Laser Scanner in Works of Art and Historical Monuments Monitoring

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Key words: Laser Scanner, survey

SUMMARY

In order to monitor and maintain the identity of monuments and historical sites of a region and preserve their cultural development, three-dimensional models represent a precise monitoring and logging tool alternative, allowing the viewing of works of art in great detail. There are several ways to view historical monuments and/or works of art in a virtual reality. Among these it can be mentioned the 3D laser scanning, also known as High Definition Survey (HDS). This modern system is a valuable tool in acquiring and processing the edifications data. Using the laser scanner, three-dimensional surveys could be done, accurately reflecting the state of objects. The acquisition and generation of information is fast and accurate, dramatically reducing the response time of several segments, including architecture.

The aim of this paper is to present projects of surveys from scanning lasers applied to works of art and historical monuments in order to demonstrate the relevance of the technique for making decisions on their conservation, preservation and restoration, since products generated by the system are of pinpoint accuracy consistent with the architecture and can be quickly obtained. In order to expose this work results, the survey was made in five historic sites, highlighting the application of laser scanner technique. 3D models of Pazo Quiñones de León facade, Neuschwanstein Castle, Neubrueck Chapel, Paiol Theatre and Bruchsal Baroque Castle have been shown. With the laser scanner applications presented throughout this work, it is concluded that it is a valuable tool in monitoring works of art and historical monuments. Not only for the time processing and analysis, but also for the richness of detail, once this system is able to capture topographic information in inaccessible places such as ceilings and irregular galleries, in the case of monuments, or even in places difficult to visualize, in case of the sculptures and / or works of art.

It is observed that the present work is of relevant significance in the generation of three-dimensional models, which in turn are important for planning and implementing projects of restoration, conservation and preservation of assets. After obtaining the data from laser scanning, the objects of interest are evaluated and it is obtained the 3D model in orthogonal projection from which the measures can be extracted.

RESUMO

No sentido de monitorar e manter a identidade de monumentos e patrimônios históricos de determinada região e consequentemente preservar seu desenvolvimento cultural, os modelos tridimensionais representam uma alternativa precisa de monitoramento e registro, que permitem a visualização de obras de arte com riqueza de detalhes. Há diversas formas que permitem a visualização numa realidade virtual de monumentos históricos e/ou obras de artes.

Entre essas pode-se citar o 3D Laser scanning, também conhecido como High Definition Survey (HDS) ou sistema de levantamento por varredura a laser. Esse sistema, além de moderno, constitui uma valiosa ferramenta na aquisição e tratamento de dados para o levantamento de edificações. Com a utilização do laser scanner, podem-se realizar levantamentos tridimensionais, refletindo exatamente o estado dos objetos. A aquisição e a geração das informações são rápidas e precisas, reduzindo drasticamente o tempo de resposta de diversos segmentos, inclusive a arquitetura.

O objetivo deste trabalho é apresentar projetos de levantamento de varredura a laser aplicado a obras de artes e monumentos históricos com intuito de demonstrar a relevância da técnica para a tomada de decisões na conservação, preservação e restauração dos mesmos, já que produtos gerados pelo sistema são de precisões milimétricas coerentes com a arquitetura e podem ser obtidos de forma rápida. Com intuito de expor os resultados deste trabalho, fez-se o levantamento de cinco patrimônios históricos, destacando a aplicação da respectiva técnica do laser scanner. Foram demonstrados os modelos 3D da Fachada do Pazo Quiñones de León, Castelo Neuschwanstein, Capela de Neubrueck, Teatro do Paiol e Castelo Barroco de Bruchsal. Com as aplicações do laser scanner apresentadas ao longo do trabalho, conclui-se que o mesmo é uma valiosa ferramenta no monitoramento de obras de arte e monumentos históricos. Não apenas pela vantagem do tempo de análise e processamento, mas também pela riqueza de detalhes, pois tal sistema é capaz de capturar informações topográficas em lugares inacessíveis como tetos e galeria irregulares, no caso dos monumentos, ou mesmo em lugares de difícil visualização, no caso das esculturas e/ou obras de arte.

