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ARCHIVO DEL LABORATORIO DE DOCUMENTACIÓN GEOMÉTRICA DEL PATRIMONIO

LABORATORY FOR THE GEOMETRIC DOCUMENTATION OF HERITAGE'S ARCHIVE

Sección de proyectos fin de carrera / Undergraduate master projects section

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Información general / General information		
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Resumen	
TITULO:	Documentación geométrica y reconstrucción de la iglesia del Monasterio de San Prudencio (La Rioja, España)
RESUMEN:	Este proyecto es el resultado de la colaboración de dos universidades: la Universidad del País Vasco (UPV/EHU) y la National Technical University of Athens (NTUA). También forma parte de un proyecto de mayor envergadura que ha tenido lugar en el Monasterio de San Prudencio de Monte Laturce (Clavijo, La Rioja) que ha sido desarrollado por profesores y estudiantes de ambas universidades conjuntamente a la Univesidad Politécnica de Madrid, la HafenCity University of Hamburg, la Università degli Studi di Siena y la Vilnius Gediminas Technical University como parte de un programa intensivo ERASMUS. Dicho proyecto ERASMUS tiene como objetivo la documentación geométrica de las ruinas del conjunto monástico mediante las técnicas más adecuadas para cada situación como punto de partida para la difusión del conocimiento del monumento y, en una futura instancia, su protección y preservación. Como parte de este proyecto, el trabajo fin de carrera se centra en la documentación de la iglesia del Monasterio (que ocupa una superficie de 20 x 7,5 metros) y su reconstrucción virtual. La documentación se ha realizado mediante modelos tridimensionales y ortofotografías. Se han utilizado dos aplicaciones informáticas de fotogrametría (*Photomodeler* e *ImageMaster*) combinando los mejores resultados para el producto final. El trabajo se completará con el modelado virtual y reconstrucción de la iglesia, esta fase se realizará en la NTU de Atenas y tiene prevista su finalización en febrero de 2012. Los resultados serán puestos a disposición pública de las universidades participantes en el proyecto ERASMUS con la esperanza de que sean una herramienta útil para futuros proyectos de investigación y formen una base de conocimiento que ayude a la protección del monumento.
DESCRIPTORES NATURALES:	patrimonio, ortofotografía, fotogrametría
DESCRIPTORES CONTROLADOS:	(Procedentes del Tesauro UNESCO [http://databases.unesco.org/thessp/]) Patrimonio Cultural, Ingeniería de la Construcción, Fotogrametría

Abstract	
TITLE:	Geometric documentation and reconstruction of the church of the Monastery of San Prudencio (La Rioja, Spain)
ABSTRACT:	This diploma thesis is the result of a collaboration of two universities, the University of the Basque Country (UPV/EHU) and the National Technical University of Athens (NTUA). It is part of the bigger project of the documentation of the Monastery of San Prudencio at the province of La Rioja at Spain, which is undertaken by professors and students of the University of the Basque Country and with the contribution of six universities of Europe (National Technical University of Athens, HafenCity University of Hamburg, Polytechnic University of Madrid, University of Studies of Siena, Vilnius Gediminas Technical University) as part of an ERASMUS educational Intensive Programme. This ERASMUS project aims to document the whole Monastery by all the adequate, in any case, methods with the long-term target to make the large history of the monument known to the habitants of the region and the rest of people and to be the background of the measurements that the government will take to protect it. As part of this project, this diploma thesis deals with the documentation of the church of the Monastery and its 3 dimensional virtual reconstruction. The documentation has been done with 3Dmodels and orthophotos. All of these methods were used to represent the whole church which consists of four walls the size of which is about 20 by 7.5 meters. The 3D model as a step to make the orthophoto and also as a tool to represent the object was made with *Photomodeler Scanner 6* and *ImageMaster* and was merged with the software *Rapidform*. The results that these two software gave us were evaluated and, at the end, the best parts of every software were used. The orthophotos were created with *ImageMaster* and where it was necessary (more than one orthophoto for one wall), they were combined within *AutoCAD*. Moreover, for completing the project of the documentation of the whole church, another part of the work must be done at the NTUniversity of Athens. This is the documentation of the outside part of the church with the same methods that the inside part has been created. Next part of this diploma thesis is the 3 dimensional virtual reconstruction of the church, something that is going to start at the NTUniversity of Athens, with the hope to be finished and presented by the end of February 2012. This reconstruction will be a representation of how the church was in the past according to historical sources that are available and with the close collaboration of archaeologists. The initial thought is that this 3Dimensional reconstruction will be created based on the 3 Dimensional models that already exist as part of this diploma thesis. All the results will be sent, saved and ready for being used in the future by the six universities which participate at the ERASMUS Intensive Programme , hoping to be a useful tool for related projects and to be a part of the base on which actions of protection for the monument will be taken.
NATURAL KEYWORDS:	heritage, ortophotograph, photogrammetry
CONTROLLED KEYWORDS:	(From the UNESCO's thesaurus [http://databases.unesco.org/thesaurus/]) Cultural Heritage, Construction engineering, Photogrammetry

Estructura / Framework

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Field of Surveying Engineering
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GEOMETRIC DOCUMENTATION AND RECONSTRUCTION OF THE CHURCH OF THE MONASTERY OF SAN PRUDENCIO (LA RIOJA, SPAIN)

Diploma Thesis

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Vitoria Gasteiz, July 2011

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Abstract

This diploma thesis is the result of a collaboration of two universities, the University of the Basque Country and the National Technical University of Athens. It is part of the bigger project of the documentation of the Monastery of San Prudencio at the province of La Rioja at Spain, which is undertaken by professors and students of the University of the Basque Country and with the contribution of six universities of Europe (National Technical University of Athens, HafenCity University of Hamburg, Polytechnic University of Madrid, University of Studyings of Siena, Vilnius Gediminas Technical University) as part of an ERASMUS educational Intensive Programme. This ERASMUS project aims to document the whole Monastery by all the adequate, in any case, methods with the long-term target to make the large history of the monument known to the habitants of the region and the rest of people and to be the background of the measurements that the government will take to protect it.

As part of this project, this diploma thesis deals with the documentation of the church of the Monastery and its 3 dimensional virtual reconstruction. The documentation has been done with 3Dmodels and orthophotos. All of these methods were used to represent the whole church which consists of four walls the size of which is about 20 by 7.5 meters.

The 3D model as a step to make the orthophoto and also as a tool to represent the object was made with *Photomodeler Scanner 6* and *ImageMaster* and was merged with the software *Rapidform*. The results that these two software gave us were evaluated and, at the end, the best parts of every software were used.

The orthophotos were created with *ImageMaster* and where it was necessary (more than one orthophoto for one wall), they were combined within *AutoCAD* .

Moreover, for completing the project of the documentation of the whole church, another part of the work must be done at the NTUniversity of Athens. This is the documentation of the outside part of the church with the same methods that the inside part has been created.

Next part of this diploma thesis is the 3 dimensional virtual reconstruction of the church, something that is going to start at the NTUniversity of Athens, with the hope to be finished and presented by the end of February 2012. This reconstruction will be a representation of how the church was in the past according to historical sources that are available and with the close collaboration of archaeologists. The initial thought is that this 3Dimensional reconstruction will be created based on the 3 Dimensional models that already exist as part of this diploma thesis.

All the results will be sent, saved and ready for being used in the future by the six universities which participate at the ERASMUS Intensive Programme , hoping to be a useful tool for related projects and to be a part of the base on which actions of protection for the monument will be taken.

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0. Intoduction

Nowadays, the constantly advancing technology permits to the mechanics and more specifically to the surveyor engineer who occupies with the documentation of monuments to have a lot of results with sufficient accuracy. The new technology at the fields of surveying, photogrammetry and laser scanning is a very useful tool for this kind of documentation.

Surveying is the science and technology of measuring the physical features of the natural and artificial environment using specialized equipment and procedures to obtain highly accurate results. It is the base of every science-method that deals with the high accuracy documentation. Its methods include clasic surveying measurements (total station, GPS[1]), photogrammtry and laser scanning. These fields of collecting and representing data can be used and combined in an adequate way depend on the desirable result.

Basic aim of this diploma-thesis was to represent the church and make the reconstruction of it, by creating orthophotos and the 3 Dimension model. For achieving it, surveying and photogrammetric data were collected. Some laser scanning data, previously collected by other project of the ERASMUS programme were also examined, as it is analysed below, in order to evaluate if they could give information that would help this project.

During the following chapters is described both the theoretically aspect of the documentation of monuments and the practically part of this specific documentation with all the results and the conclusions. More specifically, the first chapter refers to the current situation of the documentation in the world and to the different techniques and methods of it. At the second chapter is described briefly the monument regarding its location and history. The third chapter analyses all the procedure for taking, managing the data and representing the result. At this part, is analysed the work on the field and the office work with all the taken parameters, the challenges and some examples of the results which are completely presented at the forth chapter. Last but not least the fifth chapter refers to the conclusions and the proposals of this diploma thesis that will be completed by February of 2011 after the part regarding the reconstruction is done.

[1] Global Positioning System

Chapter_1: Geometric Documentation of Monuments

The geometric documentation of monuments is the procedure of taking, processing, archiving and presenting data for the determination of the location, the shape and the size – dimensions of a monument at a specific time[2].This documentation is absolute necessary for the knowledge and protection of the heritage.

1.1. Current situation for the protection - documentation of monuments

In our age the science and the technology has done enormous steps of progress and gives to our generation all the suitable tools to protect the only material signs of our previous civilisation - our monuments. Nowadays, are known many techniques to conserve, rebuilt, redevelop and generally to help the monuments to stay alive during the pass of time. First step for doing that is of course the registration – documentation of them.

Moreover, the documentation is not only necessary for rebuilding the monument or remembering it, in case that it will be ruined, but also for educational reasons. Students and people in general can ´´see´´ and study the monument through its model or photos.

In this effort to save the remains of our history and culture and offer educational possibilities, many scientists participate in different congresses that take place around the world with main aim to decide in collaboration with the governments measurements and laws related to the protection of the cultural heritage.

Some of the most important congresses, are the one of Athens in 1933 (Athen' s charter),of Amsterdam in 1975 (The Declaration of Amsterdam), the European Charter of the Architectural Heritage, which was adopted by the Council of Europe and so on. One of the most important charters for the conservation and restoration of monuments and sites is the one of Venice (1964) that gives an international framework for the preservation of ancient buildings. Its articles have definitions and suggestions of conservation, restoration, excavation, publication related to monuments. The last article of publication was the introduction of the digital libraries of nowadays as it was referred to archiving and publishing all the stages of the work in order to be available in the future.

One of the decisions of this congress was the establishment of the International Council on Monuments and Sites (ICOMOS) on 1965. It is the most valid, international, professional, nongovernmental organization, technical advisor of UNESCO [3] for the protection of Cultural Heritage with the aim of promoting the theory, methodology, technology and the provision of information about the protection and promotion of the historical monuments and sites of all the countries in the world[4]. ICOMOS currently has over 110 National Committees, which are organisations that are created at a national level. They bring together individual and institutional members and offer them a framework for discussion and an exchange of information. Each National Committee

[2] Lectures of Ioannidis Charalampos , classes of "Documentation of Monuments" (NTUA)
[3] United Nations Educational, Scientific and Cultural Organization
[4]http://www.icomoshellenic.gr/icomos_v3/default.php?pname=international-arena-activity&la=2

adopts its own rules of procedure and elaborates its own program according to the goals and aims of ICOMOS[5].

Spain and Greece, both countries with great civilization and cultural heritage need to have a strategy related to the protection of it. As members of the European Union follow the general policy which is adopted by it. They are both members of the ICOMOS with the Spanish and Hellenic National Committees of ICOMOS.

1.2. Methods of Measurement and Representation

During the years the methods for documenting an object have been changed a lot, offering to the users enough alternatives to obtain a lot of information with the desirable level of details, combining quantity and quality. These methods are classified in categories (topometric, surveying, photogrammtric, laser scanning method) depending on the equipment they use.

1.2.1.Topometric

A way to document a monument is by using simple ´´instruments´´ such as a measuring tape for measuring the basic dimensions of the object and a plumb for checking the verticality of two directions, triangles. This method does not need any difficult to move and expensive topographic instruments and under suitable conditions (small distance, not very complex shape) can obtain a good accuracy. The raw data are registered in sketches and later manually are introduced at a *CAD*[6] environment. As result the method gives distance measurements that can be represent as line drawings of the object. It is not very common to be used for document with details a monument as it is rather consuming the registration of many distances. In any case, it is quite common to take some measurement with a measuring tape at the field just for checking the final result, which of course it is not the only way to check it.

Image_1: Measuring tape

1.2.2. Classic Surveying

This method is based on direct measurements of angles, distances. The related instruments used are the theodolites and the EDM[7]. The possibilities of these instruments are nowadays combined in more advanced instruments – the total stations.

[5] http://www.international.icomos.org/natcom_eng.htm
[6]Computer Aided Design
[7]Electromagnetic Distance Measurement

For calculating coordinates are also used GPS [8] instruments which calculate 3D coordinates by measurements of time. They get signs from satellites (minimum four) and by measuring the time the message has travelled from the satellite to the instrument they calculate distances (bases). With the suitable process they can provide 3D coordinates at a global 3Dimensional system. For the measurements of altitude differences are used levelling instruments.

By using geodetic total stations, which are high accuracy instruments, the topographic method it is used usually at the documentation of monuments again where the object has a normal shape without a lot of details. The total stations measure angles and distances, so that with the suitable procesing of these data we can obtain the user 3 Dimensional coordinates. The documentation of an object can be achieved by calculating the coordinates of its more characteristic points. So when the object has not a lot of details or the user is not interested for details (the more the details, the more the characteristic points), this method is adequate. It is preferred from the previous mentioned method when the points are a lot. Also the total station measures 3D points while the tape measures 2D distances, so an intrinsically element will be better documented.

The reflectorless instruments have made possible the documentation of high or inaccessible objects. Moreover the new models permit to the user to avoid the large process of calculate the coordinates of the points, as the instrument by measuring distances and angles gives to the user directly the three coordinates in the needed coordinate system. Some total stations of new generation have even more programmes in order to do automatically calculations such as resection. Some of them have also integrated camera, the photos of which are used as sketches permitting to the user the easily recognition of the measured points.

The representation of that kind of collecting data is usually 3 Dimension vector drawings in a *CAD*[4] environment. These drawings have point and not continuous information.

For sure the topographic methods of measurements are irreplaceable in projects of documentation that requires georeference even though it is not very typical due to the complexity of the object to be used as the main method in the documentation of many monuments. Without known coordinates of a few points of the object, the following – methods might be unable to goreference the monument

Image_2: Total station

[8] Global Positioning System

1.2.3. Photogrammetric

Photogrammetry can cover the disadvantages of the previously used methods, since it offers to the user a large range of possibilities recording to 2 Dimension and 3 Dimension results. One of the biggest advantages of the method is the information of the colour. By taking at least two photos, the user can create a 3 Dimension model: wireframe, point clouds or surfaces with the more adequate colour adjustment. The model can be used to generate sections, contour lines and vector drawings and with the suitable procedure which is done by specialised softwares can be transformed into an orthophoto which is a geometrically corrected photographic image with uniform scale.

