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GEOMETRIC CHARACTERIZATION AND INTERACTIVE 3D VISUALIZATION OF HISTORICAL AND CULTURAL HERITAGE IN THE PROVINCE OF CÁCERES (SPAIN)

CARACTERIZACIÓN GEOMÉTRICA Y VISUALIZACIÓN INTERACTIVA 3D DEL PATRIMONIO HISTÓRICO Y ARTÍSTICO EN LA PROVINCIA DE CÁCERES (ESPAÑA)

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Highlights:

- Panoramic spherical photography and terrestrial laser scanning (TLS) are used for geometric characterization and cataloguing of cultural sites.
- 360º photography, 3D interactive scenes and videos are created and ready to be used online by users.
- Hypermedia atlas based on a combination of geomatics methods are used to disseminate Cáceres' cultural heritage.

Abstract:

The three-dimensional (3D) visualization of historical and cultural heritage in the province of Cáceres is essential for tourism promotion. This study uses panoramic spherical photography and terrestrial laser scanning (TLS) for the geometric characterization and cataloguing of sites of cultural interest, according to the principles of the Charter of Krakow. The benefits of this project include improved knowledge dissemination of the cultural heritage of Cáceres in a society that demands state-of-the-art tourist information. In this sense, this study has three specific aims: to develop a highly reliable methodology for modeling heritage based on a combination of non-destructive geomatics methods; to design and develop software modules for interactive 3D visualization of models; and to promote knowledge of the historical and cultural heritage of Cáceres by creating a hypermedia atlas accessible via the Internet. Through this free-of-charge hypermedia atlas, the tourist accesses 3D photographic and interactive scenes, videos created by 3D point clouds obtained from laser scanning and 3D models available for downloading in ASCII format, and thus acquire a greater knowledge of the touristic attractions in the province of Cáceres.

Keywords: terrestrial laser scanning (TLS); panoramic spherical photography; 3D modelling; historical and cultural heritage; touristic promotion; hypermedia atlas

Resumen:

La visualización tridimensional (3D) del patrimonio histórico-cultural en la provincia de Cáceres es una herramienta vital para su promoción turística. Este trabajo emplea la fotografía panorámica esférica y el uso del escáner láser terrestre para la caracterización geométrica de los bienes de interés cultural, así como su catalogación, de acuerdo a los principios de la Carta de Cracovia. El beneficio de este proyecto es alcanzar un mayor conocimiento del patrimonio cultural de Cáceres para una sociedad que demanda información turística actualizada. En este sentido, hay tres objetivos específicos en el trabajo: desarrollar una metodología de alto grado de fiabilidad para la modelización del patrimonio basado en la combinación de diferentes métodos geomáticos no destructivos; diseñar y desarrollar módulos de software para la visualización interactiva de modelos 3D; y promover el conocimiento del patrimonio histórico de Cáceres mediante la creación de un atlas hipermedia accesible en Internet. A través del atlas hipermedia, el turista accede gratuitamente a los escenarios fotográficos tridimensionales e interactivos, los videos a partir de las nubes de puntos 3D adquiridas con láser escáner y a la descarga de los modelos 3D en formato ASCII, adquiriendo un mayor conocimiento de los atractivos turísticos de la provincia de Cáceres.

Palabras clave: escaneado láser terrestre; fotografía panorámica esférica; modelado 3D; patrimonio histórico-artístico; promoción turística; atlas hipermedia

1. Introduction

According to the principles for conservation and restoration of built heritage in the Charter of Krakow 2000, there is a range of suitable technical options available for organizing the cognitive process of historical, artistic and cultural meaning (De Naeyer, Arroyo, & Blanco, 2000). Digital technology has altered our approach to the appreciation of cultural heritage and promises to continue to open new horizons

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(Haddad, 2016). For this reason, the 3D visualization of historical and cultural heritage is a vital tool for the promotion of tourism in Cáceres.

Likewise, the current economic crisis calls for a greater response to the demand for tourism by means of the transformation of consolidated economic activities and the creation of new ones. Within this area, the regional policy of Extremadura is committed to the modernization and transformation of inland tourism as a potential and complementary source of economic activity. By making more information about the historic and artistic heritage available to the tourist, interest in the province of Cáceresis increased and tourism in the area is promoted and expanded.

The purpose of this work is the geometric characterization of historical heritage by means of a combination of different methods of study and measurement to be used as a basis for touristic promotion, as laid down by the Charter of Kracow. To achieve this objective, the application of information and communication technologies is crucial to the documentation and promotion of heritage.

The main benefit of the project is the improved accessibility of knowledge of the cultural heritage of Cáceres in response to a demand for ever more up-to-date tourist information.

