Reverse Modelling and Virtual Reconstruction Project

La Blanca, Guatemala 2012

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Fig. 1 – Ruins of the Acropolis of La Blanca, Petén, Guatemala (Zacarías Herguido Alamar, 2011)

Abstract: In order to continue research in the field of Mayan archaeological heritage, we carried out reverse modelling procedures at the Acropolis in the archaeological site of La Blanca, in the northeast of Guatemala. The aim of this research is to document the technical analysis of Mayan architectural building systems (interpretation and virtual reconstruction of the original appearance) and to be made accessible to both the scientific community and the wider public. Both of these have a further objective: the study and preservation of the archaeological heritage, which also generates programs of cooperation with the development of the community of the region.

We obtained a high resolution polygonal B-Rep model from the initial point clouds, and we projected pictures taken from the original architecture onto this model to add colour information to the geometries. We generated a low-poly model using geometry simplification techniques, integrating the topological information discarded from the original one into a normal map texture.

We also developed 2D images and plans, generating a comparison factor with previous surveys carried out by traditional methods.

The use of such innovative technology in the thorough research of the Mayan architecture allowed us to obtain a maximum level of detail which previous methodology was technically incapable of obtaining.

The use of cutting edge software and 3D technology allowed us also to experiment with new different possibilities of distributing the results, such as the reproduction in virtual reality of the ruins, the reproduction of 3D physical scale models, or idealised models of virtual reconstructions of the Acropolis with accurate detail. With this model we explored the use of real-time rendering software (game engines).

Keywords: Reverse Modelling, Virtual Reconstruction, Mayan Archaeology, Game Engine, Heritage

Introduction

This paper illustrates part of the research works carried out in the first semester of 2012 within a wider project in the field of Mayan archaeology and architecture in Central America, more precisely in the Guatemala lowlands. Specifically, the works consisted of using new technologies being applied to Mayan heritage in order to find new ways of making this cultural legacy accessible, and using the study and research to gain a better understanding and preservation of what is one of the richest heritages of the pre-Hispanic America.

For this project we benefited from the collaboration of the University of Valencia, the Polytechnic University of Valencia (through its University Institute of Heritage Restoration, IRP), and the University of San Carlos of Guatemala, and with the special contribution of professor Alessandro Merlo from the University of Florence. The field works in Guatemala were carried out in spring of 2012, with the use of the use of the 3D laser scan technology for the first time in the project's history. The subsequent 3D reconstructions and other research methods were developed at the IRP (University Institute of Heritage Restoration) installations, at the Polytechnic University of Valencia.

La Blanca Project

In 2004, we had the opportunity of working at the La Blanca project, at the archaeological site of the same name in the Petén department of Guatemala (Fig.1). Since then, and after eight archaeological campaigns, we have carried out several research, documentation, preservation and enhancement projects, all with the involvement of the University of Valencia, the Polytechnic University of Valencia and the University of San Carlos of Guatemala, and mainly funded by the Ministry of Culture of Spain until 2011, through its Exterior Archaeological Projects Help Program.

The project is directed by doctor in archaeology Cristina Vidal and by doctor in architecture Gaspar Muñoz, and it consists of architects, archaeologists, historians, engineers, restorers, tourism and development cooperation experts, and last but not least, the local workforce of the area. The varied nature of the project's participants is a fundamental aspect that allows us to deal thoroughly with all the necessary tasks in order to better understand all the important cultural heritage of this archaeological site, and to make it accessible to society.

The main aim of this project has always been to highlight the importance of these areas of historic heritage, and to help the general public to appreciate and value them, all through the study and analysis of the information we have gathered. In the same way, the application of the laser scanning and 3D reconstruction techniques are focused on obtaining different outputs that will allow us to understand better this Mayan city from a urban point of view, as well as on finding new ways of disseminating this cultural heritage.

The ancient city of La Blanca

La Blanca was a minor city in the heart of the Mayan civilization, in the northern Petén department of Guatemala, located in the Mopan River valley, approximately 1km away from the Salsipuedes River. It was a border city, between the north-eastern and south-eastern regions, and we can say that La Blanca was an

administrative and trading centre, a subsidiary of a major city in the area, which could have been Yaxha or Naranjo.

Its name was taken from the name of the village that exists today about two kilometres away, La Blanca, because we haven't yet found any proof of the actual Mayan name of the ancient city. The village is located around the lake of the same name, and it has a population of two thousand people approximately.

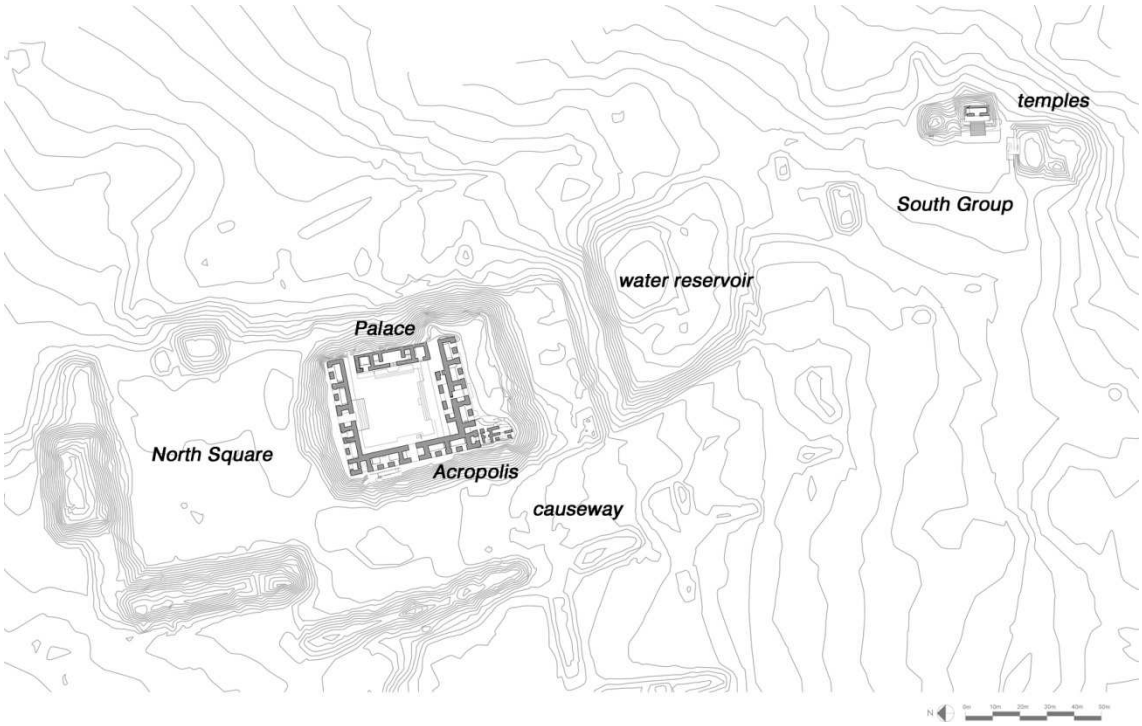

Fig. 2 – Site plan of La Blanca (Zacarías Herguido Alamar, 2012)

The city flourished in the Late Classical period (AD 600-900), and consisted of an urban structure with the Acropolis as its main bastion and dominating the site (Fig. 2). Other notable urban elements were situated around it, such as the great causeway and the North Square which formed the boundary, and the water reservoir, which had an important role at the urban scene and was visible from views towards the south.