The big number of points (continuous information) and the colour can describe with a lot of details the object and make this method quite popular among the others as far as the documentation of monuments is concerned.

1.2.3.1. Classic - Stereoscopic Photogrammetry

By simulate the human vision, the classical photogrammetry needs the axes of two photos to be parallel and a ratio between the base - B (distance between the two camera positions) and the height – H (distance between the camera and the object) to be into the limits $1/10<B/H<1/3$. This permits the user to see stereoscopically the 3 Dimension Model as the human can see stereoscopically his environment.

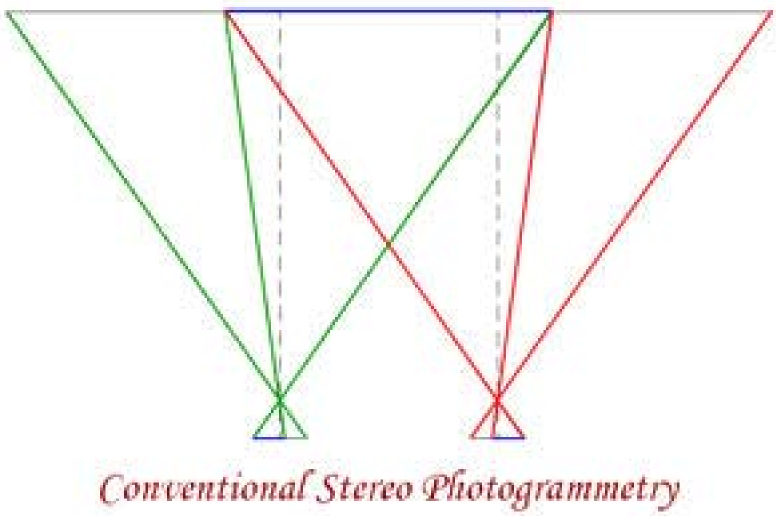


Image_3: Geometry of Stereoscopic Photogrammetry

1.2.3.2. Convergent Photogrammetry

The restrictions of classical photogrammetry (geometry of axes and base) limit the flexibility of recording data and increase the number of stereo pairs in order to resolve hidden areas. Changing the geometry and data processing strategy can solve part of this problem. The geometry that convergent photogrammetry uses, has a large overlap, practically 100% and multiple images. For a single stereo pair with 60% overlap, 40% of each image is not useable something that does not happen in this case that almost all the photo (100% overlap) is used and there is repetition. One important advantage is that the required geometry of the photos leads to more flexible position of the camera. On the other hand, it does not give the ability of stereoscopic view.

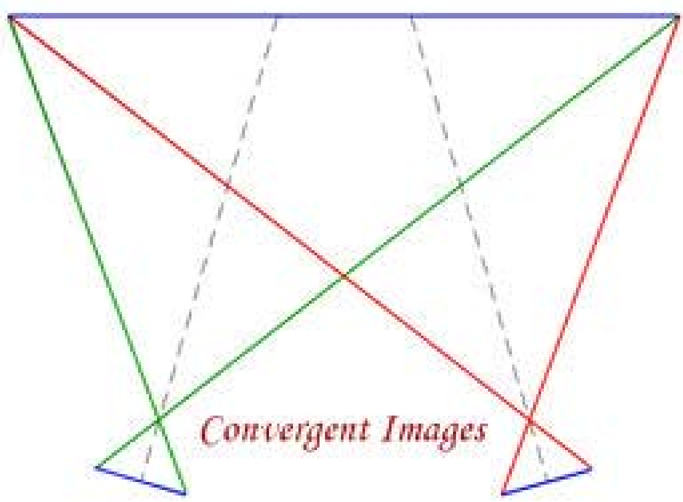


Image_4: Geometry of Convergent Photogrammetry

1.2.3.3. Single Image Photogrammetry

This kind of photogrammetry requires only one image and some control points to define a plane and gives as a final product a rectified image which is an orthophoto with uniform scale, without the difficult and time consuming procedure of creating the DSM. It is used when the object of the documentation is almost flat. At least 4 control points are required in order to solve the below formula and find the eight parameters of the rectification.

$$x = \frac{a_1 x' + a_2 y' + a_3}{c_1 x' + c_2 y' + 1} = f_x(x', y')$$

$$y = \frac{b_1 x' + b_2 y' + b_3}{c_1 x' + c_2 y' + 1} = f_y(x', y')$$

formula_1

Where: (x, y) the rectified coordinates, (x´,y´) the image coordinates, a_1, a_2, a_3, b_1, b_2, b_3, c_1, c_2 parametres

Even if the the object it is not flat, by distinguish on it smaller flat areas and applying on them the monoiscopic method, individual rectified images can be obtained and by uniting them, it is achieved the orthophoto for the complete object.

For not flat objects it can be also obtained a rectified image by using the vanishing points and the geometry of central projection. In this case the object needs to be able to be analyzed by regular shapes. On every of these regular shapes two pairs of parallel lines are required to define a relative 2D reference system.

1.2.3. Terrestrial Laser Scanning

The laser scanners give as a raw product, point clouds with (x,y,z,i) coordinates. The x,y,z are coordinates at the system of the scanner and the i coordinate is the value of signal intensity. An advantage of this method is that the raw product gives a 3 Dimension sense of the object to the user.

After processing with the adequate software these data can produce contour lines, sections, 3 Dimension photorealistic model using the image that the digital camera of the scanner can take, even orthophotos by projecting the colourized points into the adequate projection plane.

There are categories of scanners depending the way they record the data. The ´´time of flight scanners´´ measure the time that the laser beam needs to return to the instrument and the direction of it and calculate the position of the points. There are also scanners that calculate the position of the points by triangulation using one or two CCD and others that are based on the difference of phase of the returning beam.

It is very useful in cases of inaccessible objects, and where other measurement techniques are not easily useable. For example where there is not texture which makes the use of photogrammetry inappropriate because it needs it to find homologous points. Some problems of the method are the cost and the weight of the scanner. Moreover, there are some materials such as the metal and glass ones and some colours (the dark ones) that are badly scanned due to the fact that the laser beam that returns to the instrument is very weak. In addition to this, the bigger the distance between the scanner and the object, the lower is the accuracy.

1.3. Comparison of the methods

To sum up, every method to document has advantages and disadvantages, so they must be evaluated by the engineer according to the object he has to face, the needs, the required time and budget. The project of the Documentation of The Monastery of San Prudencio is a case where all the methods were used for educational reasons, but also for having the best result.

The following table (table_1) sumarises the comparison of the methods and it is a useful tool to the engineer when he has to decide which method to use in any case. These conclusions were taken into account during the planning of the work at this project too.

Method	Figurative (image) Product	3D Information	Linear-Vector Information(drawings)	Linear-Vector Information(sections)
Topometric	-	-	+	+
Topographic	-	+	+	+
Photogrammetric	+ +	+ +	+ +	++
Terrestrial Laser Scanning	+	+ +	+ +	++

Table_1: Conclusions by this project of comparing the documentation methods, where: - inappropriate, + can be used under conditions, ++ adequate

Chapter_2: Monastery of San Prudencio

Below are given some information above the location and the history of the Monastery and some more specific details of the its church.

2.1. Location of the monument

The monastery of San Prudencio is located at the northern province of Spain, La Rioja. More specifically, it is located on the mount Laturce among the villages Ribafrecha , Leza and Clavijo. It is 20 km far from the capital of La Rioja named Logroño.

Image_5: La Rioja, Spain[9]

The Monastery is inside the municipicity of the village Clavijo, which is 16 kilometers away from Logroño, has altitude of 872 meters and surface of 19, 7 km². It is a small village with only 280 habitants according to the data of 2010[10]. The documentation and preservation of the monastery could contribute to the general cultural upgrading of the area.

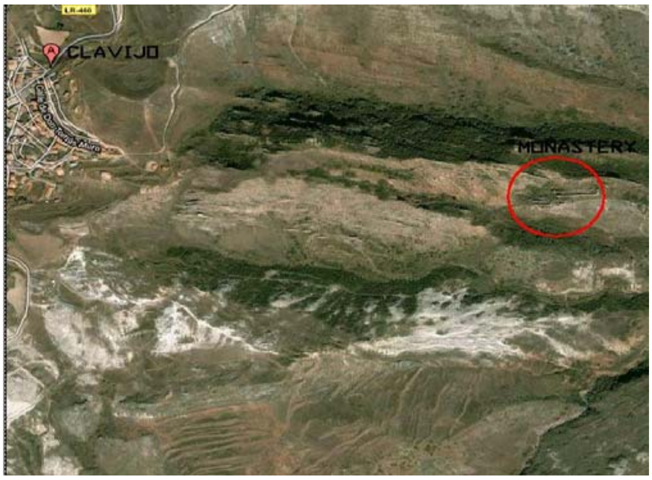


Image_4 : Clavijo and Monastery of San Prudencio

9 http://www.spanishlinguist.com/extra/spain_regions_map.html
10 http://www.ayuntamientodeclavijo.org/

2.2. History of the Monastery

There are not reliable sources that specify the exact date of building the monastery. It is suspected that was originated around 925 A.C., with the burial in this place of the Saint Prudencio, whose relics has been transferred now at the Cathedral of Logroño. The monastery was under the control of another monastery at the beginning of its life and later under the control of an aristocratic family of the area, the family Cameros. With the expropriation of the government of Mendizabal, in 1835, it was converted into a quarry and a lot of it s ruined parts were stolen. Nowadays, the monastery is completely abandoned and not used[11]. There are some remains of the construction that are very interesting by an archaeological and architectural point of view such as some arcs and Romanic windows.

Image_5: Monastery of San Prudencio

2.3. Church of the Monastery of San Prudencio (description, current state, difficulties)

As in all the monasteries the church is supposed to be the most important part since it is the place where the religious ceremonies take place. At the Monastery of San Prudencio the church is also very important by an architectural point of view, as it s walls have great interest (arcs, special details etc). It was build at the 14th century in a gothic architectural style next to the previously used church. It was divided into three parts by three transverse arcs. Unfortunately, it is one of most damaged parts. It suffers of collapse which covers most of the inside part of the temple.

[11] http://moodletic.ehu.es/moodle/file.php/1664/documents/P02_Monasterio.pdf

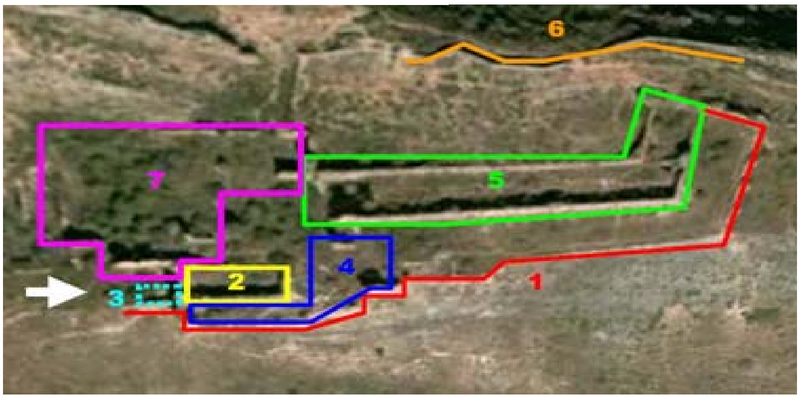


Image_8: Different parts of the Monastery, the church appears with yellow[12]

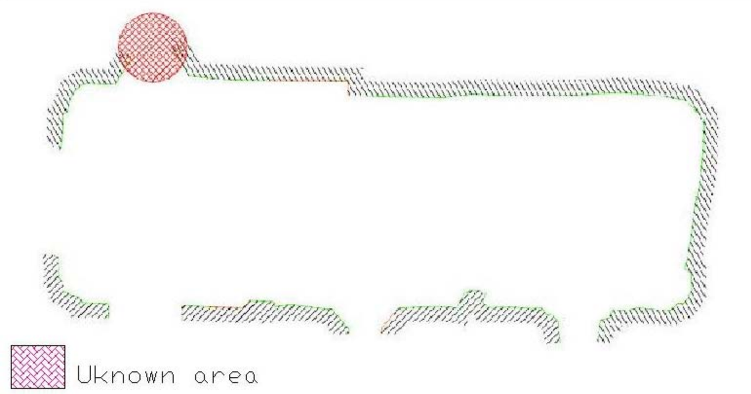


Image_7: Floorplan of the church[13]

[12] http://moodletic.ehu.es/moodle/file.php/1664/documents/P02_Monasterio.pdf
[13] Data of the ERASMUS IP, July 2010

Chapter_3 : Project

In this chapter are analyzed the aims, steps, methods, parametres and final results of this diploma thesis.

3.1. Reconnaissance of the project area

The first step in every project of documentation is to visit and get to know the monument. At this phase the surveyor needs to identify the characteristics of the monument and take some data that will help him to make a plan of his work.

The first contact with the Church of the Monastery of San Prudencio was on July of 2010, when the ERASMUS IP program first took place. Of course it was needed a new reconnaissance of the area. It was selected a day with good weather in order to inspect better the object and also to begin the first work of field. It was checked carefully the structure of the church and its features and was made a first opinion of the challenges that were going to be faced. Some photos and sketches at a big scale of the area were taken, just to have an idea of it.

The church consists of a rectangular room, while the ceiling is totally missing. One of the first conclusions of this first reconnaissance was that the church is in a really bad state, something that would make dangerous and difficult the collection of data as the ground and the collapsed parts inside the church do not permit an easy access. Moreover, the height of the northern wall and its complicated surface was noticed as something that should be taken into account, in order to make a more specific plan of work for this part. A part of the western wall was also enough high and needed more attention.

As for the geodetic reference, it was observed the whole area in order to identify the most suitable stations. As it is mentioned below, the establishment of a geodetic network was not necessary because we used the existent one.

At the same time, in collaboration with the archaeologist, who also works on the same bigger project of the documentation of the whole monastery, the area was investigated for finding evidences that would be useful at the reconstruction.

3.2. **Planning of the work**

The aim of the project is to have a complete documentation and reconstruction of the church of the Monastery. This documentation will be used by archaeologists and possibly by architects and civil engineerings in order to take measurements for its protection. Moreover it will be at the disposal of the government of La Rioja for educational (history, architecture, religious classes), promotional and touristic purposes.

So, in order to show details on the walls that have interest from an archaeological point of view and demonstrate better the features of the monument, it was decided the generation of orthophotos at a big scale. The orthophotos were chosen because they give to the users a metric ability and also they are a continuous colourful product that give a very detailed image to the users. The table below (table_2) shows the typical scales for documentation of different projects and objects.

Project	Scale of documentation
localization and correlation of monuments	1:20000

Correlation of the monument and the wider area	1: 10000-1:5000
Definition of protected zone – Urban planning	1: 2000 – 1:500
Basic geometric documentation	1: 200 – 1:100
Detailed geometric documentation	1:50 – 1:20
Decorated details (small objects)	1:10 – 1: 1

Table_2: Scales of documentation[14]

At the table below (table_3) it is presented a comparison to the usual big scales that are used to the documentation of projects like this. The comparison is done in relation with the accuracy each scale gives and the length dimension that the four walls of the churce are going to have at the final orthophoto.