The general aims of the project have been achieved:

- The historical and cultural heritage of Cáceres has been modeled by means of a combination of non-destructive geomatics methods.
- Spherical scenes have been created using photographs and 3D modeling by laser scans. In addition, software specific to the interactive display of virtual spherical 3D scenarios has been designed and developed.

Historical and cultural heritage also makes regions more attractive, thus promoting the development of city services, infrastructures and cultural organizations (Ismagilova, Safiullin, & Bagautdinova, 2014).

Furthermore, a topographical survey was conducted to rigorously document thegeometry of all historical and artistic sites (Rua & Gil, 2014).

In this respect, the decision regarding the technology to be applied is taken in accordance with the aims defined by the nature of the documentation needed. The degree of detail required may vary depending on the agents promoting tourism (Magda & Remondino, 2015).

Nevertheless, we must ensure that the differing degrees of detail are in proportion to the historical interest of the architectural complex examined and that they are adapted to the purpose of the study and the diffusion of touristic information (Dey, Acharjee, & Chakraborty, 2015).

This work has three specific aims:

1) To develop a methodology with a high degree of reliability for modeling the historical and cultural heritage of Cáceres based on a combination of different non-destructive geomatics methods, which will also be of use in its conservation.
2) To design and develop the software modules for interactive 3D visualization.
3) To promote knowledge of the historical heritage of Cáceres by creating a hypermedia atlas accessible via the Internet.

This study shows the results of the research in a synthetic way centering on methodological aspects. It is structured in eight sections. Following this brief introduction, several concepts are defined in the following Section 2. Section 3 provides a description of the area of study and Section 4 explains the materials used. Section 5 describes the methodology used and Section 6 analyzes the results obtained, including any strengths and pitfalls in the research. Section 7 forms the discussion and finally, Section 8 draws some conclusions.

2. The state of the art

The historical and cultural heritage of the Province of Cáceres was documented using two techniques:

- The provision of panoramic images in a 3D spherical view.
- The creation of 3D point clouds obtained by means of TLS.

The virtual panoramic view, a form of realistic-image technology, has undergone rapid development in recent years (Maícas & Viñals, 2017; Díez, Cortell, García & Escribá, 2017). Compared with common modeling methods the virtual panoramic view has the advantages of economy, simplicity and swift development. Moreover, the requirements for data acquisition are not strict and panoramic viewing is vivid and smooth (Feng, Wu, & Ma, 2014; He, 2015). In fact, panoramic imaging is an increasingly used application and an area of research.

This technology has applications in digital photography, robotics, film production for 360º screens, architecture, environmental studies, remote sensing and Geographic Information Systems (GIS). Applications require different degrees of accuracy depending on the aim, either 3D documentation or visualization (Huang, Klette, & Scheibe, 2008; Díaz, Jiménez, Barreda, Asensi, & Hervás, 2015).

One use of this technology is touristic promotion (Beeton, 2015; Dey, Acharjee, & Chakraborty, 2015), through the generation of virtual tours using panoramic photography (Alja'am, AlSaady, AlMarri, & Al-Kuwari, 2010; Koutsoudis, Arnaoutoglou, & Chamzas, 2007; Wu, Feng, & He, 2014).

TLS has become a powerful technology for 3D object information acquisition since it permits the use of dense high accuracy 3D terrain information, high data acquisition speed and increasingly efficient post-processing workflows (Yastikli, 2007).

It is now often used for 3D object modeling in GIS in various fields such as civil engineering and archaeology (Xu, Yang, & Neumann, 2015).The latter highlights the work aimed at the conservation of cultural heritage (Fanti, Gigli, Lombardi, Tapete, & Canuti, 2013; Calin et al., 2015; Rüther et al., 2009; Logothetis & Stylianidis, 2016; Sánchez, Naranjo, Jiménez, & González, 2016).

3. The study area

The study area is in the province of Cáceres (Fig. 1).

Figure 1: Study area of the work undertaken in the province of Cáceres, Extremadura (Spain).

The Office for the Protection of Historical Heritage in Spain is responsible for maintaining and updating the General Register of Assets of Cultural Interest and the General Inventory of Personal Property, which hold information on the sites and monuments for which either the autonomous communities or the State have decided to establish some form of protection.

Based on the historical interest of sites within the province of Cáceres, virtual tours were created from 62 monuments in 31 municipalities (Table 1).

Table 1: Municipalities in which virtual tours were made.