Observa-se que o presente trabalho é de relevante significado na geração dos modelos tridimensionais, que por sua vez são importantes para planejamento e execução de projetos de restauração, conservação e preservação de bens patrimoniais. Após a obtenção dos dados da varredura a laser do objeto de interesse, estes são processados e tem-se o modelo 3D em projeção ortogonal do qual as medidas podem ser extraídas.

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1. INTRODUCTION

The intense search of the man by knowledge of their origins and their concern about how cultures have developed, reveals the relentless pursuit of its historical significance. Once your story is a reflection of its cultural development, there is a yearning in society to find their own meaning through monitoring of buildings and historical monuments.

In Brazil there are cities with an extensive wealth of monuments and historical sites. Among the states awarded a grand collection of monuments can cite the Bahia, Minas Gerais, and among others the own state of Pernambuco in Brazil.

According with Amorim (2008), all this magnificent collection, extremely important for the Brazilian identity, has passed over the last decades has spent over the past decades, several conservation actions. However, these processes do not ensure more effective conservation of such property, either for lack of human and financial resources or lack of a policy of strategic planning, unfortunately the historical and cultural identity of these monuments have been modified and even destroyed over some preservation actions.

An example of the loss of originality of some monuments undergoing preservation activities lies in the Basilica and Convent of Nossa Senhora do Carmo, located at Praça do Carmo, Olinda, Pernambuco, Brazil. In Figures 01 and 02, it can be seen that originally wooden windows are being replaced by a more modern and glass.

Figure 01: Conventional timber windows
Source: Clayton Mamede

Figure 02: Lateral with modern glass
Source: Clayton Mamede

In order to monitor and maintain the identity of monuments and historical heritage of a region and thus preserve their cultural development, the three-dimensional models represent an alternative precise of monitoring and recording, which allow viewing of works of art with great detail. These tools allow historic heritage and / or works of art are portrayed in virtual reality. Among the ways to generate three-dimensional models can cite the 3D laser scanning, also known as High Definition Survey (HDS) or lifting system for laser scanning. This system, in addition to modern, constitutes a valuable tool in the acquisition and processing of data for the survey of buildings.

In the last ten years, the techniques of monitoring and collection of data in worldwide have been developed on a large scale. In Brazil, the laser scanner has been used, representing a new research tool for Photogrammetry and Remote Sensing, of global trend.

with the use of the laser scanner can be made three-dimensional surveys, accurately reflecting the state of the monuments and works of art. The acquisition and generation of information is fast and accurate, reducing drastically the response time of several segments, planning, geology, geotechnical engineering, civil engineering, architecture and others.

The possibility of obtaining a large amount of information and process them quickly allows the laser scanner system and analyze the strategic plan simultaneously, reducing greatly the time between office work and field.

2. OBJECTIVES

2.1 General Objectives

Submit designs of laser scanning survey applied to works of art and historical monuments aiming to demonstrate the relevance of the technique for making decisions on conservation, preservation and restoration of the same, since the products generated by the system are consistent have a millimetric precision consistent with architecture and can be generated quickly.

2.2 Specific Objectives

2.2.1 Explain the operation and processing of laser scanner for architectural projects;
2.2.2 Show applications of the importance of laser scanning for architecture;
2.2.3 Propose a tool that contributes to agility in conservation projects, conservation and restoration of works of art and historical monuments.

3. OPERATION WITH LASER SCANNER

According Centeno (2007), laser scanning system (laser scanning) is a method for determining of three-dimensional coordinates of points on the earth's surface. Its operation is based on the use of a laser pulse that is raised toward the surface. Upon reaching the surface, part of the signal emitted is reflected toward the sensor.
The laser scanning system can be divided into three main components that are, the unit of measurement laser in charge of sending and receiving the signal laser, a system scanner optical and a unit of registry and metrics support. (BALTSAVIAS, 1999).

The sensor measures both the intensity of the return signal as well as the time elapsed between emission and reception of the return, which is used to calculate the distance sensor-object, whereas the laser pulse propagates at the speed of light. Based on the distance between the sensor and the surface of the earth and the orientation of the beam, is determined the three-dimensional location where the beam is reflected. To calculate the position of each point, the instrument logs, In addition to the time, the orientation of the sensor at the instant of the emission / record of the pulse and the exact position of the platform carrying the sensor.