Scale	Eastern and wesern walls (lenght 7, 5 m)	Southern and northern walls (lenght 20 m)	Accuracy
1 : 100	7,5 cm	20 cm	2,5 cm
1 : 50	15 cm	40 cm	1, 25 cm
1 : 20	37 cm	100 cm	0,5 cm

Table_3: Comparison of big scales refer to this project

The accuracy is based on the smallest difference that a human can distinguish at a printed drawing, which in a scale 1:1 is ¼ of a millimetre (typical value used at Greece).

For the aims of this project, taking into account the requirements of the collaborator archaeologist an accuracy of 2-3 cm (less than 1.25) would be enough. But as it is showed at the table_3 the object would be represented printed quite small and the generalization would lead to loss of the details. So it was decided to create orthophotos at scale 1: 50.

For the reconstruction, it is necessary a 3Dimensional model. The model is a useful result as it gives a complete 3 Dimensional sense, where the user can "walk" through the monument, and notice it better. Moreover the 3Dimensional models are necessary in order to make the orthophotos. So as they are already made (as a pre step of the orthophoto) it was decided to work more on them, to merge and present them as another useful product. The 3 Dimensional models of course should have an accuracy that leads to the desirable accuracy of the photos. As the meshes usually are not used for getting measurements it was estimated that the accuracy of the mesh – 3 Dimensional model could be even less than 1 cm (2-3 cm), as far as it can give orthophotos of accuracy of 1 cm. Their metric accuracy can be evaluated by checking the coordinates of some control points. As the coordinates on a mesh include the 3rd dimension, the error of a control point will be bigger than the error on the orthophoto.

[14] Documentation of Monuments, Ioannidis Charalabos

After stating the needs that this project would satisfy and the products with which that was going to happen, the most suitable methodologies need to be chosen. The selection criteria was mainly the result they give, the educational obtaining that they offer, the available time and equipment.

For achieving both the orthophotos and the 3 Dimensional model it was decided to use photogrammetric methods.

The first plan of the work included photos of the four walls of the church. The available focal lengths were one of 21mm and one of 35 mm. The smaller the focal length the bigger the surface covered by the photographs. In the case of the church there was not a big flexibility to the points from which take the photos as it is a closed area. So, it was chosen the 21 mm length. The 35 mm would need more pares in order to cover the whole church as it captures in a bigger scale less area of the object (Image_8).

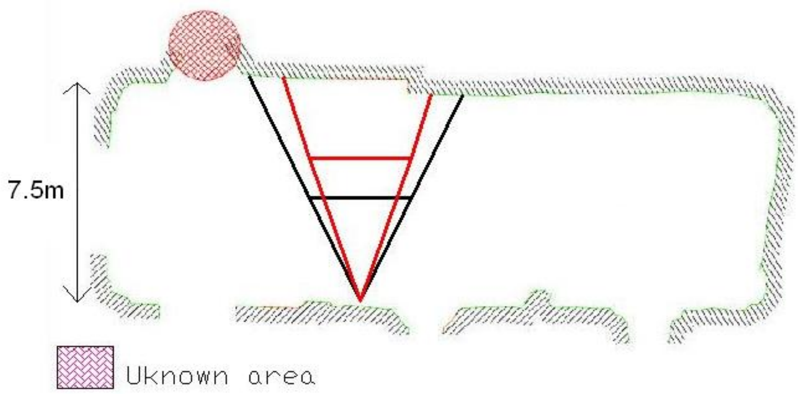


Image_8: Different focal lengths (red: 35mm and black: 21mm)

It was decided to take both oblique photos and photos with the axis (the axis that unite the point of taking the picture and the object) parallel. This way the two available softwares (*Photomodeler Scanner 6* and *ImageMaster*) could be used. The photos should cover the entire church with pairs with the suitable overlap that every program requires. For the photos used by *Image Master* , an overlap of about 60% (50%-70%) was needed with parallel the axis , while *Photomodeler Scanner 6* requires photos with big overlap-even 100% and taking photos with a big angle of the axis in order to use the geometry of convergent photogrammetry, while it can also work with the photos that were taken for *Image Master*.

As for the high parts of the western and the northern wall, it was decided to investigate the possibilities of documentation by introducing them to one model that would include the entire wall as there was no possibility to take photos elevated from the ground. As far as the western wall concerned, it was estimated that this common orientation with the rest of the wall, would have sufficient results as the surface of the wall is not very irregular. On the other hand, the northern wall had a very irregular surface so it was decided to check the possibility of using for the orientation some points with known coordinates that the laser scanner data from the ERASMUS IP (July, 2011) can give. As it is analyzed below at the ´´field work´´ there were neither targets nor natural points measured at these upper parts of the wall.

After deciding the methodology and the final products, the coordinate system was chosen in which the whole project was going to be imported. Generally, monument documentations are performedin arbitrary 3Dimensional coordinate systems and not in a national or a global one. But as this bigger project consists of a lot of smaller projects it was decided to refer all of them to a common system, the European Terrestrial

Reference System (ETRS) 89 with projection the Universal Transverse Mercator (UTM), zone 30.

The procedures of the project are briefly presented at the following diagram (Diagram_1)

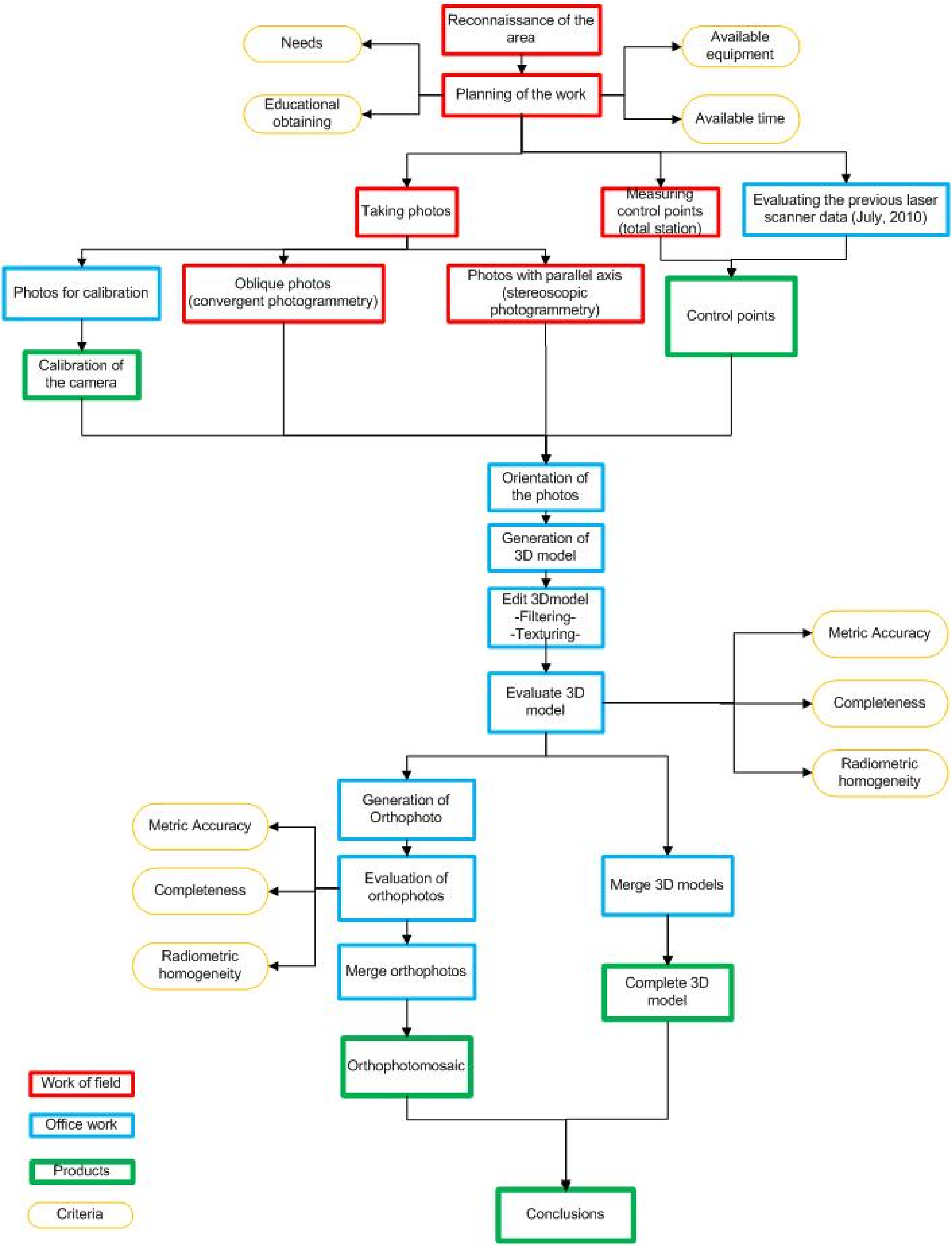


Diagram_1: Flowchart of the procedures of the project

3.3. Equipment

For execute the decided topographic and photogrammetric procedures, it was needed the suitable equipment.

3.3.1. Geodetic equipment

For measuring the control points was used the Leica TCR307 with properties that are shown at the table below.

Properties			
Leica TCR307 total station	Magnification	30x	
	Field of view	1° 30' (26 m at 1 km)	
	Accuracy of angle measurements	7´´ (2mgon)	
	Display least count	1´´ (0.5mgon)	
	Accuracy of distance Measurements (visible laser)	±(3mm+2ppm)	
	Measuring time	1s + 0.3s/10m (>30m)	
	Weight (instrument only)	4.2kg	
	Continues use of battery	>4 hours	
	Recharging time	1 hour	

Table_4: Properties of Leica TCR307[15]

3.3.2. Photogrammetric equipment

It was used the Canon EOS 5D Mark II camera. As a digital camera it offers the advantage of checking the taken photos while being still at the field. Thus, it is checked wheter these photos include the entire desirable object and if they have the suitable coverage and reduces the possibility of wrong collected data. Moreover taking a lot of digital photos is very cheap and they are directly in a digital form, eliminating the errors due to the scanning the analogical photos. The camera properties are presented at the table below.

Characteristics of Canon EOS 5D Mark II	
Sensor	36 x 24 mm CMOS sensor Full 35 mm size frame RGB Color Filter Array
Lenses	Canon EF lens mount (does not support EF-S lenses)

[15] Leica TCR 307. Technical Specifications (it is attached the whole document in the annexes)

Image sizes (RAW)	5616 x 3744 (21.0 MP) 3861 x 2574 (10.0 MP) 2784 x 1856 (5.2 MP)
Shooting modes	Auto Creative Auto Program AE(P) Shutter priority AE (Tv) Aperture priority AE (Av) Manual (M) Custom 1 Custom 2 Custom 3
Storage	Compact Flash Type I or II (inc. FAT32) Supports UDMA cards Copyright metatag support Canon Original Data Security Kit supported ("Original Image Data")
Dimensional	152 x 114 x 75 mm (6.0 x 4.5 x 2.9 in)
Weight	No battery: 810 g (1.8 lb)

Table_4: Properties of Canon EOS 5D Mark II[16]

Image_9: Canon EOS 5D Mark II

The camera was used with focal length 21 mm and images of 21 MP

3.4. Field work

The field work is very important and it should be given a lot of attention because incorrect or incomplete data lead to another day of field work; something that cost time

[16] http://www.dpreview.com/reviews/canoneos5dmarkii/page2.asp

and money, especially in this case that the monastery is 2 hours far away from the University (office work).

3.4.1 Taking photos

The field work started by putting on the walls all the targets needed for the photogrammetric process. These points were chosen using the criteria of covering parametrically the object (the walls) and to be enough for the orientation of every stereoscopic pair (minimum 3, in this project were used more than 5 at every pair). Due to the height of the northern wall was impossible to put targets at the upper part of it.

It is important to mention that the targets were placed very carefully at the walls, with silicon that ensures their temporal position, respecting the monument. These targets have suitable dimension (4cm * 4cm) in order to be quite visible at the scale of the initiative photos. Their colour allows the best contrast on the photos in order to be easily recognizable. Moreover, they have numbers on them so as to make the recognition in association with the geodetic procedure easier (image_10)

Image_10: Type of used targets

It was said above that, the photos were taken by two different kinds of geometry. This way they could be used for stereoscopic and convergent photogrammetry for educational and practical reasons too. The available licenses of the software and the number of students working with them made necessary to arrange the time that each student would have at his disposal one specific software. Therefore by taking data that can be processed by more that one programs we could optimize the workload.

A series of photos with parallel axis was taken. These photos had a coverage of 60% more or less, so that the used software (*Image Master)* could create a stereo model that permits the stereoscopic view of the object. Also, another series of photos was taken, that could be used by convergent photogrammetry programs (*Photomodeler Scanner 6*). These ones have a big coverage (80-100%) but do not lead to a strereoscopic view of the object. Due to the irregular ground inside the church and the existance of some collapsed parts of the walls, these kind of photos were more easy to take, cause it was really hard to take photos with the strict geometry that stereoscopic photogrammetry requires. In any case the ratio Base/ Height (B/H) was intended to be inside the limits $1/10<B/H<1/3$.

An important factor for taking correct photos of the object is the light of the Sun which defines the conditions of light, the accuracy with which is possible to measure points on the photo, and generally the quality of the result. The best light conditions for taking photos are when theere is homogeinity all over the object or at least at all the parts that are going to be used for one model. It is important to avoid the shadows that lead to headen parts. So it was needed to wait for the best sun position for every wall. In order to achieve the best result, the suitable value of diaphragm and velocity were intended. Both parameters are related to the light that is captured by the camera.

The diaphragm is a metallic ring of variable opening so that the selected quantity of light goes into the camera in every photo. The more closed this ring, the most dark the photo (image_11) and the bigger the part of the area that is focused. The used values for the diaphragm were between 9 and 13.

The velocity is also related with the quantity of light. The bigger the velocity the less is the introduced light. For the best combination of these parameters, they were checked the automatical values of them that the camera gives focusing at the middle part of the object and these values were fixed for the pairs of the same model in order to obtain homogeneity at the taken photos.

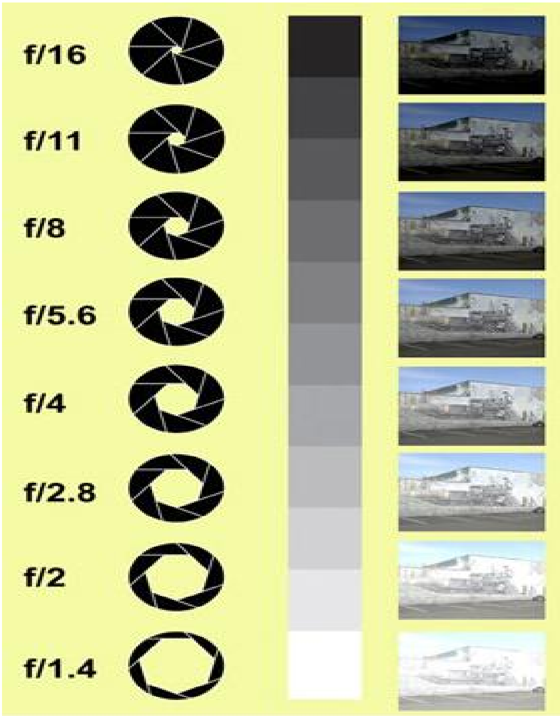


Image_11: Demonstration of the influence of the light at images (f: the opened diaphragm)[17]

Moreover, due to the difference at the lighting of the sun, the colours at the photos at each wall - direction are a little different, something that leads to radiometrical heterogeneity; however it do not influence the geometrical accuracy.