Municipalities	
Abadía	Gata
Alcántara	Guadalupe
Alcuéscar	Jaraíz de la Vera
Aldea del Cano	Malpartida de Cáceres
Almoharín	Oliva de Plasencia
Arroyo de la Luz	Pasarón de la Vera
Baños de Montemayor	Piornal
Bohonal de Ibor	Plasencia
Brozas	Robledillo de Gata
Cabezuela del Valle	Santa Cruz de la Sierra
Cáceres	Trujillo
Coria	Valencia de Alcántara
Cuacos de Yuste	Valverde de la Vera
Galisteo	Villanueva de la Vera
Garganta la Olla	Zarza de Granadilla
Garrovillas de Alconétar	

Due to the limited funds allocated to data acquisition for this research project, priorities had to be established and a selection made to restrict modeling to the most representative elements. This list of monuments on which to work was drawn up by the Provincial Government of Cáceres.

4. Materials

A Canon EOS 5D Mark III was used to capture photographs.This camera is capable of capturing 22 MP images; a lens with a focal length of 15 mm was used. The tripod used was a Manfrotto 303PH with a 'VR' spherical ball.

Panoweaver 7.0 software was applied to join photographs and Tourweaver 6.50 to generate spherical photographic scenes.

In order to obtain the 3D models two types of TLS were used:

- Leica C10, with an accuracy of 4 mm in point positioning at distances up to 50 m.
- Faro Focus 3D S120, with an accuracy of 2 mm at a distance range of 0.6 to 130 m.

The instruments used for geo-referencing the monuments are listed below:

- Leica 1200 bi-frequency (GPS+ GLONASS), which provided the flexibility, power and performance needed for all Global Navigation Satellite System (GNSS) applications.
- Leica RS500 bi-frequency (GPS) equipped with GPS antenna and receiver.

The software used was:

- Leica Cyclone Model v.7.4 software to process the 3D point clouds. This provided powerful visualization and navigation through the point cloud as well as a full set of topographic tools for high-definition surveying (HDS™).
- Trimble RealWorks v.10.1 software for the management and application of point clouds (Fig. 2).
- Panoweaver v. 7.0 is a professional photography tool capable of joining all kinds of photos in high quality, 360º or partial panoramic images. It supports the creation of High Dynamic Range (HDR) images and manual joining for the inclusion of matching homologous points. In addition, it includes formats such as full-screen Flash (based on HTML), VR, QTVR, independent SWF and HTML5 (iPad, iPhone, etc.).
- Tourweaver v. 6.50 is professional software with the specific purpose of virtual tour creation. It presents the real world in a 360° panoramic view. It allows the inclusion of up-to-date information and can exchange views interactively within each of the virtual tours generated.

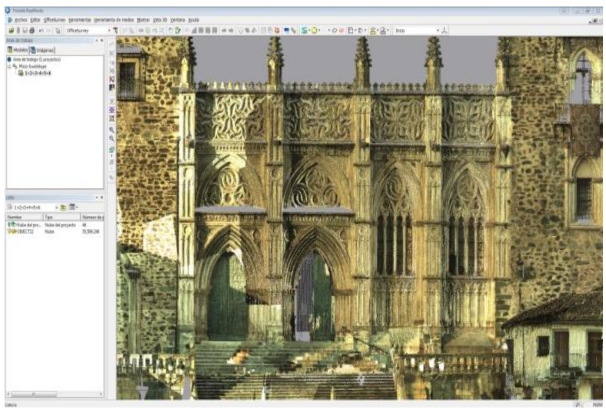

Figure 2: Screenshot of the Trimble RealWorks software, displaying a point cloud of the Facade of the Guadalupe Monastery, Cáceres.

5. Methods

Any touristic promotion of historical and cultural heritage requires information acquisition. In our case, the real geometry of the monuments had to be obtained, and the decision on the technology to apply in this regard was taken bearing in mind the use to be made of the data obtained.

The diversity of complexity and dimensions of the sites of cultural interest required the application of several technical options. While the TLS provided us with the opportunity to capture a large number of points accurately, due to the characteristics of the monuments it was not always possible to measure them completely.

As the ultimate aim was the promotion of tourism of cultural heritage, terrestrial images were also included in the generation of virtual tours. These show the entire monuments and offer quality tourist information. The general pipeline carried out is presented in Fig. 3.