The set of the data three-dimensional generated is often called cloud point, as can be represented by a dense concentration of observations in three dimensional space (Wutke, 2006).

This set of measurements is a cloud of points with three-dimensional coordinates of irregularly distributed on the surface of the monument and / or sculpture and intensity RGB (red, green, blue) (Figure 03). And it can be treated in two ways: as a data vector or raster format, which is rendered as a regular grid. The second option is usually more adopted because it implies in reducing the amount of data. Programs and software are being researched to separate the information from point cloud, in other word, grouping points in regions with the same properties. (continuar na Terceira página)

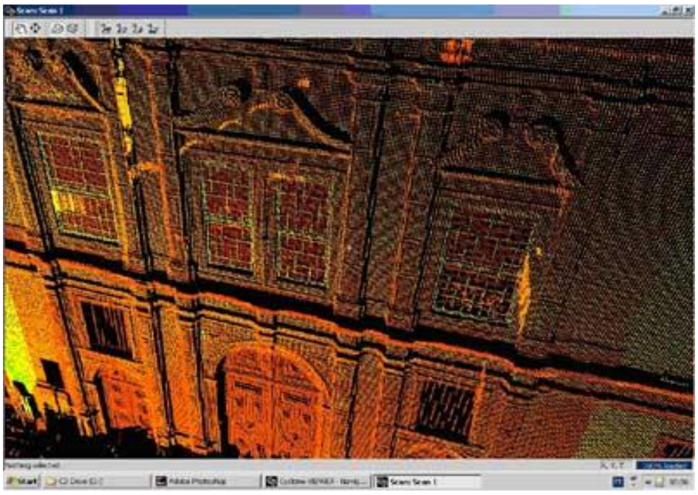


Figure 03: Point Cloud Church of St. Francis (Salvador-BA)
Source: Heritage and New Media: Scanning and GIS - Vol 3, No. 1 (2009)

In the case of monitoring of historical monuments, it is important to note that can find some obstacles such as trees, poles, walls, etc. In this case, the time of return pulses can be the solution to indicate the position of the point associated with the object of study or the point associated with the obstacle.

Although the use of the laser scanner has grown considerably in recent years, according to Medina (2011), in Brazil, the vast majority of documentary architectural surveys for monitoring and logging heritage, for overturning or even for interventions or restorations of buildings, not using terrestrial laser scanner. There is a clear need for the expansion of knowledge about the terrestrial laser scanner to professionals such as architects, engineers and restorers because it is an important tool for obtaining fast and accurate data essential for documentation and disclosure of assets and architectural.

It is important to highlight that there are several types of 3D scanner ranging according system of the scanning, measuring the distance and speed intervals of measurement. These will suit each project according to its accuracy and necessity because the accuracy and amount of points measured vary according to the type of scanner used.

4. PROCESSING TERRESTRIAL LASER SCANNER IN DESIGN OF ARCHITECTURE

The lifting of a laser scanner on the facade results in a cloud composed of three-dimensional points which are given in Cartesian coordinates, along with the information of intensity. The laser survey should be conducted at a distance that is ideal to have, preferably, a single cloud of entire facade of the work or monument, ruling out the possibility of more than one position (station).

In possession of the point cloud acquired by laser scanner, then can be performed manually the cleaning all the unwanted points and not belonging to the facade or artwork. This process is considered an operation of filtering, and provides a cloud clean unwanted points such as vegetation, towers, walls and other potential obstacles. Furthermore, each point can be linked to a radiation which corresponds to a value between 0 (zero) and 1 (one) and zero for darker materials and one (1) to the lighter.

The results depend on the software used, which determine the matrices responsible for the addition or removal of objects in images, and the effects depend on the shape or size, which are generally defined by the user based on their application. As to the facade, the classification performed after the cloud according to the intensity values obtained for the various materials found, for example, granite, white wall, iron etc., it is replaced by staining with different intensities, according to the respective materials.