3.4.2 Ground Control Points

For the correlation of all the projects related to the monastery it was necessary the common georeference. As it is already mentioned, the project will use the ETRS89 with the UTM projection, zone 30. The ETRS89 is an Earth-Centred, geodetic Cartesian reference frame. The UTM projection is an horizontal position representation that it is used to identify locations on the earth independently of vertical position and uses a series of sixty zones, each of which is based on a specifically defined transverse Mercator projection. The zone of La Rioja (Spain) is the 30th.

It was used the already established network by the participants of the first ERASMUS IP program (JULY 2010), that was made by GPS with global accuracy of 1

[17] http://www.papadakismanolis.gr/index.php?lid=1

cm. This accuracy does not influence the quality of our results because we used just one benchmark (an another to orientate) to define our 3Dimensional local system.

The coordinates of the control points were calculated by measuring angles and distances (polar coordinates) by 2 station points (S1 and S2) inside the church, the coordinates of which were calculated by resection. Thus, the establishment of a polygonal network was avoided. The 2 station points were chosen in a way that the 4 walls of the church were visible.

At the image_12 it is presented with black colour the bench mark (BM) with known coordinates. From this point were measured minimum 4 points at the western wall of the church (1,2,3,4). Then these points were used for the resection of the point S1. After the resection, the S1 had known coordinates and could be used as a station point for measuring the visible by it control points. The existence of one more station point (S2) was needed in order to be measured part of the northern wall that could not be measured by the S1 station point. For the resection to the S2 they were used minimum 4 known points of the walls of the church (1,2, 5,6). It should be mentioned that the image_12 is only a sketch and not a faithful representation of the correct positions of the points. It only demonstrates the relative positions of them.

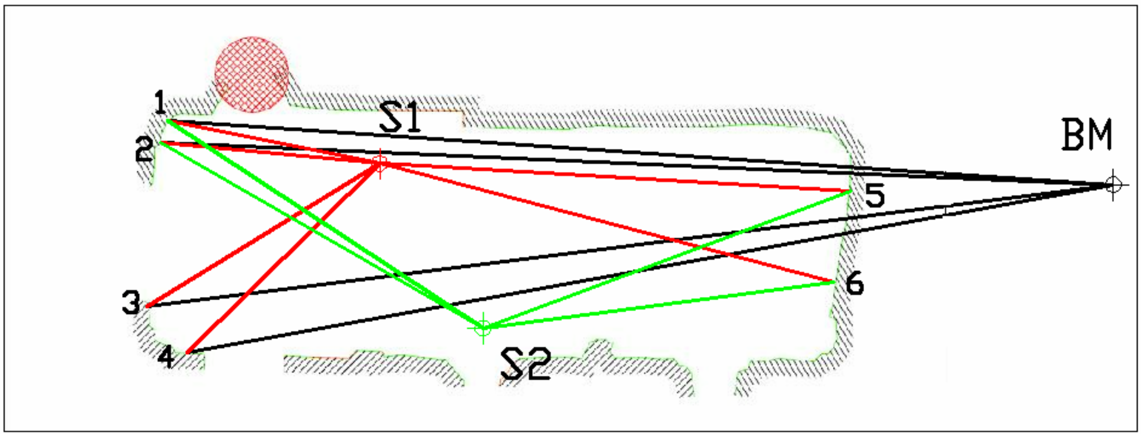


Image_12: Sketch of the resections

As far as the nothern wall concerned, its height did not permit putting targets at the upper part and its surface made difficult to recognise measured points that were not pointed out by targets. So no points were measured at this area.

3.5.Office Work

3.5.1. Data Management

All the selected data were downloaded and properly stored, so that everyone who works at the project of the documentation of the whole Monastery would be able to find them easily and use them. It was used a common code in archiving by all the participants of the project.

The raw photos that the camera gives were transformed by *Photoshop* at a format (JPG) that permits them to be read by the photogrammetric software. The data of the total station were downloaded with the *Leica Survey Office* in different kind of formats (notepad, excel) so that they could be used by different programs. The data were 3 coordinates but also horizontal and vertical angles, horizontal and slope distances too. Although the angles and the distances were not used, we chosed to save them because they are the direct - raw measurements that the instrument took and they would be useful in case of needing the recomputation of the coordinates.

3.5.2. Calculations

Due to the fact that the establishment of a polygonal network was avoided, no calculations were needed. The instrument is programmed to give us directly 3 coordinates in the asked coordinate system saving a lot of time.

3.5.3. Calibration of the camera[18]

The identification and the estimation of systematic errors resulting from an instrument is a necessary action at regular periods because of changes at the fixed parameters of the instrument due to bad or prolonged use of it. This identification is done by the process of calibration. Calibration in cases of digital cameras is the set of measurements and computational procedures that determine the geometrical and physical characteristics of the camera. This is an important process and necessary so that the resulting picture is metrically useable.

The images can be considered with sufficient accuracy as central projections of the real word, so the model that describes better the photographic display is the central projection. The purpose of calibration is to adjust the geometric model of the central projection which describes in the best way the geometry of the specific camera. In order to determine the position of the centre of the projection related to the level of the image it is required to be known the focal length of the lens and the image coordinates of the principal point. Apart from the above parameters it is necessary to be taking into account the deviations of the optical ray from the ideal central projection because of errors of the lens. Due to the geometry of the lens, there is one radial and symmetric distortion that is also called distortion Seidel.Due to this distortion, the points on the image are relocated radically and symmetrically from the principal point. (image_13). This difference is described by a formula of the following kind

$$\Delta r\ (s) = k_1 * r + (k_2 * r^3) + (k_3 * r^5) + (k_4 * r^7) + \ldots \qquad \text{formula\_1}$$

where, k_1, k_2, k_3, k_4 ....: parameters of radial distorcion
r: the radial distance on the image from the principal point

[18] Notes, formulas and shapes are based on the book ´´Intoducion to photogrammetry, P.Patias´´ and lectures of Georgopoulos Andreas , classes ´´Photogammetry I´´ (NTUA)

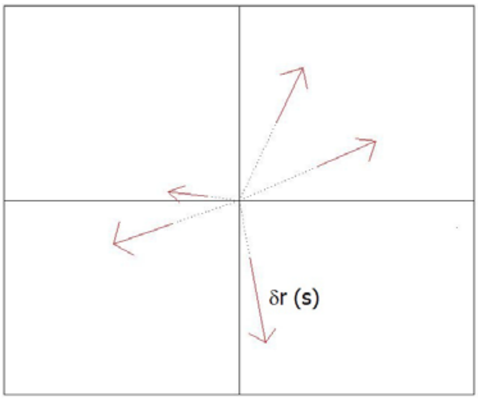


Image_13: Radial distortion Seidel (Δr (s))

The number of the parameters of the formula that are used in order to identify the radial destortion Seidel depends on the desirable accuracy. Usually the k_1, k_2, k_3 are enough for documentations of high accuracy.

In addition to this, there is another non symmetric distortion due to the decentering of the lens, which can be divided at one radial component and one perpendicular (image_14).

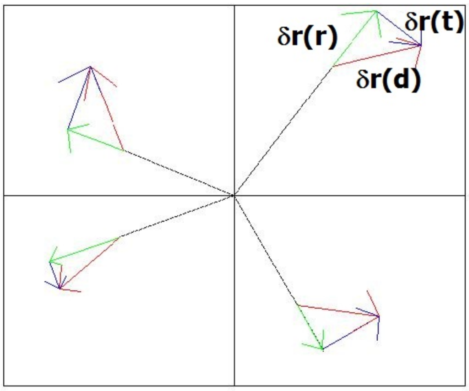


Image_13: Distortion due to decentring of the lens (Δr (d))

A formula that can describe this distortion is

$\Delta x = \{P_1 * [r^2 + 2 (x-x_o)^2] + 2 * P_2 *(x- x_o) *(y-y_o)\}$ Formula_2

$\Delta y = \{2*P_1 *(x- x_o) *(y-y_o) + P_2 [r^2 + 2*(y-y_o)^2]$ Formula_3

Where Δx, Δy : the components of the distortion at the (x,y) axis of the image
P_1, P_2, : parameters that are defined differently by each software and
x,y: image coordinates
x_o, y_o : image coordinates of the center of projection

For the needs of this project, two calibration procedures of the same camera were done. The first one was done by the software of *Image Master* and the second one of *Photomodeler Scanner 6.* Every program uses its own calibration parameters for the distortion at its procedures. The f (focal length) and the x_p, y_p (image coordinates of the principal point) have the same values for all the similar softwares, but the parameters of the radial distortion differ. One option for avoiding the second calibration was to use the corrected from distortion images that one software give i.g. *Photomodeler Scanner 6* to the other (*Image Master).* At the second program the photos can been introduced with zero distortion as they are already corrected.

But the fast, completely automatic process of calibrating permitted the calibration by the 2 ways. The only task was the taking of the photos that each method requires. The photos used by *Photomodeler Scanner 6* were already taken for the summer project (08/06/2010), so the only photos needed were the ones of *Image Master.*

3.5.3.1. Image Master

After placing the calibration sheet on a plan surface for not distorting the shape of it, five photos by different point of view of the sheet were taken. The photos had to include the entire sheet under the geometry that appears below.

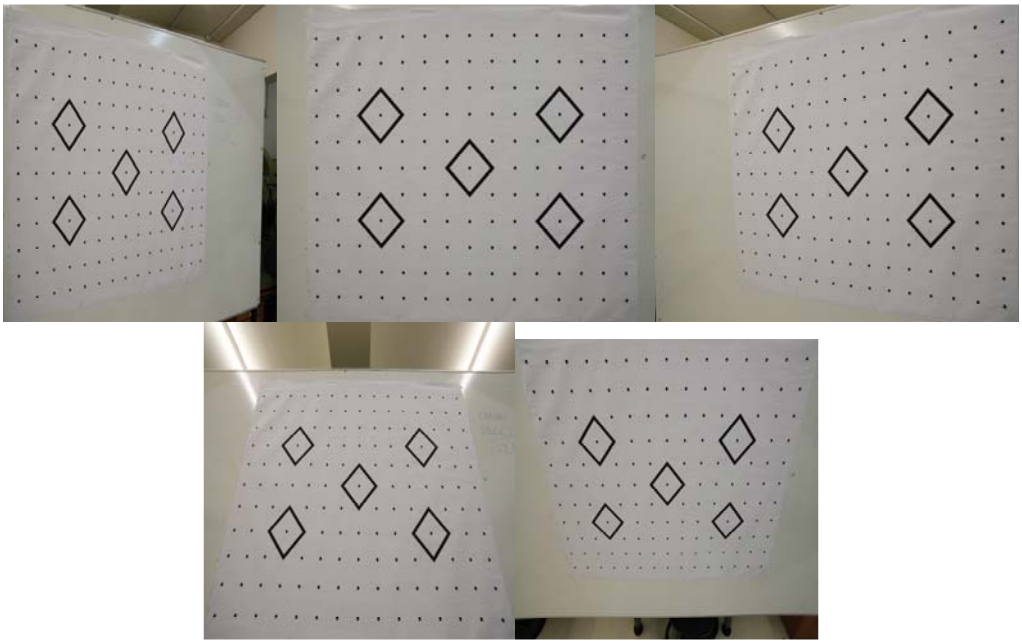


Image_14: Photos required for the calibration of *Image Master*

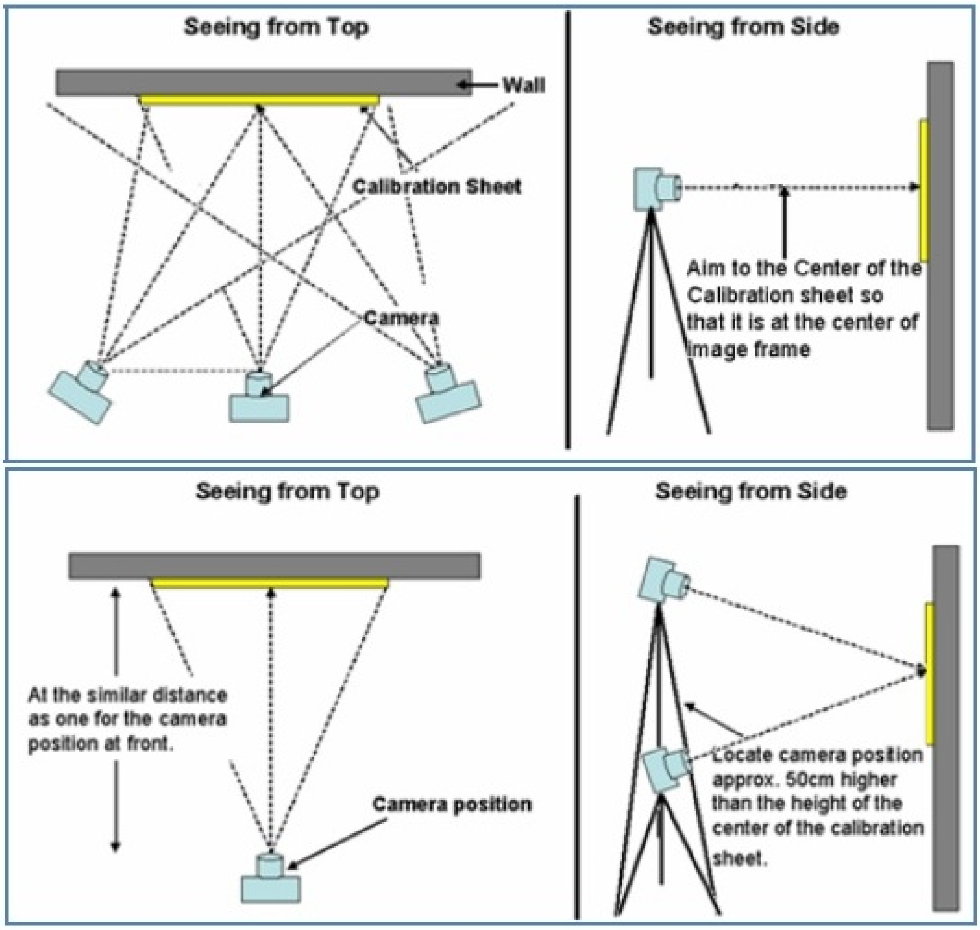


Image_15: Geometry of the taking photos for calibration[19]

Below are shown the results that the calibration gives in a pdf format. The software also gives the results in other types of format and of course at a format compatible with *Image Master*. At the image_16 it is presented also graphically the difference that a raw image (red lines) and a corrected image (black lines) have. This difference can influence the final result as influence all the measurements on the image that are totally necessary at all the photogrammetric procedures.