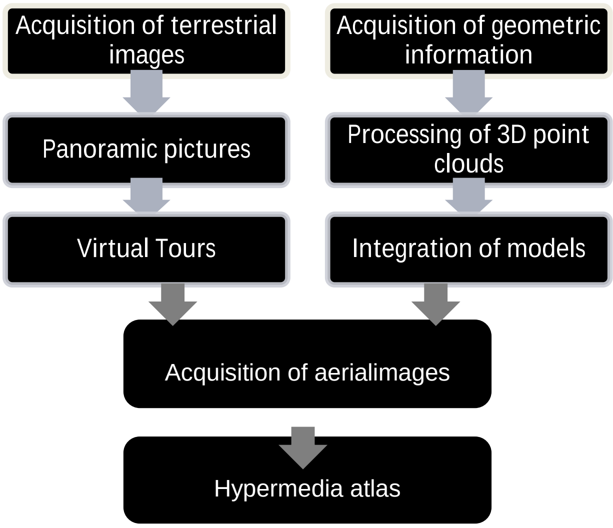

Figure 3: Pipeline followed to undertake the hypermedia atlas.

A topographic network had to be created, and in this case a local high precision geodetic network was calculated and set up. In order to ensure that all the work would be correctly geo-referenced and that this network could be applied in the future, the network was set up using observations by GNSS from each of the municipalities.

Each of the networks designed was made up of at least nine GNSS bases in two categories, internal and external networks:

- External network GNSS: a first external network of 3D control (XYZ) was established outside the possible influence of the site of cultural interest.
- GNSS proximity network: a second network of proximity of 3D control (XYZ) was set up in the areas of influence of each site of cultural interest.

Leica SR500 dual frequency (GPS) and Leica 1200 dual frequency were used for observations. A network of at least four bases was set up in areas surrounding the working area. Likewise, the network was linked to the nearest permanent station of the Extremadura positioning network.

The name and WGS-84 coordinates of the new implementation bases were then saved in digital files in the GNSS equipment terminal. The RINEX data from the permanent GNSS station were downloaded.

The data were uploaded to the Leica software Geo Office and the calculation of the UTM ETRS89 coordinates began. A least squares adjustment was then carried out by analyzing each base line, resulting in the final solution of the coordinates of the bases.

5.1. Acquisition of aerial images

The use of aerial images was crucial to the task of locating each of the monuments examined. These images were used to plan the different sites where the TLS measurements were taken and to plan the different photo shots for creating the virtual tours. To aid in this task, the Regional Government of Extremadura offered aerial photographs and orthophotographs through its Spatial Data Infrastructure (SDI) Geoportal (www.ideextremadura.es/Geoportal/) (Fig. 4a), providing the opportunity to download this information for use on the condition that reference is made to the source.

Figure 4: a) A sample of orthophotography with locations of spherical scenarios and captures by TLS; b) Location of the 3D spherical view; and c) Place name.

The location of panoramic spherical photographs (Fig. 4b) was included in aerial photography and the most representative place names (Fig. 4c) shown so that the web page user can locate them.

5.2. Acquisition of terrestrial images

In order to obtain photographs suitable for creating virtual scenarios, the camera must be correctly mounted on the spherical panoramic head. To do so, the camera must focus towards the ground and its optical axis must be paired with the main axis of the tripod, once it has been levelled.

Then, by placing horizontally the optical axis, several sequences must be taken from different horizontal angles, in our case 14 shots with a separation of 24°. In addition, a photograph was taken of the zenith and another of the tripod to fulfill this requirement (Fig. 5).

Intense sunshine should be avoided when taking the photographs.

Figure 5: Camera mounted on the tripod.

5.3. Generation of panoramic photographs

Once the single photographs had been obtained for the panoramic views, EasyPano Panoweaver software was used to join the photographs into one single panoramic image, initially fusing all the photographs that cover the scene (both horizontally and vertically) to obtain a cubic panoramic photograph (Fig. 6).

Figure 6: Images captured with the camera to generate a photograph (12 horizontal photographs, one zenith and another towards the ground).

In some areas of the images, this phase was problematic since matching the calculated homologous points yielded excessive residuals. As a result, the panoramic photography obtained was not continuous (Fig. 7).

This photo was then transformed into a cubic panoramic photo, made possible by the algorithm used by this software to recognize corresponding features. Finally, in order to enjoy the virtual tours, a Flash file was generated (Fig. 8).

5.4. Generation of virtual tours

Tourweaver 6.50 Professional software was used to generate the layout of the virtual tour. Once the different spherical panoramic photographs had been created, they were linked in order to facilitate the virtual interactive immersion of the user in the desired scene. Each spherical view contains a text indicating its municipal location and its name, according to the catalogue of monuments of cultural interest.