With regard to the architecture, the most impressive examples of the buildings in La Blanca are found within the complex of palaces of the Acropolis, and they have dimensions and constructive features that show the skills and knowledge of the builders, as well as the economic capacity and power of the city rulers.

The Acropolis, located within the Great North Square, has its palaces situated around an enclosed courtyard of approximately 36 meters on each side, with the buildings in the north, west and south connected in a C shape, and facing outwards. The eastern building is the only detached one and faces directly into the private courtyard, as the residence of the city's leader, and it is what we call the Oriental Palace.

Following the causeway towards the south, we find the water reservoir, and at the end, the South Group, which is the oldest part of the complex, built in the Early Classic Mayan period (AD 250-600). There we have the pyramid temples, which had a religious purpose, although that remained as a secondary role in this commercial city.

Today, we only can see the ruins of what was once the Mayan city, after being hidden under the Guatemalan jungle for centuries after its inhabitants left it at the collapse of the Mayan civilization. The archaeological works and its recovery didn't start until 2004, and from then on, most of the architectonic structures have been documented, studied, consolidated and protected. Now tourists and locals can visit it and get to know the history of the city and of the people who lived there, all with the help of the visitor centre built by the La Blanca Project, and the new local trained guides.

Laser scanning works

Methodology

Scanning at the site

The first process of the reverse modelling works was the use of the laser scanning we performed at the site. Until that moment, all the surveying works had been carried out with traditional methods, such as being measured by hand or topography. In recent years however, technology has offered us new ways of recording field data, analysing and disseminating it. In 2012, we had the opportunity of using a scan laser in the archaeological site, with the participation of Professor Alessandro Merlo from the University of Florence, an expert architect in this sort of technology and architectonic surveys (Fig.3).

Fig. 3 – Picture of the scanning process at the Acropolis courtyard of La Blanca (2012)

For the survey we used a laser scanner Faro Focus3D S120, a device than measures anything for 360 degrees around, 320 degrees vertically and within a distance of 100 metres. It works with phase shift technology, calculating the distance of each point by comparing the times of the exit signal with the return

one, i.e. the variation of the sent and reflected phase. The laser scan also assigns a colour pixel to every registered point.

Due to the short time we had for this project, we focused the field works on the Acropolis and the Oriental Palace within it. We carried out a total of 9 scans for the Acropolis courtyard and 26 more for the Palace, obtaining approximately 1.350 million points' worth of data, with a good range of coverage and detail of all the buildings in the Acropolis. So, in the case of the Palace, we could obtain a more thorough study of the reconstruction of its original morphology.

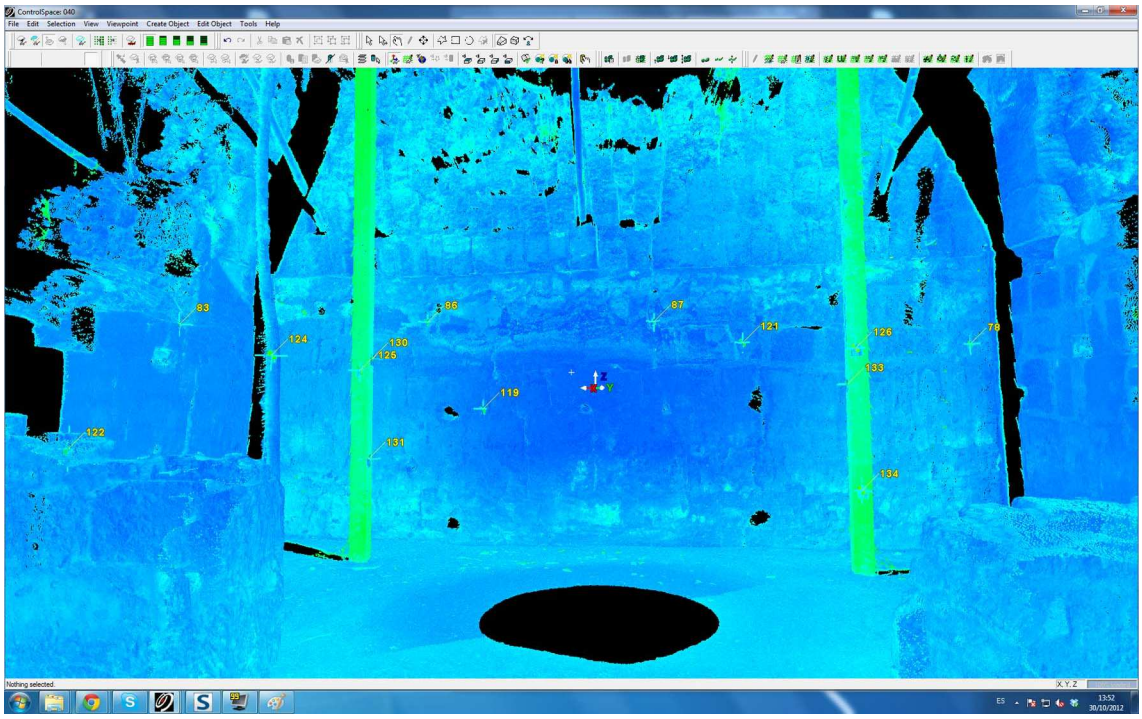

Fig. 4 – View of the point cloud of the Palace, showing the targets (Zacarías Herguido, 2012)

Data Processing

We registered every point cloud obtained from each scanning process, and thanks to the different targets we placed on the buildings (always at least 5 in common between 2 different scans) (Fig. 4), we stitched them together using suitable software, fixing a maximum error constraint of 3 mm for the resulting general point cloud (Figs.5 and 6).

We also divided the resulting model so that we could work with the data separately; the acropolis courtyard and its buildings on the one side, and just the palace on the other side.