According Tomasselli (2003) laser scanner has been increasingly used in land surveys, due to its advantages such as high speed data collection and processing, high point density and homogeneous accuracy of measured points. This sweep provides several important characteristics such as:

4.1 It is an active method that does not rely on reflected visible light, although some models have scanners inappropriate behavior in the total absence of light;
4.2 Remote operation, which means that the object does not need to be touched;
4.3 The principle geometric calculation of the coordinates can be triangulation, time intervals or phase difference, depending on the model, but in all cases the scanning can be done with only one station per target;
4.4 The answer is available in real time, after the scan operator has at his disposal millions of points with known coordinates, being able to provide answers about the objects as distances between parts, dimensions, volumes, vertical surfaces, etc.;
4.5 High density of points collected and hence very high redundancy in the description of discrete objects;
4.6 It is possible to perform quality control during the collection and redo if necessary;
4.7 Operation simple and flexible, just one operator to position and operate the system;
4.8 You can combine several numerical models generated from different positions, which can cover almost the entire visible surface of objects;
4.9 Some systems have software for obtaining parametric descriptions of objects by setting the point cloud, which allows an greater accuracy in relation to isolated points; in addition, due to the high density points yhe automatic tools of some systems make search

of the points belonging to the same objects or surfaces with little operator interaction, which substantially increases the productivity.

The laser scanning system of land surveys exposed in this research is static and can be classified according to the principle of its operation into three groups, the first being the first time-of-flight or time interval also called LIDAR (Light Detection And ranging), it estimates the distance through the return time of the laser pulse (Time of Flight) emitting thousands of pulses per second. The pulse is diffusely reflected by the object and part of it returns to the system (Wutke, 2006) (Figure 04).

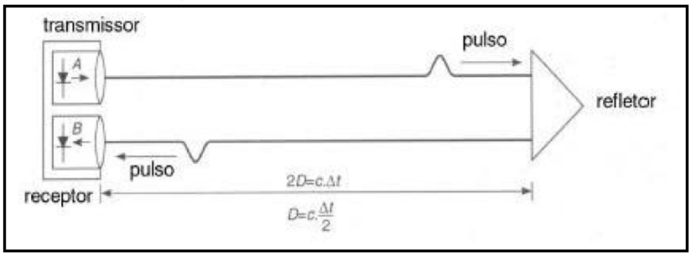


Figure 04: Principle of scanning time-of-flight (time interval)
Source: MAIA, 1999

The second principle is based on the phase difference, scanners based on this method operate according Maia (1999) from the following evidence: the measure of phase difference between the transmitted and reflected signals, of the fractional part of the total length is less the value of the integer of the wavelength-modulated (FIGURE 05).

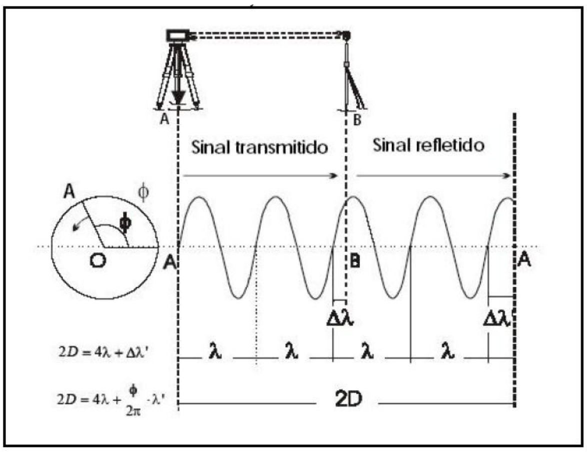


Figure 05: Determination of distances by road double
Source: MAIA, 1999

And the third principle is based on triangulation, where a laser pulse is emitted by the system and the light reflected from the object is recorded by one or more sensors `s CCD (Charge Coupled Device) digital cameras (Wutke, 2006). This kind of sensor transforms the reflected light into electrical signals that in turn are converted into bits through a circuit termed analogue to digital converter. The sweep angle of the pulses is recorded in the system laser scanner every pulse emitted. Knowing the fixed base between the laser sensor and the camera through a calibration process determines the position of the points reflected by the object (FIGURE 06).