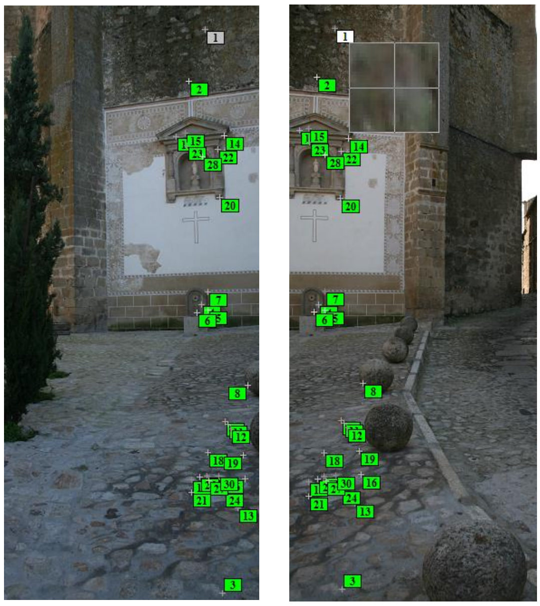

Figure 7: An example of an image with errors.

In addition, information buttons were created to access historical information every time the visitor moves the mouse over it. In the same way, other buttons were created to change the position of the virtual visit (Fig. 9).

5.5. Acquisition of geometric information

The structures of the monuments of cultural interest were represented in 3D. The TLS carried out the topographic surveys quickly and efficiently with an accuracy to within a few millimeters.

The TLS took into account illumination and brightness conditions in each of the pieces measured, always using a vertical field of view with a bandwidth of 270 degrees, and a horizontal plane of 360 degrees.

The data to be collected were then planned and the optimal scanning resolution selected for the detailed representation of the monument.

To ensure that no part of the monument had been left out of the measurement, a check was made that the captured point clouds covering the entirety of the measured monument. A laptop was used for this purpose at the time of data collection.

The prior definition of these data facilitated the maximization of information collected. At least four targets between two areas were always established and scanned so that the overall set of scans could be successfully merged.

This target resection method uses the identifiable targets scanned at high resolution to provide common matching points between scans. This method requires fieldwork planning since the placement of these targets is crucial to achieving a single merged point cloud.

5.6. Processing of 3D point clouds and integration of models

One of the first phases of point cloud processing is merging the different scans which, in our case, had been carried out using Leica Cyclone v. 7.4 (Leica Cyclone 7.4, 2015).

Figure 8: An example of a panoramic photograph targetting the *Arco de la Estrella*, Cáceres.

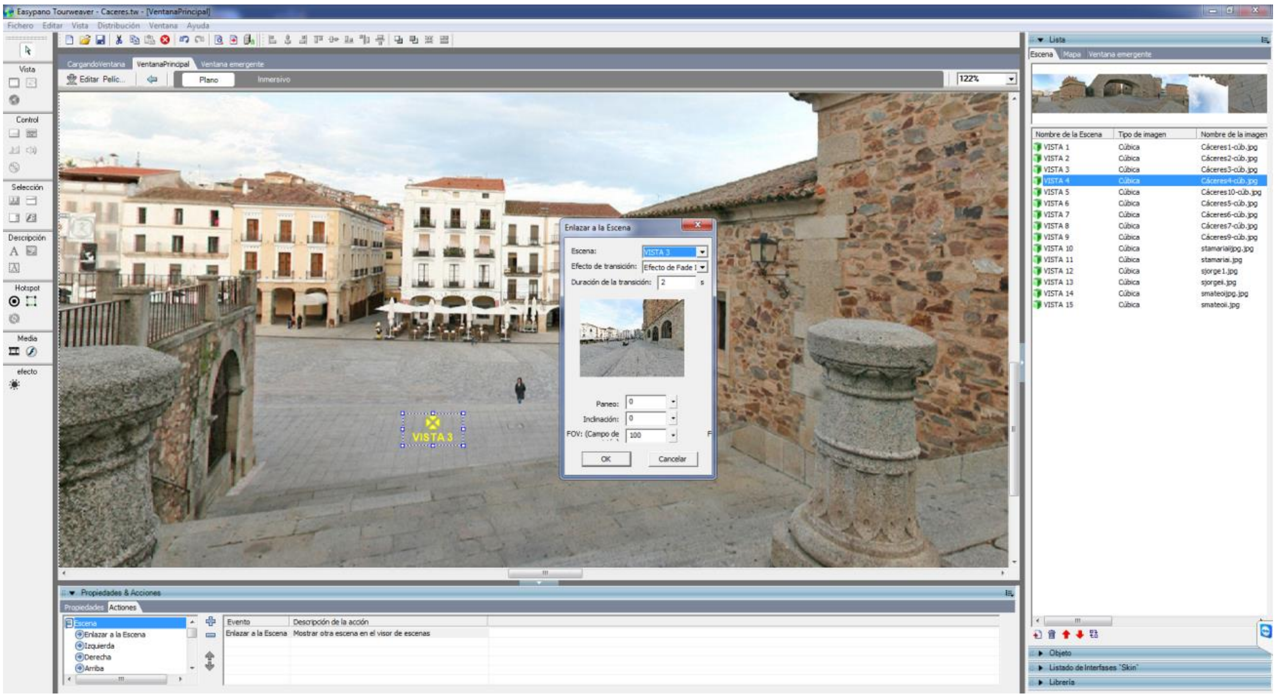

Figure 9: Inclusion of historical information. View of the *Plaza Mayor* from the *Arco de la Estrella*, Cáceres.

