert the landscape context of the objects into a mechanism to enrich their sense of place with the museum collection.[7] In this sense, the combination of VR experiences and the museum collection can also enrich the school curriculum with knowledge of Nicaraguan prehistory and its material culture, thus creating an outreach platform for community cohesion and preserving local identity.

In the case of more educationally-interested leisure tourism, larger groups are more likely and the number of persons would make it too time consuming for each person to take a turn with the VR headset. However, this could be remedied by investing in a number of Google Cardboard sets. With each person having access to their personal mobile device, and access to free wireless internet, the experience could be downloaded while perusing the museum.

[7] This sense of actively involving people's experiences can be applied to other parts of the MAGAB collections as well, such as the agricultural history of the region being connected with people's livelihoods.

Nicaraguans in diaspora (immigrant or migrant communities) are an audience that lacks the direct physical contact with the museum sculptures. For them, replicating size, physicality, and spatiality is central to an experience of the sculptures. Here we would suggest using a set of VR Google Cardboard glasses so each member of a large group is able to experience the VR walkthrough from anywhere in the world. There is also potential with VR to show the sculptures as they once stood in examples of likely original settings with a series of layered experiences that give audiences an immersive observation of what the indigenous cultural landscape may have looked like in pre-colonial times.

Finally, in a physical context, the photogrammetry data allows us to produce 3D prints of some of the sculptures so as to give a sense of the texture and weight of the objects that is missed in the purely visual VR and AR experiences. These experiences (both virtual and 3D printed) could serve, for example, in workshops centring on Nicaraguan culture past and present, with customs, performances, food, handicrafts as well as innovation and industry on display.

Conclusions

At some point in the mid-first millennium AD, indigenous communities in central Nicaragua began to quarry and carve monoliths and position them in the landscape at particular locations. These larger-than-life stones carved with anthropomorphic designs became the site of salient identity comparison, functioning as what we could call 'fixing agents'. Relatively minimalist in their carved expression, the sculptures added to everyday life in formal, essential terms. The sculptures were carved with a model in mind but maintaining a sufficient amount of fluidity in the iconography to allow for people to relate across a regional context.

A similar sense of relating to these sculptures is what we are proposing to here. Despite the extensive amount of time passed since their creation, these sculptures maintain the agency to tell stories, and impress and engage audiences. VR approaches offer multiple promising avenues to realize such engagement. In general, approaches to archaeological materials from the past, including archaeology and art history, are increasingly advancing in a process of digitisation. Especially with regards to recording, digital technologies are often deemed an almost non-negotiable signal of improvement. What we have tried to argue here is that the potential for increasing the quality and diversity of recorded artefact details is indeed substantial, but that basic procedures need to be in place to properly assess the feasibility and intensity of the work and its projected digital products. The illustrated case of the corpus of prehistoric stone sculpture in the Museo Arqueológico Gregorio Aguilar Barea has shown both the complexity in photogrammetry recording as well as the potential for mass diffusion through incorporation in virtual reality museum environments.

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