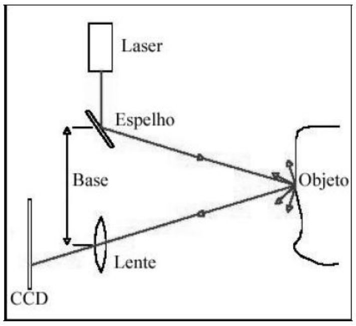


Figure 06: Scanner based on the principle of triangulation
Source: BOEHLER apud Wutke, 2006

5. APPLICATIONS OF LASER SCANNER IN PROJECTS OF ARCHITECTURE

Wutke's (2006) research show that the laser scanner for applications in the field of architecture and documentation of historical heritage, and geometry are important information reflectance surfaces and also the colors for the complete description of the object under study.

In order of publish existing jobs using the scanning system for monitoring of works of art and historical monuments, was conducted survey four projects with the technique.

5.1 Facade of the Palace of Quiñones de León.

The facade of the Palace of Quiñones de León, which is a typical house of the aristocracy in the region of Galicia of century XVII and is located in the city of Vigo, Spain. With the laser Terrestrial Laser Scanner 390zi of Riegl was performed the survey on the facade which has an area of approximately 30 meters long by 15 meters high (Figure 07).

Figure 07: Paco de Quiñones de León Figure 08 Cloud of points gained by the Laser Scanner Sources: Medina et al 2011

The laser survey was conducted at a distance of 41 meters away so that had just one cloud around the facade. The dot density was 1 (one) inch spacing which provided us with a cloud of 5,888,344 points. Figure 08 shows the point cloud acquired by laser scanner.
Having the point cloud acquired by Laser Scanner was performed manually the cleaning. This is the removal of unwanted and all points outside the façade, thereby obtaining a cloud cleaner. The intensity of reflection Riegl magnetic scanner is between 0 (zero) and 1 (one) and zero for darker materials and one (1) to the lighter. The choice of the value of the intensity of the different materials was performed manually in different parts of the facade, thus covering its entire length, thereby obtaining multiple values for the same material. With these values we performed a simple arithmetic average for each material and used as a reference for classification of the point cloud of the facade.

After obtaining the average values of intensities of materials existing in the facade, was classified the information of different interest. To extract the contours of the features of interest, applied mathematical models able to define the contours desired.
The first results obtained with the methodology was cleaning the cloud of elements that do not belong to facade as soil, vegetation and fountain that was in front of the facade. Figure 09 shows the result of manual cleaning performed on the point cloud laser.

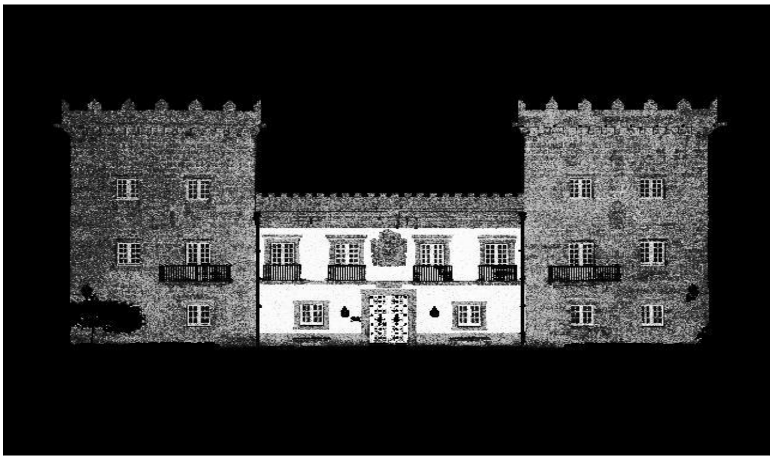


Figure 09: Result of cleaning performed on the point cloud
Source: Medina, 2011

Figure 10 shows the facade after performed the classification of the cloud with the intensity values obtained for the various materials found, namely, granite, white wall and iron.