Figure 10: An example of a point cloud. Roman Temple dedicated to the builder Julio Caio Lácer.

Each consecutive pair of point clouds was oriented towards four common targets to provide a set of orientation-related parameters. These parameters were used were used as an initial solution in a procedure of adjustement block, an interative procedure that was performed until the residual errors had been adequately compensated.

Subsequently, the composed block of the point clouds was cleaned of noise, all disturbances to the point cloud that are not necessary for the creation of the 3D result. In the process, some elements were omitted from the final version of the model, such as people crossing during measurement, trees or highly reflective surfaces (Fig. 10).

The block obtained was then geo-referenced (Leica Cyclone v. 7.4, 2015) and all the point clouds were arranged in an absolute reference system using the Leica SR500 with an accuracy of 2 cm. Trimble RealWorks 10.1 software was used to generate videos from the point clouds.

6. Results

Once all spherical photographic scenarios and point clouds had been obtained, they were uploaded to the Internet.

The web page http://colometa.unex.es/ceresvirtual/ was created for using as a hypermedia atlas (Fig. 11). Information can be accessed in different ways through the menu at the top of the screen: location and display mode (laser scanner or spherical scenarios).

Figure 11: Detail of municipalities in the hypermedia atlas.

Nevertheless, a more intuitive way is available for accesing information, by simply clicking on one of the green dots on the on-screen map of Cáceres (Fig. 11) to go to the municipalities where the monuments are, or by selecting the laser scanner directly and then searching the desired municipality to see the videos and spherical scenarios available (Fig. 12).

Figure 12: Spherical view of the *Arco de la Estrella*, Cáceres.

As for the interactive visualization of the virtual scenarios (Fig. 12), the user of the web page will find a list of the views available on the left. These are represented by a cubic panoramic image and corresponding number. In the lower left-hand corner, there is also a drop-down menu with the same views available for selection. Thus, one way or another, the user can choose the view. Alternatively, the user can change the view interactively by clicking on the yellow marks. The name of the site appearing in the virtual tour (Fig. 12) is shown in the text in the bottom left-hand corner.

The lower part includes green buttons for use in navigating through the virtual stage. These buttons allow scrolling from left to right, top to bottom and zooming in and out. In addition, two additional buttons have been enabled, one so the user can start the virtual tour again from the beginning, and another to allow full-screen visualization (Fig. 13).

Regarding diffusion, points of interest have been marked using small magenta-coloured icons. Thus, when the user passes the mouse pointer over an icon, a pop-up text box appears at the bottom of the image containing the historical and artistic information of that element (Fig. 14).

Figure 13: Full screen spherical scenario of the *Plaza de Santa María*, Cáceres.

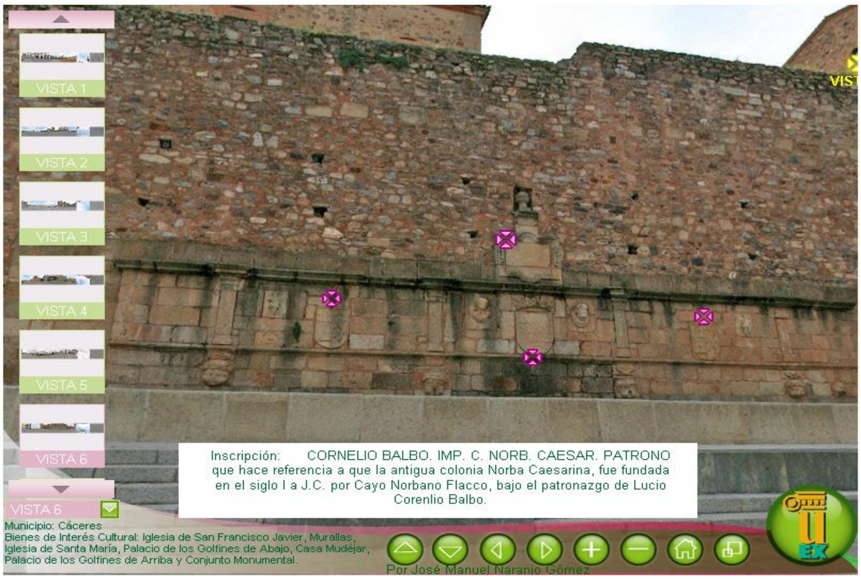

Figure 14: Text with information emerging from the virtual scenario of the *Foro de los Balbos*, Cáceres

As for the information obtained by TLS, the user can view the videos in two ways. The first is the same as when accessing the virtual scenarios, by clicking the green dot located on a municipality and then selecting the option "Laser Scanner". The second way is also accessible on the main page, by clicking the "Laser Scanner" option on the menu at the top (Fig. 15).