Outputs

The first output we obtained from the point clouds was the creation of 2D images, from which we created a new planimetry of the buildings. In order to do this, after taking screenshots of the point clouds, we performed the vectorization (or image tracing) of every single detail we could see in them. We created these vector graphics through a CAD platform, which made us possible to measure distances and areas, and to quantify the graphics analysis. (Figs. 7 and 8)

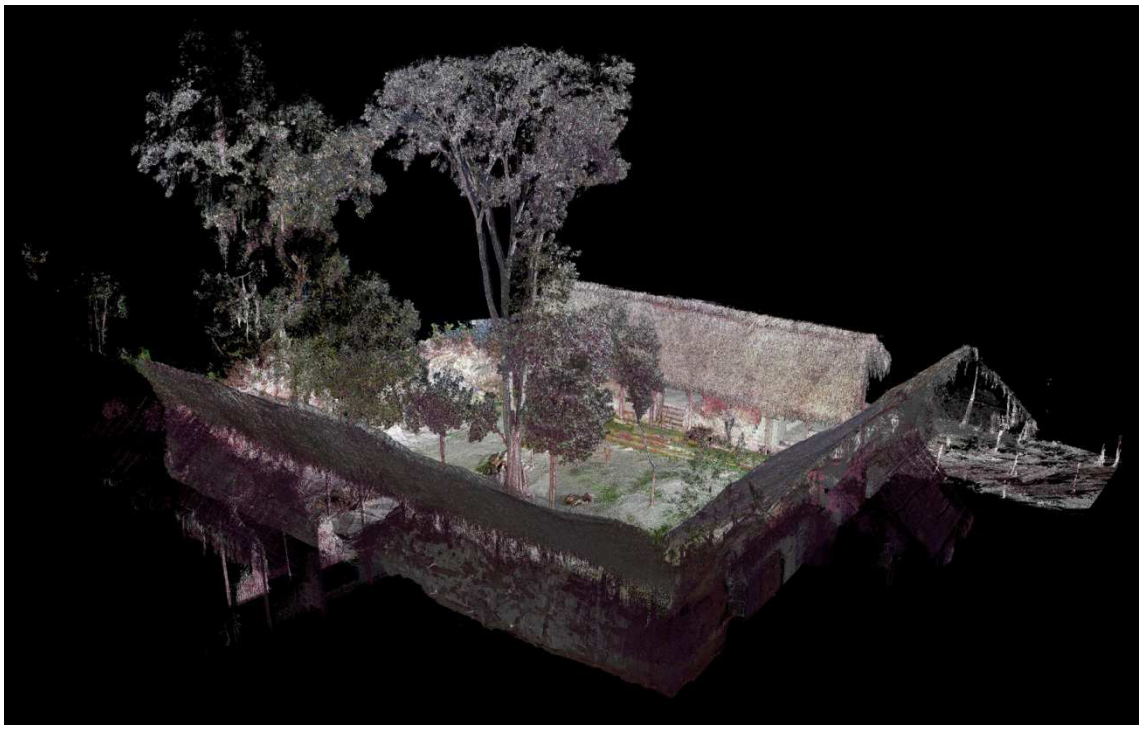

Fig. 5 – Screenshot taken from the point cloud of the Acropolis (Zacarías Herguido, 2012)

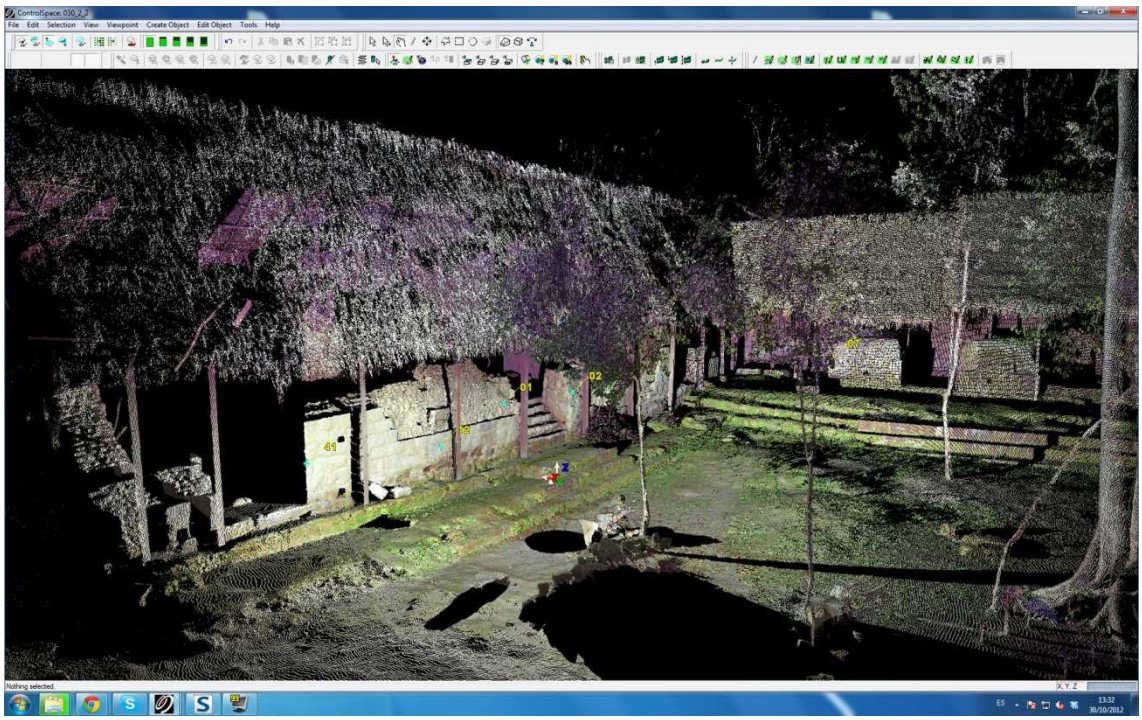

Fig. 6 – View of the point cloud of the Acropolis courtyard, with the pixels assigned to the points (Zacarías Herguido, 2012)

We compared the new plans with the ones we had previously obtained using the traditional methods and photogrammetric surveys. In this case, we could verify that the results we had obtained before using of the laser scanner were precise enough, because we didn't find any significant differences between either of the architectural surveys.

In addition to these results, we also proceeded to create the polygonal mesh from the point cloud. Figures 9 and 10 show the high poly models as a mesh, representing the current state of the main palace of the ancient city. With the mesh completed we could also display the same sort of plans we had obtained from the point clouds. One of the main aims of our project was to complete the most important structures of the site, so we had to obtain suitable quality 3D models in order to optimize them later for the virtual reconstructions of the original morphologies of the Mayan buildings.