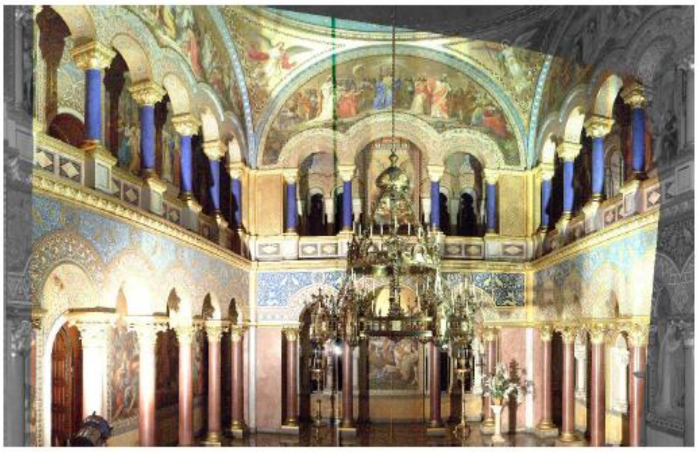
Figure 10: Facade classified (in blue granite, white wall in red and yellow iron)
Source: Medina, 2011

The application of laser scanner in this study used the value of the intensity as parameter of the classification, this allowed verification and obtaining satisfactory results. It was evident that this kind of monitoring allows the extraction of important characteristics that make up the facades of historic buildings.

5.2 Castle Neuschwanstein

The objective of this project was to document the interior of Castle Neuschwanstein in Germany and create a three-dimensional model with actual colors and textures. Figures 11 and 12 show the interior of the castle: The reflectance image is superimposed with the information corresponding to the RGB (Red, Green, Blue) captured by the camera attached in laser scanner unit (ABMAYR et al, 2004).

In this study we used the scanner Imager 5003 of Z + F to generate the point cloud, this was coupled a chamber Eye Scan with a system of rotation integrated of 360 ° in the sensor CCD to obtain the photographs allows an overview photorealistic of the castle.



Figures 11 and 12: Interior Castle Neuschwanstein
SOURCE: ABMAYR et al, 2004

The authors show the development of the laser scanner in projects accurate and with large dynamic reflectance property of the objects represented, allowing the generation of color maps and geometry of Castle Neuschwanstein.

5.3 Chapel of "Neubrueck"

The example of the chapel of "Neubrueck" which is in Switzerland represents a typical application of laser scanner for historical and cultural. In this case, the four sides were scanned and the chapel was also performed a scan within. The scenes were recorded (together) using spheres as targets. Additional information was obtained on the basis of point cloud registration. As mathematical information, volumes and distances were calculated, and also a 3D model was created. The following figures show the point cloud (Figure 13) and the 3D model with textures (Figure 14) (INGENSAND & SCHULZ, 2004).

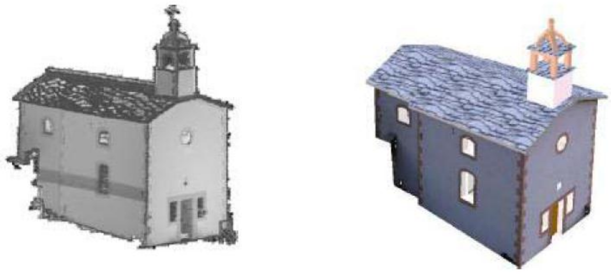


Figure 13 and 14: Point Cloud and 3D model of the Chapel "Neubrueck"
SOURCE: SCHULZ & INGENSAND, 2004

5.4 Theater of Paiol

The laser scanner was used to generate three-dimensional model of Paiol Theatre in the city of Curitiba. This building was built in 1874 and was used as a magazine of powder. This is an old depot of gunpowder, circular building that has been disabled by the Army of Brazil. In 1971 this old armory was recovered and transformed into an theater of arena. Keeping the characteristics of the original construction, the building was renovated to house a theater shaped arena with 225 seats. This theater called Theatre of Paiol, was opened in 1971 and is part of the tourist attractions of the city of Curitiba in Brazil.