Figure 15: "Laser Scanner" selection menu on the home page.

Either way, the user accesses a screen showing a description of the municipality first, after which the video can be viewed (Fig. 16). In addition, the point clouds (in ASCII flat format) can be downloaded free of charge (Fig. 17).

The incorporation of other smaller towns on the website would extend the project and broaden the scope of the information on the heritage of the province. In this case, the website created should be updated constantly to provide information on current activities or latest news and events.

All the information corresponding to both the virtual scenarios and the point clouds that appears on this website can be visualized using free software.

The virtual scenarios and videos are embedded, so they are displayed on the web page and no additional free software facilitating access to information is needed. This makes the service easier and more attractive to potential tourists.

Figure 17: Downloading the point clouds to visualize the 3D model of the monument from seven different viewpoints.

Following the creation of the web page, the transfer of project results to other educational, scientific and social institutions is assured, since it fulfills one of the initial objectives of this research project. All the information obtained is on the website, and can be used for future projects (Fig. 17).

According to the Charter of Krakow 2000, the use of modern technologies, data banks, information systems and virtual presentations in the heritage catalogue should be promoted. In this respect, this website complies with this principle in each of the monuments and declared Cultural Interest Sites included.

First of all, the use of modern technologies is enhanced, in our case by using panoramic spherical photography and measurement by laser scanner.

Second, the information is stored in a data bank. In this respect, all information on the website is hosted on a server at the University of Extremadura. Each site of cultural interest has a unique identifier as supplied by the Spanish Ministry of Education, Culture and Sport.

And finally, an information system is used in which each site of cultural interest is considered a unique element regarding the treatment and administration of the data it offers.

Sites of cultural interest are thus organized and ready for later use on the website. Virtual presentations are made available by panoramic imagery as well as videos and point clouds obtained by laser scanning. From the perspective of touristic promotion, this is the ultimate aim and must comply with the website that presents the hypermedia atlas**.**

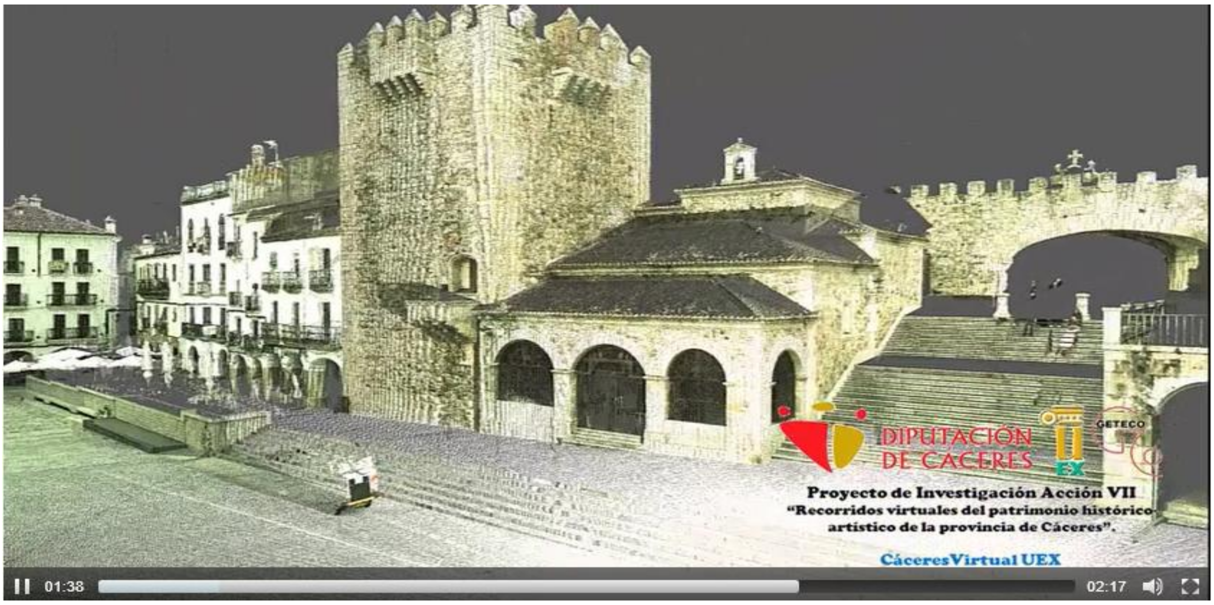

Figure 16: Video obtained from the point clouds measured by TLS.