[19] http://dspace.lib.ntua.gr/bitstream/123456789/3192/3/triantoue_gpt7003i.pdf

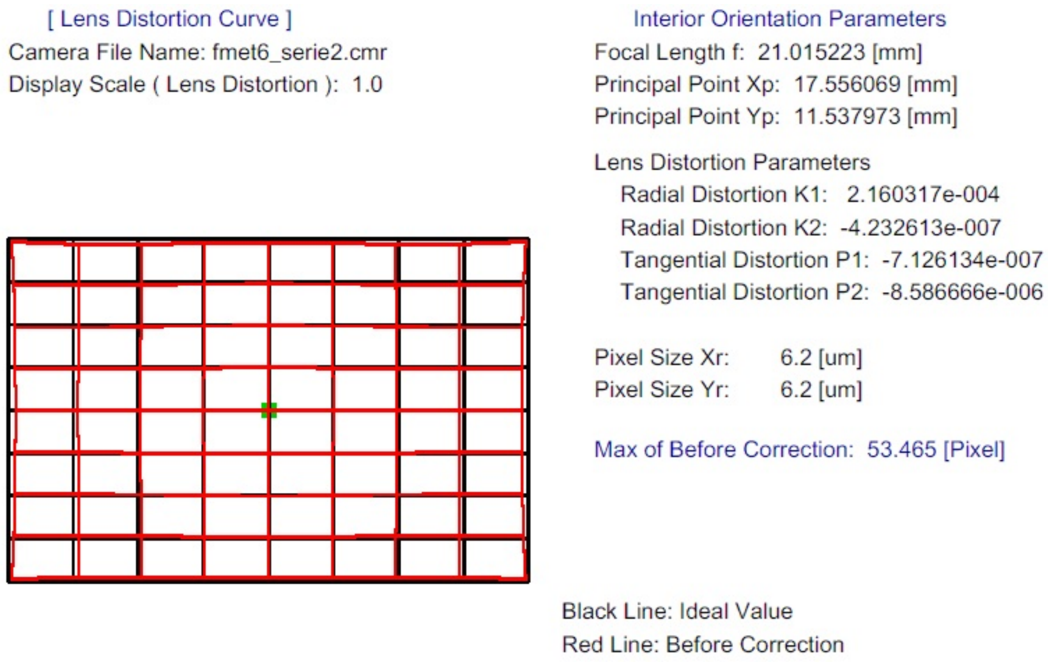


Image_16: The results of calibration

3.5.3.2. Photomodeler Scanner 6

For *Photomodeler Scanner 6 12* photos are necessary with the suitable geometry similar with the one that *Image Master* needs. At this moment, it is needed to mention that the initial photos for the calibration were not very good as it is shown on them a lot of area outside the calibration sheet that *Photomodeler Scanner 6* uses (different from the one of *Image Master*). Moreover as these photos were taken on 08/06/2010, the calibration does not take into account the changes of the interior orientation that the system has since this date.

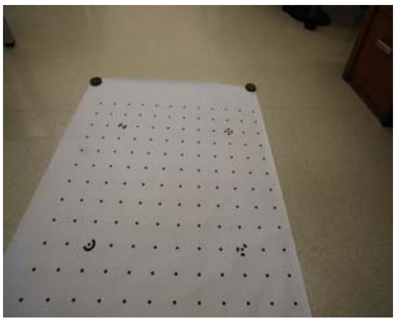


Image_17: ´´Bad´´ photo for calibration

Below (image_18) it appears the calibration results made by *Photomodeler Scanner 6*

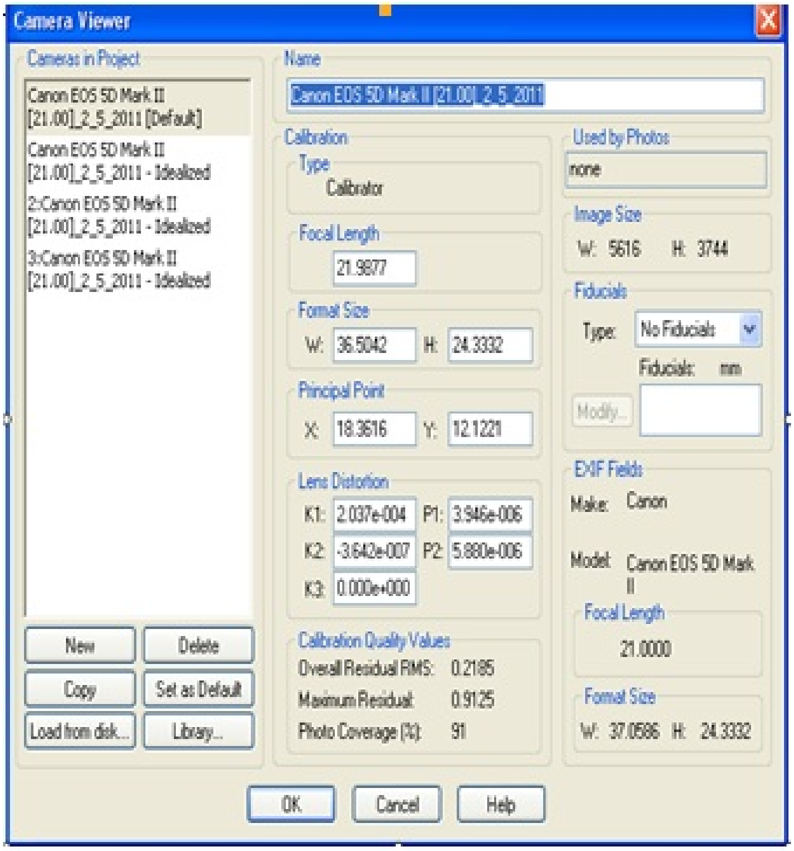


Image_18: Calibration results of *Photomodeler Scanner 6*

3.5.4. Generation of 3D model

The 3 Dimention model was necessary for generating the orthophotos and for the recostruction. It was produced by both the available software in order to evaluate them and at the end to choose for the representation the best one. The models of all the church were merged with *Rapidform* in order to have a complete model of the interior of the church and at the same time to check the accuracy of each model. The metric accuracy is checked:

- For individual models by measuring the diferrences of the control points on them. It was itented no to use all the control points at the procedure of the orientation so that the not used ones could be checked and give a better estimation of the metric accuracy. These are more reliable than the already used points which of course are more accurate as the whole orientation of the mesh was based on them

- For the merged model by checking the overlap that the models have. It was checked the relative position of each model and the adjustment at the common parts.

As for the accuracy of the model related to its completeness, it was checked by careful observation in order to find areas that are not presented.

Moreover, as a pre step for generating the mesh (Triangulated Irregular Network-TIN), the *Photomodeler Scanner 6* gives the point cloud. We also decided to use this point cloud as a representation, as it gives a 3 Dimension sense of the object without continuous information but with sufficient detail for educational applications.

The work is composed by four different and concrete projects, one for every wall. Although there are possibilities to work even the whole church with one orientation; creating one model with the suitable photos that have the needed geometry; this possibility was not used by this project, because some tests that we did with just two of the walls did not give us satisfactory results.

For every wall were chosen the suitable pairs of photos with the axis and the overlap required by each software and with the criteria of the vision of the whole object. The smaller the wall and the more flat, there was more flexibility at choosing the photos.

As far as the corners of the walls are concerned, they were not worked in different projects but it was made an effort to produce the model of them by both the projects in which they appear (as they are corners they appear into two walls , so into two projects).

The meshes in both softwares after being created, they were edited. It was necessary to remove the noise by ´´cleaning´´ the points of the point cloud *or* the triangles of the meshes, something that the user needed to do manually. The texture is put automatically.

3.5.4.1. Image Master

The first software that was used for the processing of the photos was *Image Master*. Its abilities are the generation of orthophotos, of Digital Terrain Model (DTM) or Digital Surface Model (DSM) consisted of Triangulated Irregular Network (TIN) , a textured Model and the stereoscopic view of the object.

For the relative (eliminating of Y parallax) and absolute (scale, Xo, Yo, Zo, ω, φ, κ) orientation it was used the bundle adjustment method (all the photos were orientated together) with known parameters the ground and image coordinates of the control points, the parameters of the interior orientation that were produced by the calibration of the camera and the image coordinates of the tie points (homologous points at minimum 2 photos without known ground coordinates). The software gives the option of manual or automatic selection of them. In order to be more accurate the selection it was selected the manual function.

For watching the model stereoscopically it is necessary the existence of a special 3D screen and glasses. As this screen was not available, it was used for drawings (breaklines) a function that splot the screen in two and shows one image in each part.

The software creates a DTM or DSM selecting the proper interval according to the required level of details, the nature of the object and the desirable result (accuracy of the orthophoto). This digital model can be introduced from a file in case that it is already produced by other procedure. In order to obtain homogeneity at the final result it was selected the same mesh interval for all the walls. It was selected to create the mesh sampling points every 2cm. This leads to a very detailed representation of the monument that it consists of walls without small details, hense a very condensed mesh it is not necessary.

Next one will be presented some of the specific characteristics and challenges that each wall had.

It should be mentioned that the word ´´model´´ it is used to describe the 3D model (point cloud, TIN or textured model) and should not be confused with the stereomodel that only two pairs of photos can give. In this case a model can be created by more than one pair of photos.

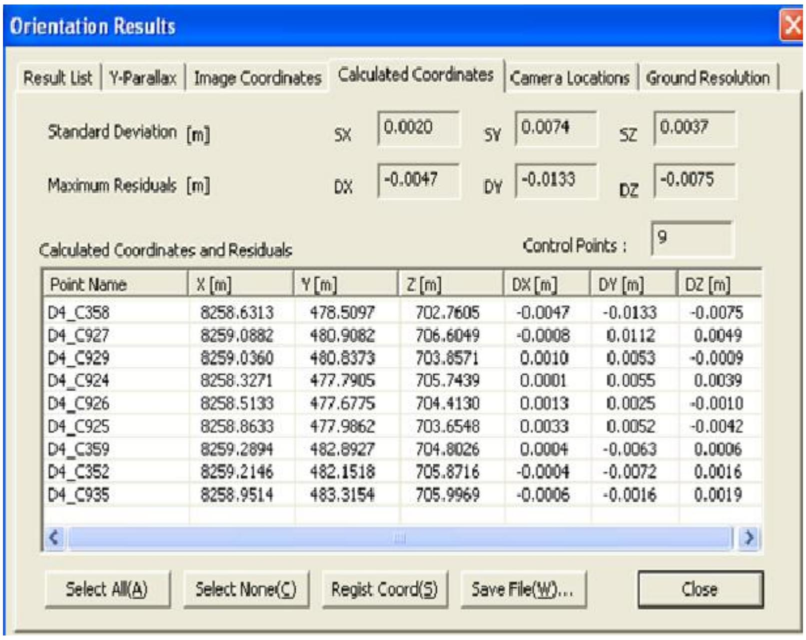
Eastern wall

Its length (7.5m) and shape permitted one single project. So they were chosen 3 photos – 2 pairs that covered the entire wall. Below (image_19) appear with red colour the problematic areas. They are areas covered by plants that cannot be represented well on a model. In addition to their shape, their movement as they are not part of the wall (maybe they are not in the same position at the two photos), create problems in the mesh. It is estimated that the plants at the bottom of the wall should have been cleaned before the taking of the photos. However the plants at the upper part of the wall, cannot be removed and moreover it was evaluated that the cut of them would create static problems to the wall.

Image_19: Problematic areas

For the relative and absolute orientation of the wall 9 points were used and the mean error of the absolute orientation was 0.002m at the X coordinates, 0.007 at the Y coordinates, 0.004 at the Z coordinates as it is shown to the image (image_19) below.

Four points were not used for the orientation in order to be used to check their position at the final products (3 Dimension models and orthophotos). The analysis of this checking will be presented in chapter 4.



Point Name	X [m]	Y [m]	Z [m]	DX [m]	DY [m]	DZ [m]
D4_C358	8258.6313	478.5097	702.7605	-0.0047	-0.0133	-0.0075
D4_C927	8259.0882	480.9082	706.6049	-0.0008	0.0112	0.0049
D4_C929	8259.0360	480.8373	703.8571	0.0010	0.0053	-0.0009
D4_C924	8258.3271	477.7905	705.7439	0.0001	0.0055	0.0039
D4_C926	8258.5133	477.6775	704.4130	0.0013	0.0025	-0.0010
D4_C925	8258.8633	477.9862	703.6548	0.0033	0.0052	-0.0042
D4_C359	8259.2894	482.8927	704.8026	0.0004	-0.0063	0.0006
D4_C352	8259.2146	482.1518	705.8716	-0.0004	-0.0072	0.0016
D4_C935	8258.9514	483.3154	705.9969	-0.0006	-0.0016	0.0019

Image_20: Error at absolute orientation

<u>Southern Wall</u>

Our first effort to create one mesh of the entire wall gave us a disappointing result, (image_21). There were triangles linking points that should not be joint to each other and the noise of the mesh was impossible to be cleaned, something that was avoided spoting the are in three big meshes and some smaller ones.

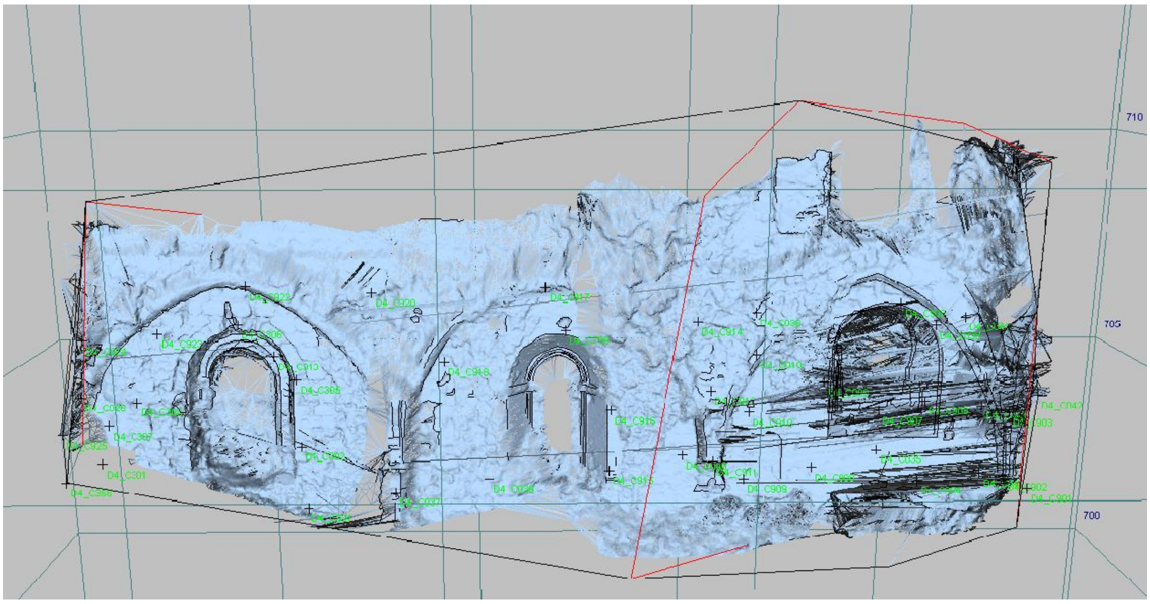


Image_21: South wall in a go

The three models were decided as a result of its big length (20.1m). These models were created with the same common orientation but with chosen different smaller area of creating the mesh.

Moreover, the wall had some parts that were not visible in the first pairs that were selected to create the model, so new models with new pictures and new orientation were made. A characteristic part was the column between the two big openings. For taking the complete model of this column it was needed to make 2 small meshes only for this area. In order to create these meshes were selected photos that had all the information for the column. With a pair of two photos was taken the information for the left part and with another pair was taken the information of the right part (image_22). It was not possible to combine the four photos at one orientation and one mesh due to the fact that their axis were not parallel. The software should permit orientation like this, but in this case did not work, maybe due to the geometry of the photos that need to have specific characteristics for that kind of orientation.