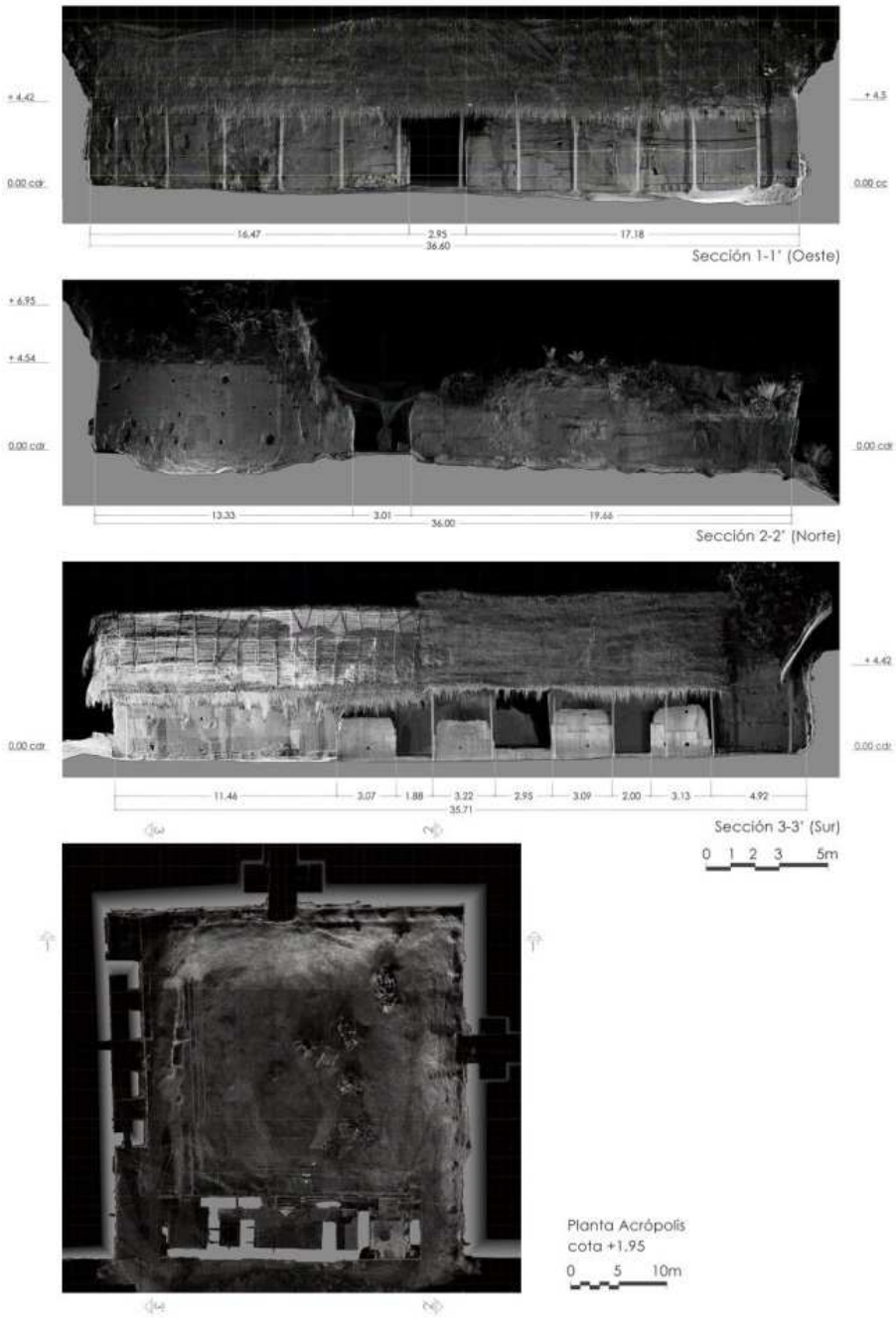

Fig. 7 – Plans of the current state of the Acropolis taken from the point clouds (Zacarias Herguido, 2012)

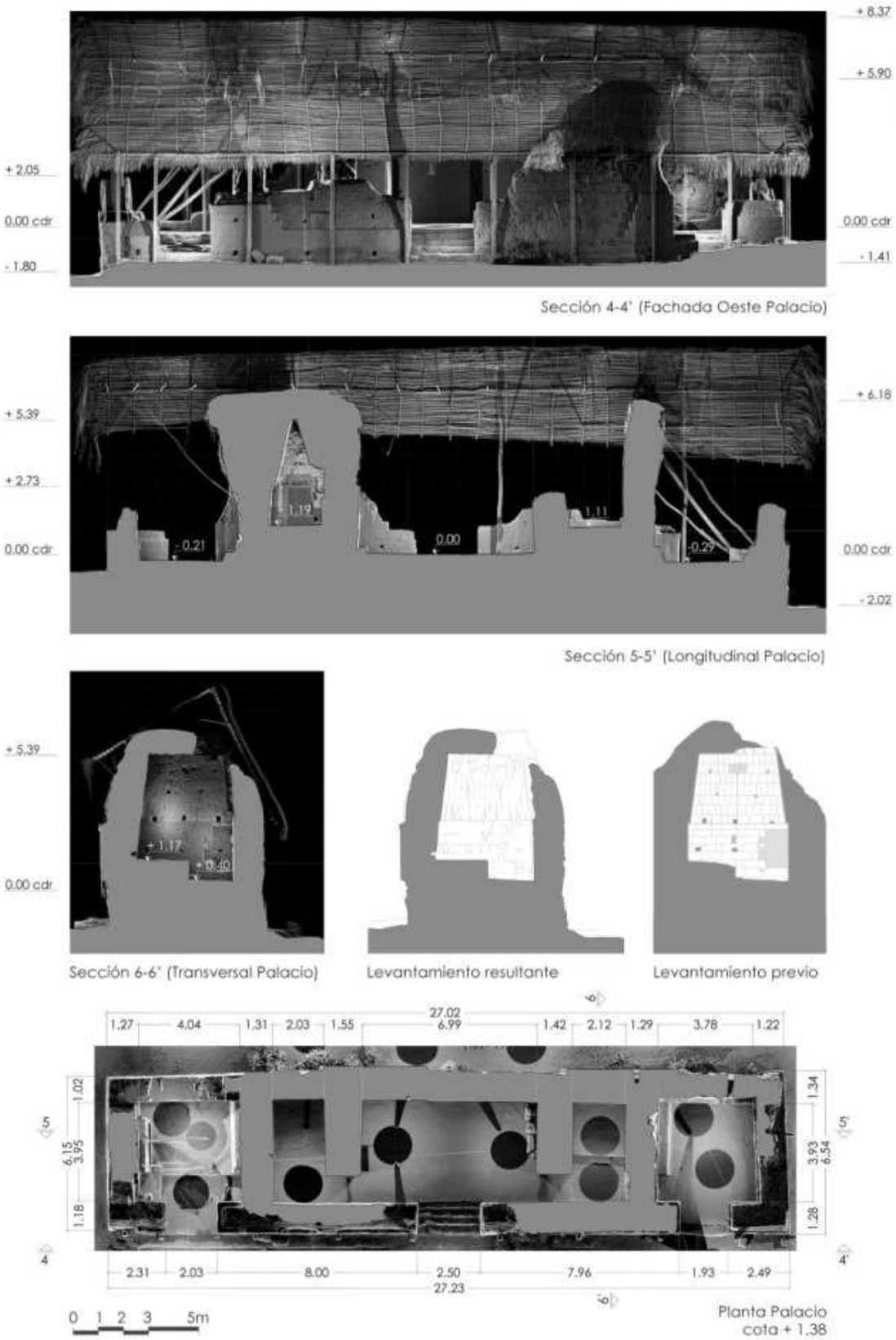

Fig. 8 – Plans of the current state of the Palace taken from the point clouds (Zacarias Herguido, 2012)