7. Discussion

Today's tourist plans trips by doing prior searches for information online to make an informed choice of their preferred attractions and planning visits accordingly. The best way to ensure the development of emerging tourism is to offer information that realistically represents the points of tourist interest in order to attract potential visitors' curiosity. This information and its inclusion on an accessible website are no substitute for traditional documentation, but they do provide an improved overall view of the site.

Spherical panoramic views, virtual tours and videos allow the tourist to discover new places and to familiarize themselves with the cultural interest sites in greater detail through their capacity to recreate itineraries that simulate real tours. Moreover, they allow the visualization of the heritage at any moment and from any point. Point clouds are also useful in this respect as they make possible the 3D reproduction of monuments and cultural interest sites for different purposes.

Cáceres enjoys a rich heritage of great importance. The better its state of conservation and enhancement, the greater the benefits. Its exploitation has a positive impact on the province as a cultural resource both for locals and tourists. In addition, the new technologies and the economic crisis have revolutionized tourism, giving rise to new communication and attraction strategies.

The quality of detail and precision in the measurement of each monument is part of a unique and novel inventory. Not only do these results contribute to improving decisions regarding future restorations, but also respond to the challenges of preserving the quality of these artistic testimonies.

On the international level there are several websites offering virtual tours, of which Google Street View (www.google.es/intl/es/streetview/) is probably the most used, but these are only available for places accessible to vehicles. Panoramic photographs are added to these tours by some visitors in pedestrian areas, though this has yet to be done in Extremadura.

Nevertheless, Google has created a more selective website for emblematic sites around the world: Google Arts & Culture (www.google.com/culturalinstitute/beta/). In the case of Extremadura, virtual visits are only offered to sites in Cáceres and Mérida.

On the national level, many websites offer virtual toursand explore the most representative pieces of Spanish heritage in 360º, such as www.españaescultura.es, but none of these cover Extremadura. Another is www.viajesvirtuales.es, but this only includes panoramic 3D scenarios, not virtual tours, and none in Extremadura.

On a regional level, several websites have also been created along the same lines, such as www.extremaduravirtual.net, www.extremadura360.es. In these cases, the user can access virtual visits, though these are limited to a few sites of cultural interest selected from the heritage of Cáceres.

The above mentioned websites generally agree with our project regarding the promotion of heritage tourism and the offer of virtual visits. Even so, the visits offered to the user are scarce considering the rich heritage of Cáceres.

Our website differs from these in terms of 3D scenarios, videos and point clouds measured using the laser scanner. As far as the historical and artistic heritage of the province of Cáceres is concerned, it is the only website available on the net that offers resources such as tourist promotion, valuation and cataloguing of sites of cultural interest free of charge.

Our website therefore complements and improves the information that can now be consulted on the internet regarding the heritage of the province of Cáceres (Caro, Luque, & Zayas, 2015; Jamhawi & Hajahjah, 2016; Li, Whitlow, Bitsura-Meszaros, Leung, & Barbieri, 2016).

8. Conclusions

The concept of an element of cultural heritage must be established in society so that we all become aware that any damage it comes to or the way in which it is benefited affects us. Tourists and, indeed, locals sometimes fail to appreciate the rich heritage of Extremadura because they do not have the right tools to do so.

It is essential to do everything possible to facilitate the transference of knowledge of cultural heritage among administration, experts and the public.

In this regard, the regional policy of Extremadura is committed to the modernization and transformation of interior tourism as a potential and complementary source of economic activity in an attempt to transcend classical items, such as rural tourism, which tends to focus on nature alone, and urban tourism with its one-night stays, to a new more comprehensive form of tourism.

This new model facilitates knowledge and enjoyment in regional terms. As a direct consequence, the duration of the typical stay is expected to increase. To help achieve this goal the tourist can review and evaluate the vast cultural heritage of Cáceres in advance by means of the hypermedia atlas.

From these general benefits, other more specific and detailed ones arise, as listed below:

1) The application of information and communication technologies to promote and document heritage.
2) The promotion and dissemination of information on monuments with free and open access.
3) The creation of a highly accurate 3D geometric model for future study, research and intervention on monuments.
4) The transfer of project results to institutions and educational, scientific, and social entities.

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