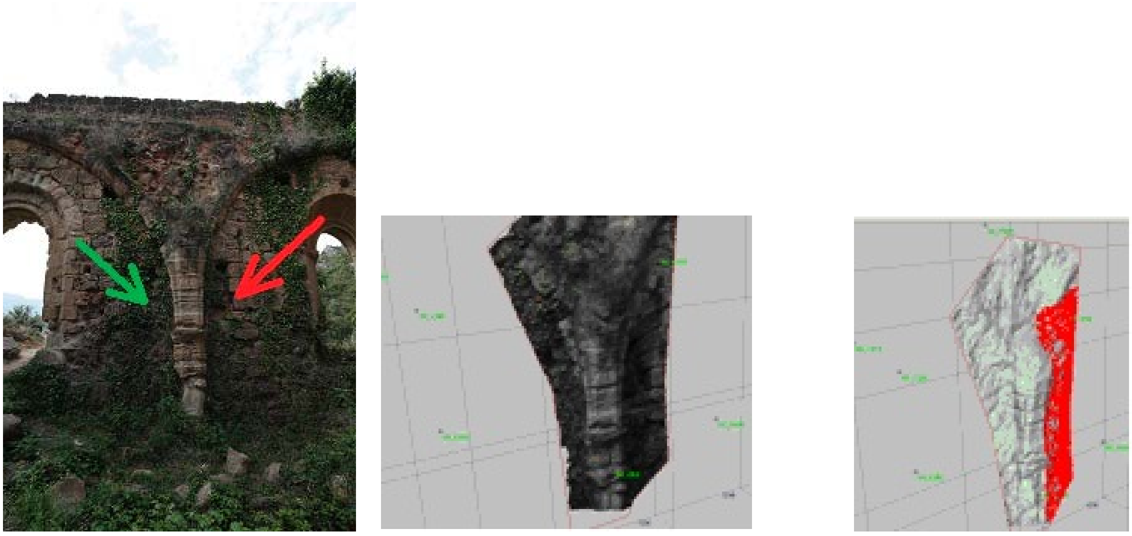


Image_22,23 & 24: Column at Southern wall

The Image_23 shows the textured TIN[20] model made by one of the two pairs of the column. This model shows well the left part of the column and bad the right one (red colour – image_24). So it was used only the left part at the model and at the generation of the orthophoto too. The other pair was used in order to cover the right part. For the common correct parts of the two meshes, it was selected the one with the best accuracy checked by the control points.

Another part of the southern wall that needed additional work was the window of the most western part of the wall. This window had a profound curve that should not appear at the orthophoto but it should appear at the model as it shows the total wall of all the points of views. This window needed to be made by 2 models as well, one bigger that shows its outside form and another more specific that shows the western part of its curve (image_26). The eastern part of the curve is missing because there was a lack of photos for this part.

The small meshes of the column and the window were orientated with control points very close to these areas. The fact that these parts were orientated separately from the other wall, leads to a difference between the meshes that at the phase of merging the meshes did not create problems.

[20] Triangular Irregular Network

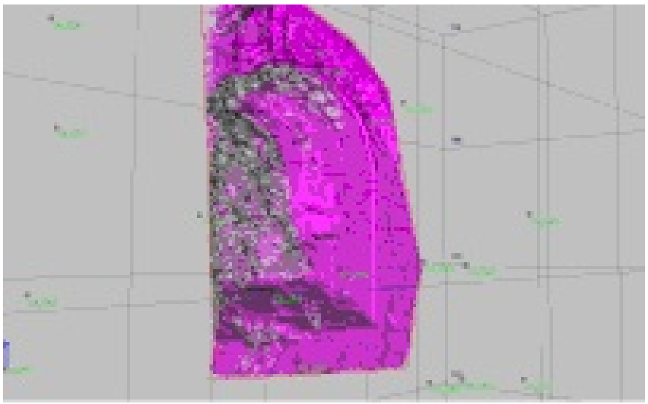



Image_25 & 26: The western curve of the window of southern wall

Western wall

The model of the western wall was also done in two parts.The first one used photos perpendicular to the object and did not include the highest northern part of the wall (image_27). So they were chosen 6 photos – 3 pairs that covered almost all the wall and 2 more photos – 1 pair that covered this part on top. It should be mentioned that this above part did not have enough control points to be orientated by itself. So there were choosen photos that include more part of the wall on which was based the orientation.

One more pair should have been worked for the highest southern part of the wall, but there were no photos that this part was completely visible. Moreover this part had a lot of creepers something that did not help the documentation of it.

Image_27: Highest part of western wall that was worked on a differend model

Northern wall

This was the most difficult wall regarding its documentation. It is a 20m wall and at the western part it is very high. Two different orientations and meshes were created for the short eastern part of the wall that gave acceptable 3D model and orthophoto as it is analyzed later (chapter 4). Unfortunately, the western part could not be done successfully. The possible reasons were the bad orientation at this part due to the lack of control points and the impossibility to find homologous points at the two photos due to the irregular surface and the bad geometry of the photos.

For solving the first possible problem and improve the orientation at this part it was checked the possibility of using the data of scanner that already existed (ERASMUS IP, July 2010). They were checked the data of Z+F scanner read by the software Z+F Laser Control-[3D View]. All the inside part of the church was scanned and the scanning was orientated. So, there were available coordinates of points of the church that could be used as control points at the orientation. But this point clouds that Z+F scanner gave also did not show well this high area.

We also tried to orientate only the lower part of this area, but the result was also bad even though there were enough control points. Due to the irregular surface and the texture, it was not possible to be recognised many homologous points at the two photos something that leaded to a bad – not dense mesh. So it is concluded that the surface and the texture of the object was the main problem and not the lack of control points (lack of control points at the highest part of the western wall lead to a sufficient result). For these kinds of surfaces are needed photos from different points of view.

Image_28: Part of the northern wall will irregular surface

<u>Corners</u>

The corner between the eastern and the southern wall was presented only in the mesh of the eastern wall. This was due to the fact that when the model of the southern wall was done, this corner did not appear in two pictures.

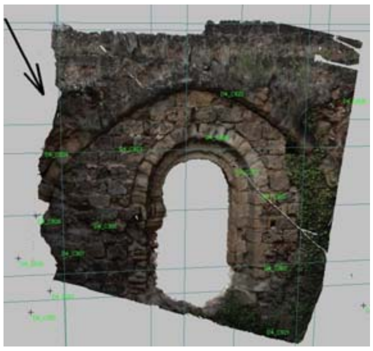



Image_29 & 30: The eastern-southern corner

The corner between the southern and the western wall was presented in both models of each wall but in each model appears a different part of it. This was normal as the two models were created using photos from different points of view, so that different parts of the corner were visible. Consequently, the one model completes the other. After merging the two different models with *Rapidform* we saw that the adjustment at the part of the corner was good.

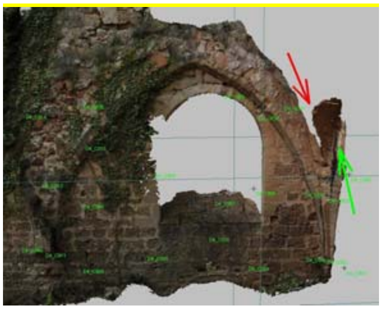



Image_31 & 32: The corner as it appears at the model of the southern wall, where: red the not presented part, green the appeared part

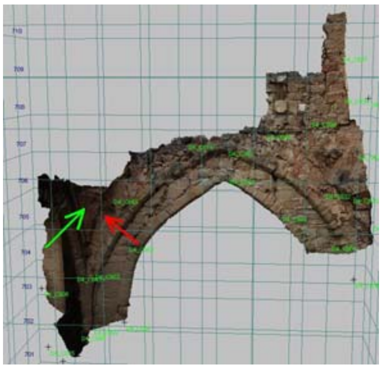
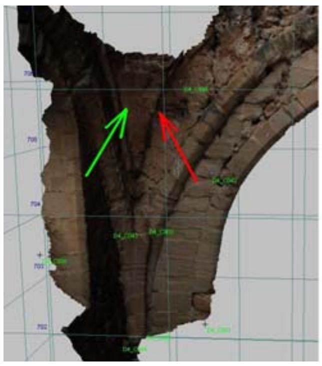



Image_33 & 34: The corner as it appears at the model of the western wall, where: red the not presented part, green the appeared part

The corner between the western and the northern walls was visible only in the model of the western part. As it is already analyzed the model of the north could not be created (irregular surface, geometry of photos, lack of control points) wall at this part.

At the image_36 it is demonstrated the bad representation of the corner regarding the part of it that is visible from the top. In order to improve this representation, photos from this point of view (from the top) should have been taken.

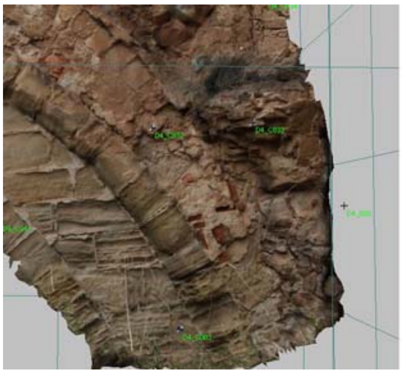



Image_35: Northern – western corner
Image_36: Northern – western corner, problematic area

The northern – eastern corner is represented in both the projects of the two walls. In a first effort to create the model of the northern wall the corner was not appeared (image_37) something that was corrected (image_38) by choosing the suitable photos in a stereopair.

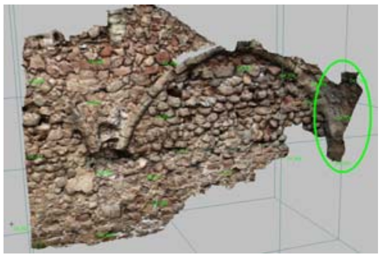



Image_37 & 38: The corner as it appears at the model of the northern wall

Image_39: The corner as it appears at the model of the eastern wall

The adjustment at this part of the two models during the merging of them was satisfacctory and the connection was good.

3.5.4.2.*Photomodeler Scanner 6*

The second software that was used for the processing of the photos was *Photomodeler Scanner 6*. Among its abilities are the generation of elevation drawings, rectified photos from single and multiple photo projects, the generation of the 3 D models (point clouds, TIN), the photo textured 3D models, the orthophotos[21]. Below are presented some more feautures:

- Create CAD-like models
- Perform accurate measurements
- Model man-made shapes
- Print and use Coded Targets
- Automate Projects
- Model organic and natural shape
- Dense Surface Modeling (DSM)
- SmartMatch

It was again used the bundle adjustment method with the parameters of calibration that the software computes. There is not the possibility of stereoscopic view.

For the generation of the point clouds we need to define the interval. It was decided an interval of 1 cm for all the models in order to obtain homogeneity, something that leaded to a good result but also made the procedure very slow. So at the end it was estimated that a less dense interval should have been tried and evaluated.

The advantage of this software is that the required photos permit the generation of one model for each wall, as the combination of photos of different point of views can give information for headen areas. Due to the fact, though, that the manual recommends not to use a lot of photos at the same project and due to the very slow procedure of creating the mesh, it was decided to divide the southern and the northern walls in three smaller projects.

At this part it should be mentioned that at the end instead of using pairs with 90 – 100% overlap and whose axis had a big angle, according to the initial planning of the work, they were used pairs that had small angle between them. This was because the software had as default a limit of 30g between the axis of the photos. According to this limit and other parameters that refer to the geometry of the photos, the software recommended to be used photos with a stereoscopic geometry.

The advantage of *Photomodeler Scanner 6* at this case was the fact that was possible the orientation and the generalisation of the model by combining pairs with different axis direction. So, it was taken more information by different points of view for the same object.

It should be mentioned that at the end the northern wall was not worked at all on this software due to lack of time and after deciding that the production of orthophotos would be done only by the models of *Image Master*.

Moreover, the models presented in this diploma thesis produced by *Photomodeler Scanner 6* are only point clouds. It was created only one TIN mesh (western wall) for being compared with the western TIN mesh created by *Image Master*. Based at this comparison (3.5.4.3) it was decided not to create more and to keep only the point clouds.

Below are presented some of the specific characteristics and challenges that each wall had.

<u>Eastern well</u>

[21] http://www.photomodeler.com/applications/architecture_and_preservation.htm

At the eastern wall they were used 8 photos. The number could be smaller as the surface of the wall is quite simple but it was intented to take photos with an angle of the axis of 10 g. The result of the relative orientation is 0.5 pixels and of the absolute is 0.004m (Image_40). For the creation of the whole model (one orientation) more than one meshes were created combing in the best way the used photos with the criteria of covering all the wall.

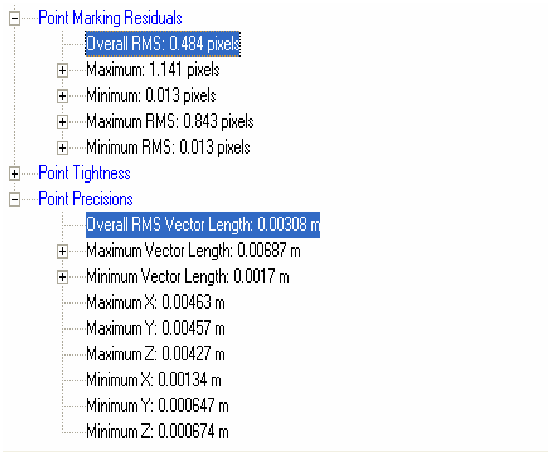


Image_40: Report of the east wall project

Southern wall

In order to make the procedure easier, the wall was worked on three projects (western part-project_1, central part-project_2, and eastern part-project_3). Each project was orientated seperately and as a result gave the point clouds.

By using this software it was possible to take all the information of the western part (project_1) of the southern wall in one model which was not possible using *Image Master*. For example, the window of this area (image_41) was covered by a pair of photos that were orientated at the same bundle adjustment of the whole project. This leads to an homogeneity concerning the result of the orientation.

Image_41: Point cloud of the western part of the southern wall created all in one project (one orientation)

Western Wall

It was worked in one project that was consisted of 12 photos. We paid a lot of attention at the corner with the southern wall (image_42).

Image_42: Western – Southern corner

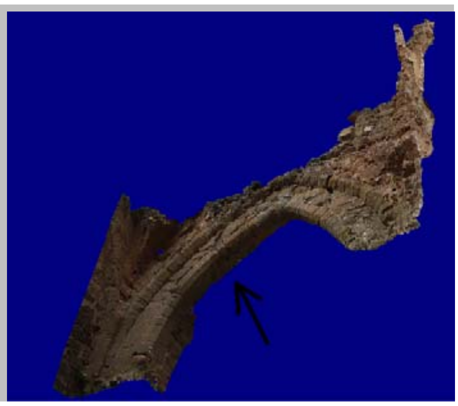
It was examinated the possibility of creating only one orientated model in which the whole corner will appear. So to the already orientated model (image_42) in which it was not visible all the corner, two more photos (one pair) were added covering the rest of the column. After these two photos were added at the project, a new orientation of all the photos were done and was created a mesh with this new pair.