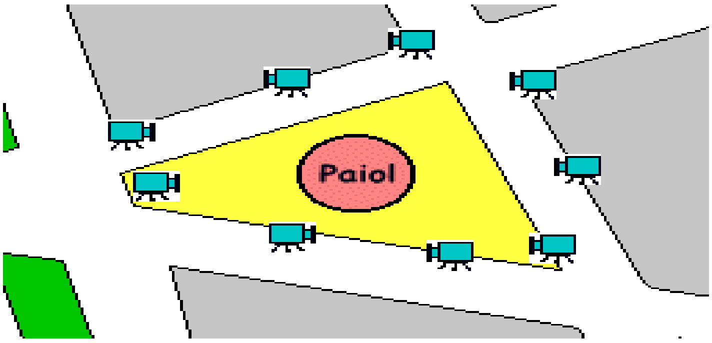


Figure 15: Sketch stations acquisition
Source: Centeno, 2007

After the survey, the data are processed to generate three-dimensional model of the object. The final step is generating of the three dimensional model for display.

For the visualization of the three dimensional model, there are three alternatives. At first, the model can be viewed only as a surface without texture. The second option is to use the data from the intensity of the return as texture. This option allows a representation more realistic of the object, but the spectral information from the laser scanner is very poor, this is the reason that discourages the use of this data. The best alternative is the use of the photographic image obtained during the survey. The images can be overlaid on the three-dimensional model, thus creating a realistic view of the object. The figure 16 shows the result of the superposition of textures derived from images in three-dimensional model of the theater Paiol.

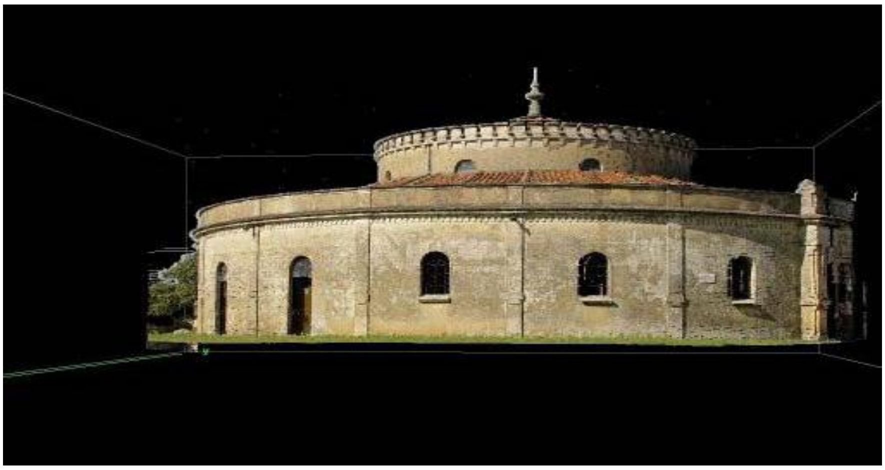


Figure 16: Facade of the western theater Paiol
Source: Centeno, 2007

It is important to remember that taking pictures of some obstacles hindered the surveys. Figure 17 shows some more problems caused by such obstacles. Senses a failure of covering in the lower of the roof due the impossibility of positioning the apparatus in a location higher to cover the region. Also in this same image may be noted the absence of data in the upper region of the roof caused by a tree located in front of the imaging area.

Figure 17: Facade of the eastern theater Paiol
Source: Centeno, 2007

It is also worth reporting that during the survey, conditions lighting varied and with this the colors in the pictures were different. The problem has worsened due to the time of image acquisition, around 15-16 hours when the sun is already quite low.

6. CONCLUSIONS

The laser scanner is a valuable tool in monitoring of works of art and historical monuments. Not just for the advantage of the time of analysis and processing, but also for the richness of details, as this system is able to capture topographic information in inaccessible places like ceilings and gallery irregular in the case of monuments, or even in places difficult to visualize, in case of sculptures and / or works of art.

One of the great advantages of a scanning laser scanner is no need to obtain homologous points for the generation of three-dimensional model, which facilitates the generation of models.

The three-dimensional models are important for planning and implementing projects of restoration, conservation and preservation of assets, after obtaining data from laser scan of the object of interest, they will be prosecuted and will have three-dimensional model in orthogonal projection in which the measures can be extracted from the model obtained.

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