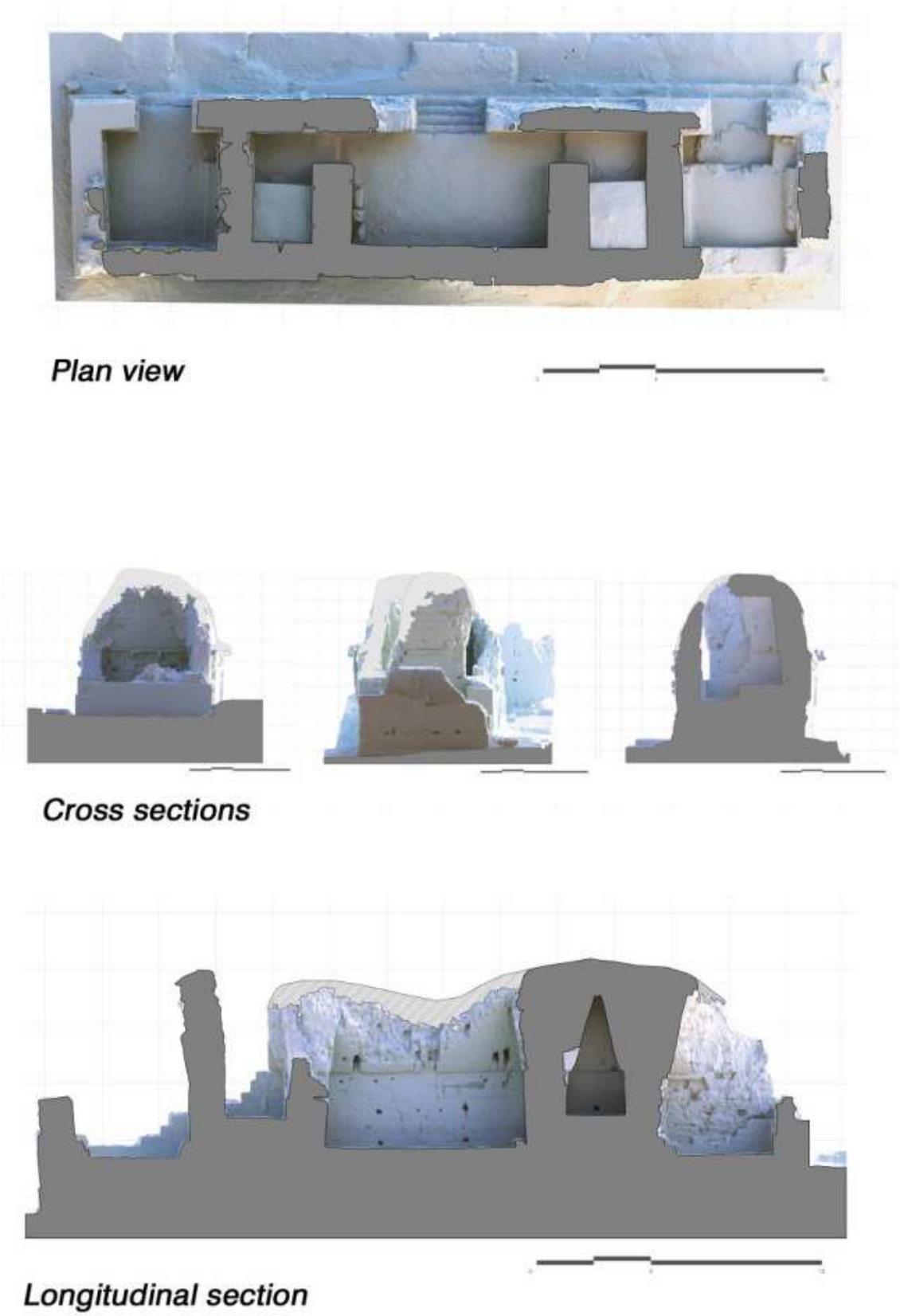

Fig. 9 – Plans of the current state of the Palace. Rendered mesh from the scanning process (J. Leonel López H., 2012)

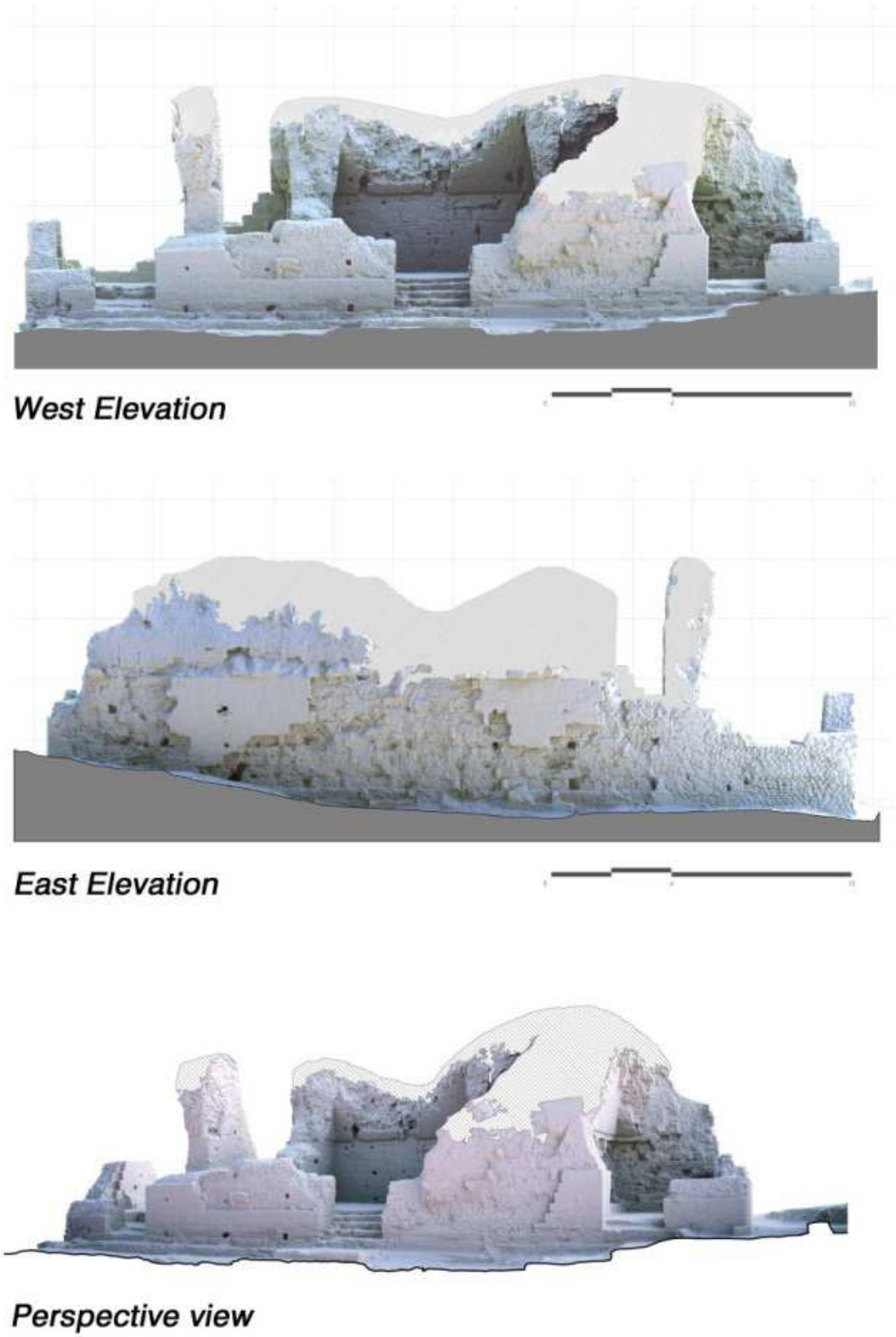

Fig. 10 – Plans and views of the current state of the Palace. Rendered mesh from the scanning process (J. Leonel López H., 2012)

Virtual reconstruction process

Methodology

The reverse modelling technique allows us to compile data of the exposed architecture and the morphology of the existing mounds in an archaeological site, so that we can afterwards digitalize and process all the information obtained in order to get a 3D model. This model will have all the details, measures and proportions of the object we are dealing with.