When merging the meshes the adjustment at the corner was not good at the common parts. This might be explained with the fact that the first created mesh was created with an orientation in which the new pair did not participate. So the two meshes were created with different orientations. Of course, even in this case as they are orientated in the same coordinate system, their adjustment should be good. A possible reason for not happening this is the errors of the orientations.

3.5.4.3. Comparison of Model – Evaluation

Both softwares gave sufficient results.

The geometry of the photos that *Photomodeler Scanner 6* uses permits to obtain more information in one model. At the images_44, 45 & 46 is pointed out the fact that the Photomodeler Scanner 6 in one only model could represent better than *Image Master* the bottom of the arc. These two projects use the same set of six photos for representing this wall. These six photos included almost all the information that *Photomodeler Scanner 6* used in order to create point cloud for this area. With the same six photos *Image Master* could not create mesh for this area. A possible explanation for this, is that the bottom of the arc is in the same direction with the axis of taking the picture. The areas that *Image Master* can represent well are the ones that are perpendicular to the axis of taking the picture.



Images_44: The western wall
Image_45: The bottom of the arc part represented at *Photomodeler Scanner 6*

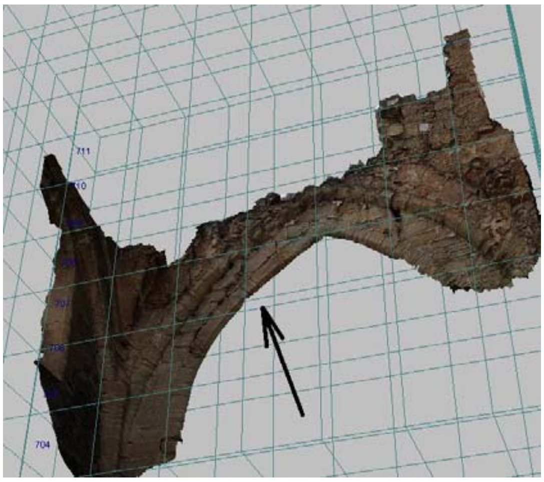


Image_46: The bottom of the arc part represented at *Image Master*

Below, at the images 47 and 48 are presented two small areas of the two meshes that the softwares produce. The mesh of *Photomodeler Scanner 6* is not adjusted as well as the one of *Image Master*. This could be to due to the algorithms that its software uses for interpolation of the color or for smoothing the mesh.

In addition to this the procedures of creating the mesh using this software are slower than the ones of *Image Master.*

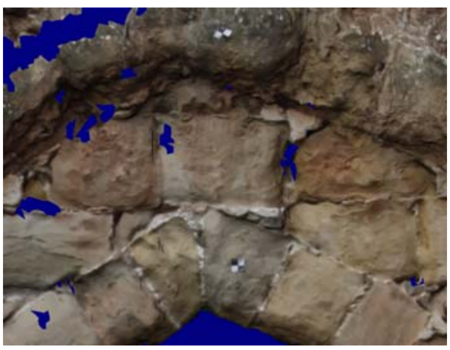


Image_47: Mesh of *Photomodeler Scanner 6*
Image_48: Mesh of *Image Master*

Moreover, the calibration of the *Photomodeler Scanner 6* was not so accurate as it used bad taken photos.

Taking into account the quality of mesh, the time needed and the calibration, it was estimated that *Image Master* is more suitable for generating the orthophotos.

3.5.5. Generation of Orthophotos

The following diagram (diagram_2) describes briefly the flowchart in order to create an orthophoto. All these procedures are done automatically by the used software using the basic photogrammetric formulas. The user needs to introduce the suitable data (initial photos, coordinates of the control points), the Ground resolution - Ground Sample Dimensional (GSD), that it is the dimension of the object that the pixel is going to represent, the part of the mesh that is going to be used for the generation of the orthophoto, the projection plan, the initial photo by which it is going to have the colour interpolation and the mathods of it (nearest neighbour, linear or bilinear).

In this project in order to produce a uniform result, all the generated orthophotos were made using the same parameters. It was chosen a GSD of 5 mm that it is recommended[22] for final scale results on a scale 1:50.

As projection plans, it was chosen one plan for every wall that was adjusted in a sufficient way at the mean plan of the wall.

The products were evaluated by checking the position of the control points on them. In order to improve the evaluation, they were checked some control points that were not used at the procedure of the orientation. All the results and their accuracies are analysed at the fourth chapter.

[22] Metric Survey Specifications for English Heritage

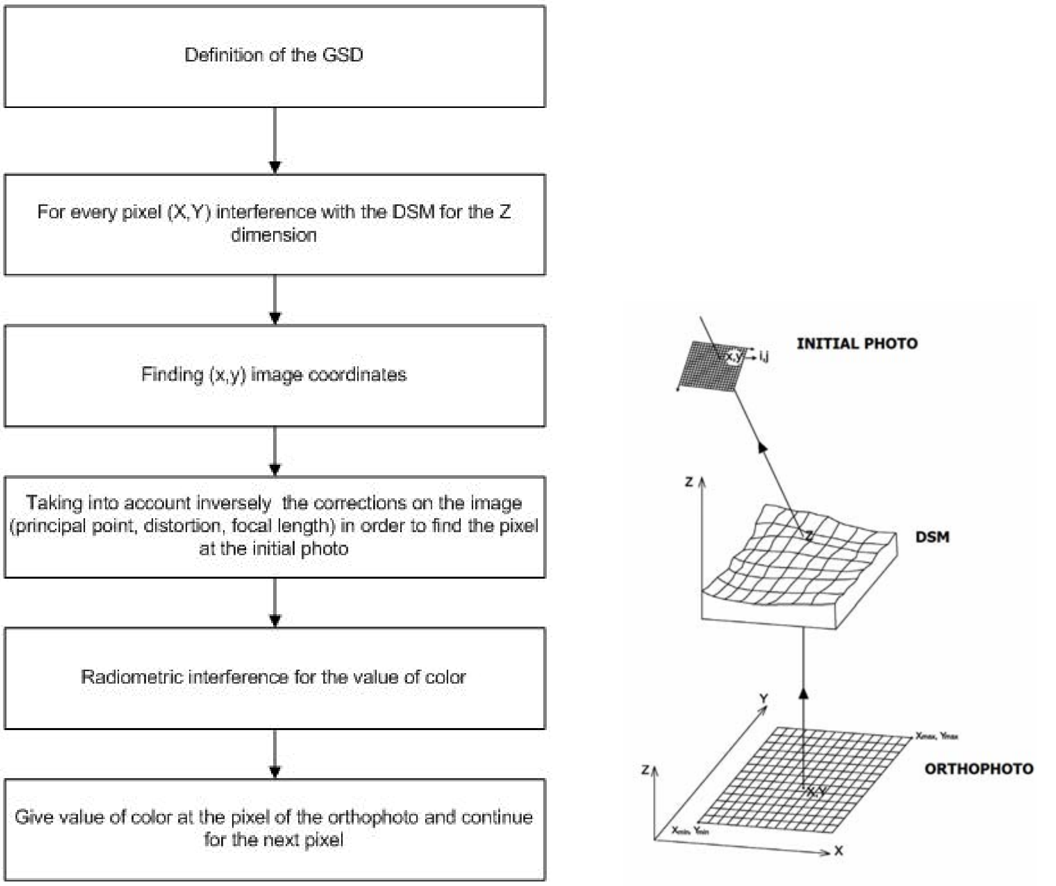


Diagram_2 & Image_49: Generation of orthophoto [23]

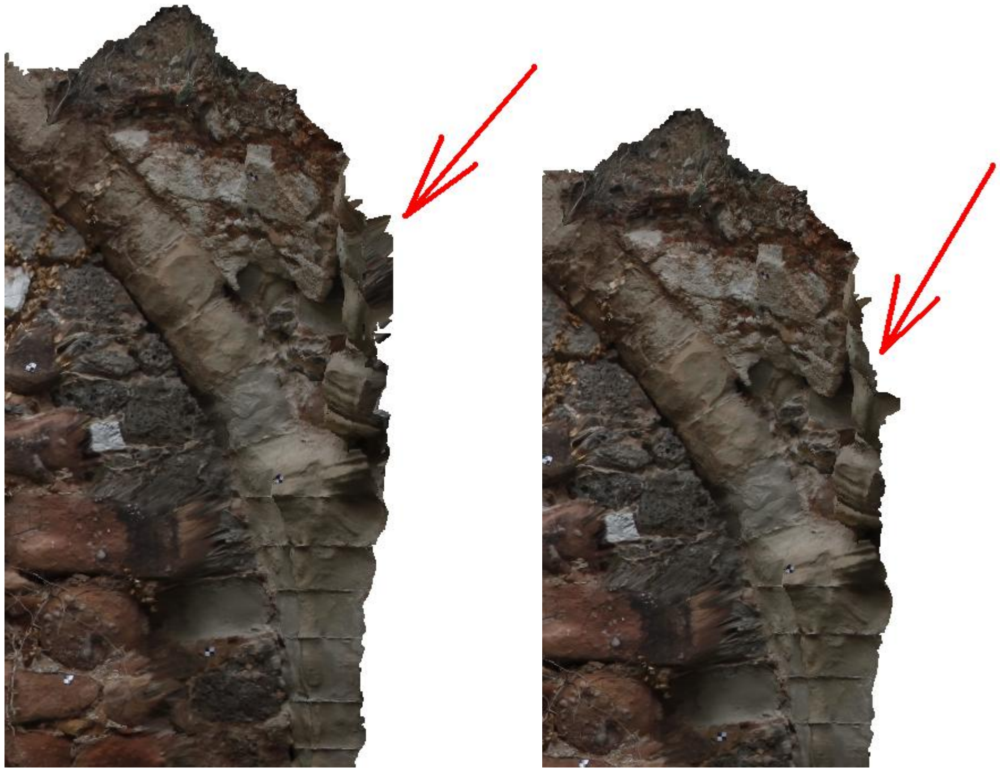
3.5.5.1. Image Master

The orthophotos are depended on the meshes. For areas where there is no mesh, can not be produced orthophoto. So the orthophotos follow the management of the meshes that was analysed at this chapter (3.5.4.1. Image Master).

Eastern wall

It was created only one mesh for this area, based on which was created the orthophoto. Before achieving the final result, they were made some edits to the mesh in order to obtain better orthophoto. More specifically, the corner with the southern wall was projected badly at the chosen projection plane so this area was cut from the mesh end did not appear at the orthophoto. It is better not to have information than have a bad not estimated information.

[23] Lectures of Ioannidis Charalabos, Photogrammetria II, NTUA



Images_50 & 51: Orthophoto with bad and no information at the corner

Southern wall

For this wall they were created three basic orthophotos (image_52,53 & 54) for the three different meshes.

Images_52,53 & 54: Orthophotos of the southern wall

As for as the plants on the walls (creepers), they are not represented at all the parts well (correct position and shape) as the meshes at these areas was bad due to the irregular shape they had. But due to the fact that they are part of the wall, as they are stuck on them, it was decided to leave them even in a not correct position. In any case, these areas only complete the view of the walls and they should not be used for measurements.

The parts of the wall that are not visible at no one of the orthophotos and due to their shape and the initial obtained photos could not be represented, were designed in *Autocad* as missing surfaces.

As it is already analyzed, more meshes were created for areas (window and column) that one mesh could not have all the information and photos of a specific point of view were needed. As for the window (image_54) and it s part in depth (image_25, page 35) it should not be appeared at the chosen projection plan, so no more actions were taken place for this part.

As it is visible at the images_52 and 53 it is missing the column between these parts. Using the suitable photos by the appropriate point of view there were created the meshes and the orthophotos for this part (images_55 & 56)

Images_55 & 56 : Orthophotos of the column (southern wall)

For the common parts that different orthophotos have (images_57 & 58), it was used the orthophoto with the better geometric accuracy, checked by the control points.

Images_57_58: Common parts at different orthophotos

Western wall

For this wall were created two orthophotos, one with almost all the information of the wall and one with the northern highest part of it.

Image_59: Orthophoto of the western wall consisted of two united orthophotos

Northern wall

For this wall were also generated two orthophotos, based on two meshes. For the common parts was chosen the orthophoto that had the better adjustment – accuracy at these parts.

Image_60: Orthophoto of the northern wall consisted of two united orthophotos

Chapter_4: Results - Evaluation

At this chapter are presented all the results with their evaluation. The criteria with which this evaluation both for the meshes and the orthophotos was made was:

- The completeness of the object. The object was devided into two areas. One area that was needed to be documentated and another that its documentation was not important. For example at the second category were classified areas that there is no need to be measurements, such as the parts of wall with plants. Moreover the interior part of the holes at the eastern wall was an area that after descussing with the collaborator archaiologist was decided not to be documeentated.

- The metric - geometric accuracy of the product. This creteria is very important for the areas that are going to be used for measurements. So, for the areas that have been classified as no important to be documentated (criteria_1) the metric accuracy is not important. So, the no information or the bad information of this area does not reduce the quality of our project. For the rest area, at the orthophotos the desirable accuracy is 1, 25 cm ≈ 1 cm, which is the required for the selected scale 1: 50. As for the meshes, the basic demand is that they are able to produce the required accuracy at the orthophotos. A metric accuracy of 2-3 cm is enough as they are not going to be used for measurements but only for 3Dimensional visual observation of the church.

- The quantity of noise. The noise in a point cloud or a mesh is points or triangles that should not be appeared (points representing the sky, points over the surfaces of the walls). This noise of the meshes can be expressed at the orthophotos with projected areas that should not be represented.

- The radiometric homogeinity. This criteria refers mostly to different meshes and orthophotos of the same wall.

4.1. 3 Dimension Models

The 3 Dimension models can be observed, checked and edited in a scale 1:1 by different softwares that manage this kind of products. Below are presented the models as screenshots by a perspective point of view chosen in a way that the model can be presented better. Both Point Clouds and TINs, are presented with their texture. Their metric accuracy was checked by measuring the differences from the original coordinates of the control points and their images on the textured model. The control points that were not used during the orientation gave a fairer estimation of the accuracy. The differences are analysed at the components of the three axis (X,Y,Z) so that it can be noticed the direction of the deviation – error.

The point clouds were checked only regarding their completeness in describing the object and their noise as there was not measuring distance ability.

Eastern wall

- Textured mesh of *Image Master*

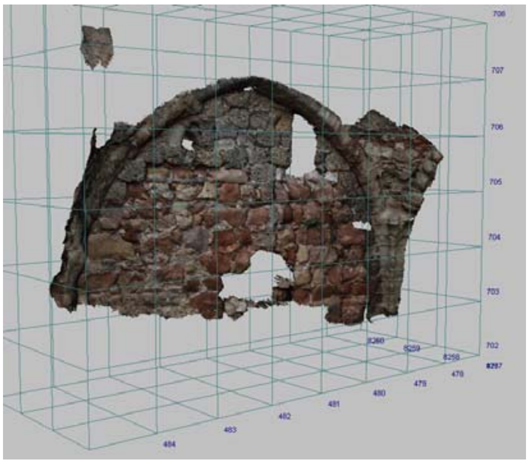


Image_61: Mesh of eastern wall

It is represented the bigger part of the wall. The areas where there is no information are mainly dark holes. A proposal for taking information for these areas if it is needed (i.g. archaeologist and architect needs), is to use special lighting condition for taking the photos.