The virtual reconstruction process starts with the visualization of the 3D digital object through a CAD or similar software, and from that, we can work on the recreation of the original morphology of the object. There is no established methodology or recipe for that task; nevertheless we can list the factors we considered for the virtual reconstruction of the Palace in La Blanca.

One of those factors is the set of plans we obtained from the projection of the point clouds in two dimensions, once we have transformed them into vector graphics. These plans help us to check the components in two dimensions of the 3D model we are recreating: plan views, elevations and cross-sections. From the plan views we made from the point cloud, we can create the first polygons for the virtual recreation. Also, with all the polygons of the different plans, we can compare the mesh we deal with now with the previous surveys. Here we have here our first decision to make: for the reconstruction criteria we need to consider the hypothesis made by the archaeologists and architects of the project, who have a solid experience in the field of this type of restoration work. However, we find at this stage some elements without a defined shape, some architectonic parts of the building that, even with an accurate scanner survey, only a well trained eye can recognise.

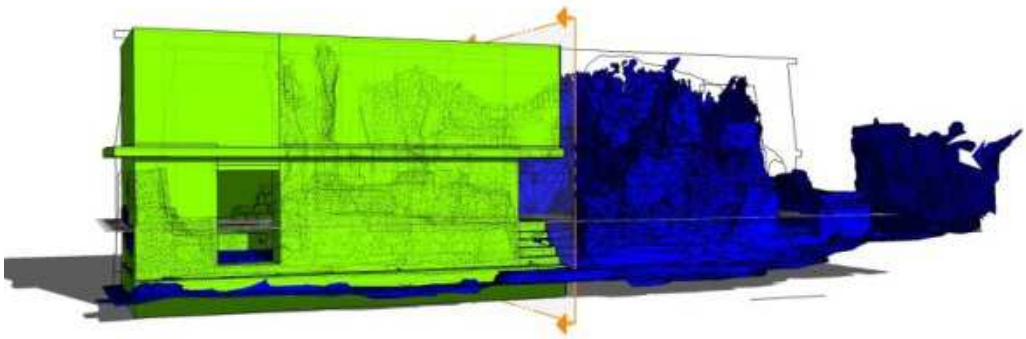

Fig. 11 – Reconstruction process image. Green: calculated volume of the original building. Blue: Low poly mesh. Floor plan from point clouds. Cross-section plan taken from previous surveys (J. Leonel López H., 2012)

The creation of the original morphology of the structure from these 3D models is an interactive process for the architects and archaeologists, and helps them to understand and visualize the spaces in a more complete way.

Once we have the plan view of the original shape of the buildings, already compared with the point cloud, the mesh of the current morphology of the ruins, and the previous surveys, we can extrude the resulting plan and give it a height dimension. In order to determine the correct height, we repeat the same process of using the elevations and cross-sections obtained from the point clouds, as advised by experts on this discipline (Figs. 11 and 12).

When we try to reconstruct missing volumes in the mess of the current status of the buildings, the experience and opinion of the archaeologists is essential. We haven't got any comparison or approximation factors in this case, so we rely on their knowledge of the relevant Mayan architectonic canons, and in this case, of the buildings of La Blanca, such as the symmetry, the use of the odd numbers when disposing stairway steps, openings and solid volumes of the buildings, the materials, the masonry disposition, the existence of cornices, etc.

The resulting polygonal model after the initial stage of the virtual reconstruction is the first hypothesis of the original morphology of the architectonic object. This polygonal model is still quite incomplete, poorly defined, and with all its sharp edges.

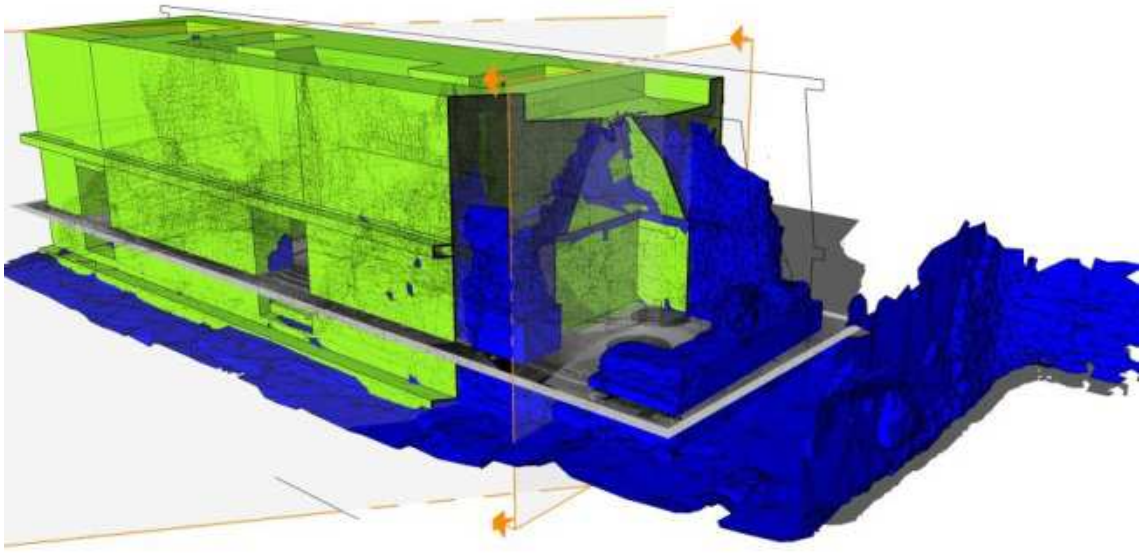

Fig. 12 – Reconstruction process. Green: calculated volume of the original building. Blue: Low poly mesh. Floor plan from point clouds. Cross-section plan taken from previous surveys (J. Leonel López H., 2012)

This is the point at which we start the process of recreating the textures and materials in order to improve the quality of the polygons of the baseline structure. In this way, we remove the straight edges of the Palace walls and smooth them out. We also add some imperfections on the stucco surfaces by using a polygonal recreation of those irregularities and applying the new texture improving the detail level and optimizing the amount of polygons. This new stucco appearance results from the creation of a diffuse texture mapping with

the information of the original stucco colours, and the repeatable image of the stucco texture. Then we apply a bump mapping to this texture, simulating bumps and wrinkles at the wall surfaces, apart from the volume and polygon deformations that we had previously obtained. In order to reduce the scale of the stucco texture effects, such as the small dust and earth spots in the stucco mixture, we use displacement mapping, which contains a black and white image of the texture map and a noise factor that helps to cause an effect of real stucco.

Fig. 13 – Image of the virtual reconstruction of the Palace (J. Leonel López H., 2012)

The next stage is the rendering process, in which we simulate a calculation of the light levels through a rendering engine for CAD software. The final results achieve high definition and realism, and we can then contemplate the virtual reconstruction hypothesis in full detail (Fig. 13).
After completing the virtual reconstruction of the Palace, we began the development of the rest of the Acropolis and the whole city of La Blanca, with the previous surveys of the current status of the site. These surveys had been carried out with topography and other conventional methods. Although the level of detail of the recreation of the rest of the structures is not as good as the one we have for the Palace, we can show this building within its urban and special context (Fig. 14).

Outputs

Static images

As we develop the technology and apply it to the graphic arts, we increase the number of different output methods for the information we have created until this point. For the virtual reconstruction project of La Blanca, from the beginning we considered using a set of static images that we could exhibit at the visitor centre, in order to give a better visualization of the site and help with the understanding of the city before and after visiting the ruins (Figs. 15 and 16).
Our aim is to attain a high level of realism with the recreations, but we were restricted by the time available to complete the project, the hardware resources and the capacity of information processing. Every single image takes approximately six to twelve hours, depending on the clarity of the image we have chosen, the configuration parameters for the calculation stages of the lighting and the other parameters.

Fig. 14 – Virtual reconstruction view of the Palace and its context. (J. Leonel López H., 2012)

Fig.15 – Virtual reconstruction view of the North Square. (J. Leonel López H., 2012)

Videos

A different option for the outputs is the creation of videos, i.e. a sequence of images or frames. In order to create 3D virtual tours, we define a route for the virtual camera through the city model space. The architects, archaeologists and the 3D technician make the decision in this part: the itinerary to follow and what the camera is going to show. If a rendering to get a static image took up to twelve hours, videos last even for much longer with very high definition quality, because they are a sequence of those frames. If our video has

30 frames per second, we need 180 hours for the rendering process, although for video projects we reduce the resolution and quality of the video images in order to shorten times. The product we obtain with this technique can be noteworthy, but they need a big investment of time and effort.

Fig. 16 – Virtual reconstruction view from the 'South Group' (J. Leonel López H., 2012)

Game Engines

Methodology

We define game engines as the rendering engines which calculate lighting, sound and animations in real time, creating video games that involve the interaction of any user, with the consequent feedback on the video device used. We call it real-time because it calculates the stages needed for the lighting of static images up to 120 times per second. That is achievable through the calculation of lighting simulation performed by the GPU, or graphics processing unit, unlike the rendering engines in CAD software, which use the central processing unit (CPU) for that purpose. When we use the GPU, the models must have the optimum number of polygons, in order for the graphics processor to use the appropriate amount of definitions to achieve the right level of detail for the model we are dealing with.

Each object which is represented by a set of polygons inside the game engine is called an asset. For the recreation of the model of the city of La Blanca, we optimized the high definition models we had obtained from the rendering of the static images, obtaining the assets needed for the game engine (Fig. 17).

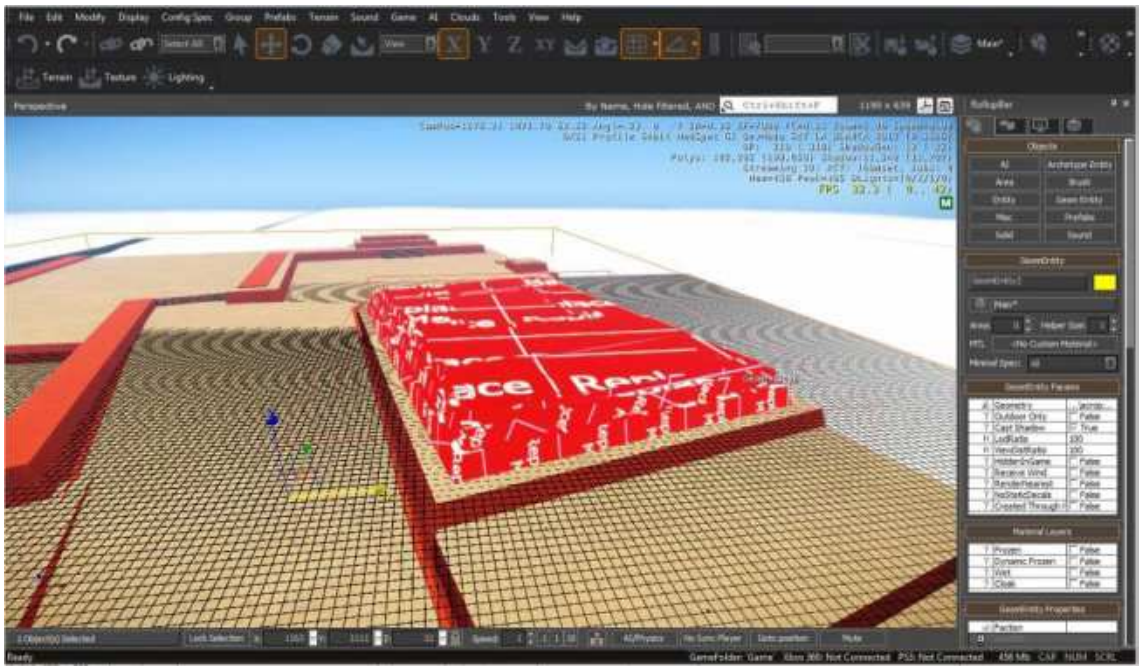

Fig. 17 – Image of the asset composition process. (J. Leonel López H., 2012)

In order to achieve these results, we needed to optimize the models we had created from our first virtual reconstruction in the form of static images, obtaining low poly versions of these previous models. We then had a simpler geometry that could define the surfaces of the volume of the object (i.e. the assets). By including displacement and normal mapping, we retained a highly realistic appearance and the high level of depth and sense of detail we had achieved with the high poly versions of the model, because the software calculates the movement over the simple polygon surfaces, simulating the detail of the texture.

The real-time rendering works with a speed of creation of frames per second in a way that allows the user to visualise and navigate through the virtual model as he wishes. We aren't restricted to follow a previously determined guided route, and in this way, we can interact directly with the virtual model, and travel all the way around and inside it in a virtual tour through the pre-Hispanic city.

Each game engine system has a default library of objects we use in order to recreate the environment for our model. In this case, for the city of La Blanca, we looked for similar vegetation to that which exists in lowlands of the north region of Guatemala, a tropical rainforest (Fig. 18). The possibilities for recreating the conditions of the environment are now unlimited, we can simulate the weather and climate, including the rain, the sun's movement and the changes of shadows. On top of this, we can add atmospheric sounds, background music and other sound effects, helping to increase the sense of reality of this virtual world. There are other complex effects, called particles, such as smoke simulations, fog or fire. It is more complex to estimate these components, and requires a higher number of setting parameters.

About the game engine we used

The available game engine software is increasingly easier to use. They work following the WYSIWYG (what you see is what you get) system, in which all the tools required to create games and the virtual domain are within everyone's reach.

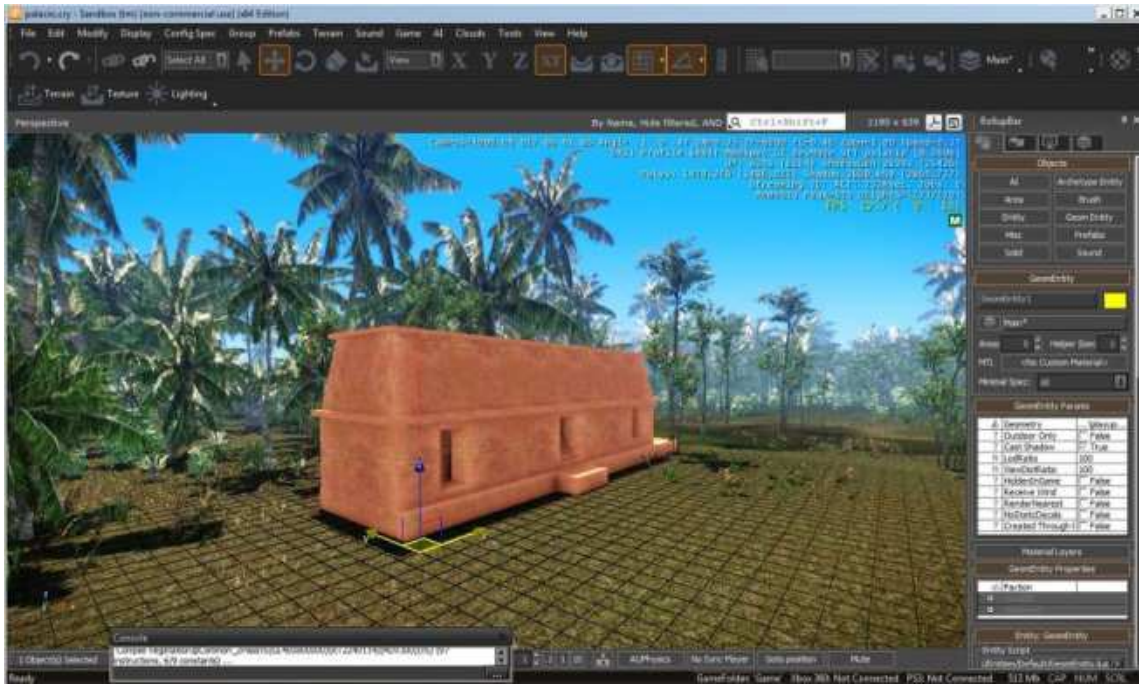

Fig. 18 – The Palace asset on game engine. La Blanca Virtual Reconstruction Project. J. Leonel López H. 2012.

In this project we worked with CryEngine®3, one of the most advanced game engines at the moment, designed by the developer Crytek. The format provided by this particular game engine is compatible with standard computers or video game consoles, so there are more possibilities for the visualization of the information. The technology of this software makes it possible to create realistic environments, and a better understanding and simulation of the virtual recreations of pre-Hispanic cities and other areas of heritage. We used the software development kit of this game engine, CryENGINE®3 Sandbox™ to edit and manipulate the 3D models.

The engine converts and optimizes the assets in real-time, with an increase of the speed and quality. The effects on lighting, material and modeling changes can be seen within moments, and the material editor can modify the shaders used for the assets by layers, simplifying the editing process. The almost-real lighting creates shadows which have a dynamic response to natural movements in real time. High-resolution, perspective-correct and volumetric smooth-shadow implementations are also features of this software we used. It also features a real-time dynamic global illumination solution, optimized for current and next-generation platforms. It supports without pre-computation or geometric limits, light-bounces, color bleeding and remarkable effects in real-time.

The developers of this software were pioneers in developing the screen space ambient occlusion: the game engine provides a real-time simulation of ambient light occlusion, allowing the real darkening of edges and corners as in the natural world.

The software also includes normal mapping and offset bump mapping, for all supported platforms, to give a sense of depth to a surface texture applied to a polygon, to achieve realistic levels of detail without needing hi-poly models. This is a very important aspect in order to improve the stability of the software, and it also makes possible to run the application in conventional platforms.

These features and some others we haven't mentioned in this paper allow us to recreate complex environments with a high sense of reality. And besides, these tools are free and accessible to all, and they don't necessarily require high computer skills.

Results

After the edition process we obtained a video game (Fig. 19) in which through the model of the whole city and its environment, we can individually explore a hypothetical virtual reconstruction of the place with realistic effects. In this way, we manage to obtain a better understanding of the scale and the urban composition of the city. The simulation of the site we created allows the user to learn about it and consolidate their knowledge of the ancient city through the direct experiencing and interacting with the 3D model, as a result of the previous research work on the archaeological site.

The quality and levels of realism we have attained in this project could still be considerably improved, giving us particularly realistic models and scenes, which would allow us to have memorable experiences and leave us with a clear idea of Mayan culture and possible scenarios of daily life. Once the project is improved and finished, we will dispose it at the website of the La Blanca Project (http://www.uv.es/arsmaya), so the game is accessible to society.

Conclusion

Even though the use of laser scan technology is still experimental in the fields of Mayan archaeology and architecture, and despite the many difficulties posed by the fieldwork, we aim to open the way for new research proposals and different ways of making the wealth of heritage of the Mayan remains more accessible through this project.

Our ambition is to continue the research of this technological strand, and to identify which methods are most useful in the research field and in making the scientific results we obtain accessible.

The 3D models and virtual reconstructions we have created represent a new approach to archaeological interpretations of the site of La Blanca. They also add new information about the real and exact state of the buildings we have analysed, with the possibility of being consulted at any time in the future.

In addition, by heading into the area of game engines and virtual reality of the reconstructed original morphology of the buildings, we are faced with the new challenge of how to explore the different hypotheses on the origin of these ancient sites without affecting the Mayan remains. As well as being a scientific method, the use of game engines would appear to be a suitable way of connecting with the general public beyond the scientific community, and making the Mayan culture known for them, allowing the users to interact within the recreated models so they can interpret the spaces and buildings virtually, as an additional feature of visiting the actual side.

We believe that with the improvement of technology, the research will take new directions, and time and economic costs will be optimized with the development of new hardware and software. It is our duty to apply the new technologies, such laser scanning and game engines, in the field of cultural heritage.

Fig. 19 – Sequence of images taken from the Game Engine. The Acropolis viewed from the North Square up to the courtyard (J. Leonel López H., 2012)

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We would also like to thank the University of Valencia and the Polytechnic University of Valencia, and also Professor Alessandro Merlo, and Professor Filippo Fantini from University of Florence for their training and advice, and for their guidance in order to obtain the results we show here.

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