Below it is presented the table with the differences from the original coordinates of the control points and their images on the textured mesh. It should be mentioned that all the following meshes regarding the accuracy of the meshes, calculate the difference like this:

original coordinate – image coordinated

This clarification is useful in case that we need to check the direction of the error of the mesh.

Eastern Model						
wall	point	DX (m)	DY(m)	DZ(m)	horizontal distance (m)	slope distance (m)
east	D4_C924	-0,003	-0,008	-0,006	0,009	0,011
	D4_C925	-0,006	-0,008	0,002	0,009	0,009
	D4_C926	0,001	-0,006	-0,002	0,006	0,006
	D4_C927	-0,012	-0,016	-0,017	0,020	0,026
	D4_C929	-0,003	-0,008	-0,004	0,009	0,010
	D4_C930					
	D4_C932					
	D4_C933					
	D4_C934	0,003	0,001	0,006	0,003	0,007
	D4_C935	0,002	-0,002	0,009	0,003	0,009
	D4_C358	0,001	0,012	0,005	0,016	0,017
	D4_C359	-0,010	0,003	-0,007	0,010	0,012
	D4_C352	0,001	0,008	-0,006	0,008	0,010
				mean difference:		0,011
	not_used_points	DX(m)	DY(m)	DZ(m)	horizontal distance (m)	slope distance (m)
	D4_C357	-0,002	0,018	0,006	0,018	0,019
	D4_C928	-0,014	-0,019	-0,010	0,023	0,025
	D4_C931	-0,002	-0,013	-0,010	0,013	0,013
	D4_C356	0,007	0,014	0,000	0,015	0,015

				mean difference:	0,018

Table_5: Precision of the mesh as it is measured by checking the position of control points

The mean difference is 0.011m for the used at the orientation and 0.018m at the not used points. The point D4_C928 has the worst accuracy 0,025m. It is estimated that it could be enough good depending on the producted orthophoto according to the criteria that are mentioned above.

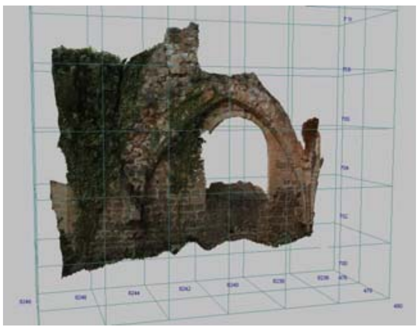
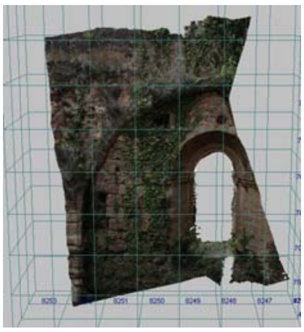
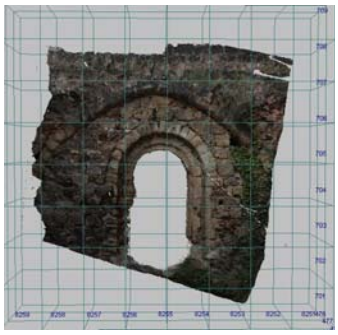
- Textured point cloud of *Photomodeler Scanner 6*

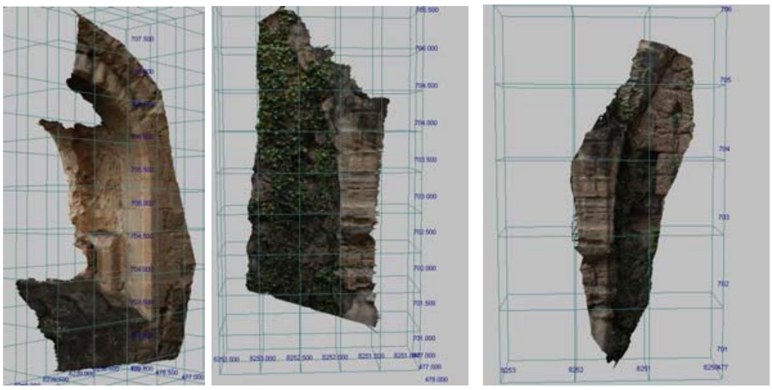
Image_62: Point Cloud of eastern wall

There is possibility for a better obtained result by editing more the point cloud. There is some noise at the upper part that should have been cleaned.

<u>Southern Wall</u>

- Textured Mesh of *Image Master*



Images_63, 64, 65, 66, 67 & 68: Meshes of southern wall

There are parts of the wall that are missing but most of them are not included at the needed for documentation area, because they are part of the walls with plants. Something that was needed to be represented but failed due to a lack of suitable photos was the eastern part of the window (image_66).

But in general there is a sufficient percentage of the whole wall that is represented well, so the criteria of completeness it is covered.

As for the area of the plants that it is represented it should be mentioned that this area is not represented well and it should not be used for measurements.

Below it is presented the table with the differences from the original coordinates of the control points and their images on the textured mesh.

Southern Model						
wall	point	DX (m)	DY(m)	DZ(m)	horizontal distance (m)	slope distance (m)
south_part_1	D4_C004	-0,002	0,002	0,001	0,002	0,003
	D4_C907	0,003	-0,004	-0,004	0,005	0,007
	D4_C041	-0,004	0,002	-0,001	0,004	0,004
	D4_C906	-0,005	0,004	-0,001	0,007	0,007
	D4_C008	-0,005	0,004	0,000	0,006	0,006
	D4_C010	-0,006	0,005	0,001	0,007	0,008
	D4_C911	0,001	0,001	0,002	0,002	0,003
	D4_C902	0,000	-0,006	0,000	0,006	0,006
	D4_C903	0,002	-0,003	0,001	0,004	0,004
	D4_C914	-0,002	0,006	-0,001	0,006	0,006
	D4_C915	-0,009	0,001	0,003	0,009	0,010
				Mean difference		0,006
south_part_2	D4_C915	-0,009	-0,004	0,006	0,010	0,012
	D4_C799	0,008	0,006	-0,008	0,001	0,013
	D4_C039	0,004	0,000	-0,001	0,004	0,004
	D4_C920	-0,013	-0,002	-0,007	0,012	0,015
	D4_C037	0,000	0,007	0,000	0,007	0,007

				mean difference		0,010
south_part_3	D4_C313	0,005	0,011	-0,001	0,012	0,012
	D4_C306	0,003	0,014	-0,002	0,014	0,015
	D4_C307	0,009	-0,009	0,008	0,012	0,014
	D4_C308	0,014	0,016	-0,008	0,022	0,023
	D4_C923	-0,011	-0,002	0,004	0,011	0,011
	D4_C920	-0,017	-0,014	0,001	0,022	0,022
				mean difference		0,016
column	D4_C037	-0,003	0,003	0,000	0,004	0,004
				mean difference		0,004
				Mean difference of all the parts		0,009
	not_used_points	DX(m)	DY(m)	DZ(m)	horizontal distance (m)	slope distance (m)
south_part_1	D4_C043	0,003	0,000	0,002	0,003	0,003
	D4_C044	0,003	0,002	0,001	0,003	0,003
	D4_C035	0,001	-0,002	-0,006	0,003	0,007
	D4_C038	-0,005	0,002	-0,001	0,005	0,005
	D4_C036	-0,006	0,005	-0,001	0,008	0,008
	D4_C910	-0,001	0,006	0,001	0,006	0,006
	D4_C909	0,002	0,006	0,003	0,006	0,007
	D4_C913	-0,004	0,003	0,000	0,005	0,005
	D4_C040	-0,002	0,008	0,003	0,008	0,009
	D4_C916	-0,011	0,005	0,004	0,012	0,013
				mean difference		0,007
south_part_2	D4_C918	-0,015	0,001	-0,004	0,015	0,016
	D4_C917	-0,015	0,000	-0,011	0,014	0,019
				mean difference		0,017
south_part_3	D4_C305	0,002	0,005	-0,001	0,006	0,006
	D4_C922	-0,035	0,010	-0,004	0,036	0,036
				mean difference		0.021
				Mean difference of all the parts		0.015

Table_5: Presicion of the mesh as it is measured by checking the position of control points

Points that are appeared at two different meshes are used for checking the accuracy of each mesh and choose the best mesh that represents the common area.

The mean difference of all the walls is 0.009m for the used at the orientation and 0.015m for the not used points. The point D4_922 has the worst accuracy 0.036m. The area with the plants has a bigger error that due to the lack of control points at this part can not be estimated, but as we said above this area will not be considered. For the rest part the accuracy it is enough good according to the criteria of the accuracy of the meshes (completeness, 2-3 cm geometric accuracy).

- Point cloud of *Photomodeler Scanner 6*



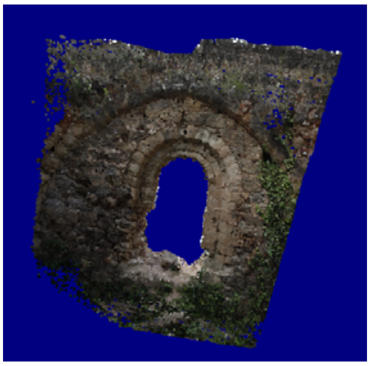


Image_69, 70 &71: Point Cloud_1, 2 & 3 of southern wall

These models also need to be cleaned better from the noise. For example, at the image_70 are appeared some white points that have colour information of the sky. These points should be deleted.

<u>Western wall</u>

- Textured Mesh of Image_Master

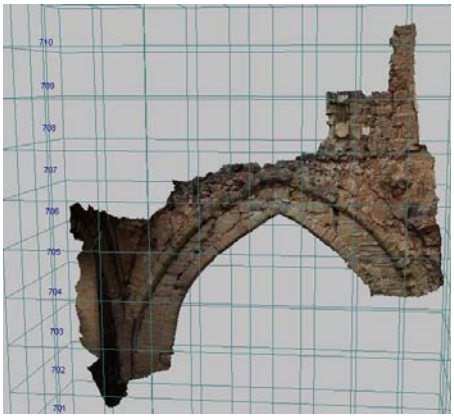


Image_72: Mesh of western wall

The mesh completes enough the representation of the wall. It is missing the southern upper part due to the fact that there were not photos for this part. The bottom of the arc is also missing. Some photos taken by a point of view that this part is visible is the solution for completing this area.

At this mesh it is also represented a part of the southern wall, that it was also checked by control points (D4_C043, D4_C044) the error of which was more at this mesh than at the corresponding mesh of the southern wall (image_63, table_7)

Below it is presented the table with the differences from the original coordinates of the control points and their images on the textured mesh.

wall	point	DX (m)	DY(m)	DZ(m)	horizontal distance (m)	slope distance (m)
west	D4_C834	0,003	-0,002	0,000	0,004	0,004
	D4_C838	0,003	-0,004	-0,001	0,005	0,005
	D4_C832	0,008	0,000	-0,003	0,008	0,008
	D4_C003	0,016	-0,002	-0,003	0,016	0,016
	D4_C840	-0,005	-0,004	-0,001	0,006	0,007
	D4_C841	-0,006	-0,001	0,002	0,006	0,006
	D4_C843	0,002	0,002	-0,001	0,003	0,003
	D4_C842	-0,005	0,000	0,002	0,005	0,005
	D4_C844	-0,003	-0,003	-0,003	0,004	0,005
	D4_C042	-0,002	-0,001	0,000	0,002	0,002
	D4_C902	-0,002	0,000	0,001	0,002	0,002
	D4_C903	-0,006	0,001	0,001	0,001	0,007
				mean difference		0,006
	not_used_point	DX(m)	DY(m)	DZ(m)	horizontal distance (m)	slope distance (m)
	D4_C845	0,049	0,003	0,004	0,049	0,049
	D4_C044	0,010	0,002	0,000	0,010	0,010
	D4_C043	0,008	0,002	-0,001	0,008	0,008
				mean difference		0,023

Table_7: Precision of the mesh as it is measured by checking the position of control points

The mean difference is 0.006 mm for the used at the orientation and 0.023 mm at the not used points. The point with the worst metric accuracy is the D4_C845 with error 0.049, that it is a lot but at the orthophoto this point is appeared satisfactory good. This is because at the components of the selected projection plan (Y,Z) the error is acceptable. The big error is at the X component, which expresses the depth.

- Point cloud of *Photomodeler Scanner 6*

Image_73: Point Cloud of western wall

The visual result is quite sutisfactory. In contrast with the mesh of *Image Master,* at this point cloud it is represented quite well the bottom part of the arc.

Northern wall

Image_74 & 75 : Meshes of northern wall

At this wall a big part was represented badly due to reasons that have already been analyzed (3.5.4.1). Therefore, it was decided to leave out this area. The rest of the wall is quite accurate as far as the control points used (table_9). The mean error for the used and the not used (only one point) to the orientation points is 0.005m and the worst one is 0.010m for the point D4_935.

Northern model					

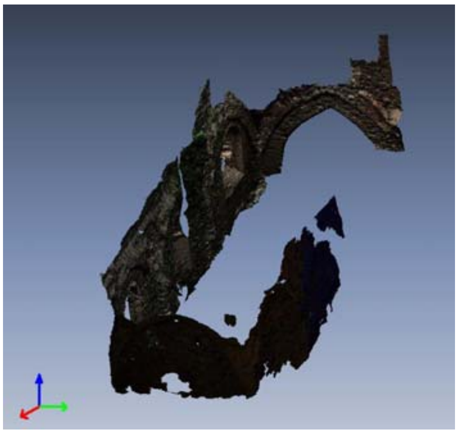
wall	point	DX (m)	DY(m)	DZ(m)	horizontal distance (m)	slope distance (m)
north_part_1	D4_636	-0,002	-0,002	0,003	0,003	0,004
	D4_364	0,001	-0,001	-0,002	0,002	0,003
	D4_362	0,000	0,004	0,003	0,004	0,005
	D4_936	0,002	-0,001	0,000	0,002	0,002
	D4_822	0,003	0,005	0,001	0,006	0,006
	D4_933	0,002	-0,002	-0,001	0,003	0,003
	D4_934	0,003	-0,001	0,000	0,003	0,003
	D4_636	-0,002	-0,002	-0,003	0,003	0,004
	D4_935	0,007	0,006	-0,004	0,009	0,010
	D4_011	-0,001	0,005	0,000	0,005	0,005
	D4_825	-0,001	-0,001	0,002	0,001	0,002
	D4_826	-0,001	-0,002	-0,003	0,002	0,004
	D4_828	0,006	-0,002	0,001	0,007	0,007
	D4_827	0,002	-0,001	-0,003	0,002	0,003
	D4_824	0,001	0,001	-0,002	0,001	0,002
	D4_823	0,003	-0,005	-0,004	0,006	0,007
	D4_367	0,000	-0,006	-0,002	0,006	0,006
	D4_368	0,003	-0,004	-0,002	0,005	0,005
				mean difference		0,005
north_part_2	D4_825	0,000	0,001	-0,003	0,001	0,003
	D4_826	-0,001	0,002	0,004	0,002	0,005
	D4_828	0,008	0,000	0,000	0,008	0,008
	D4_827	0,003	-0,001	-0,003	0,003	0,004
	D4_831	0,003	-0,004	-0,002	0,005	0,005
	D4_372	0,000	0,003	-0,002	0,003	0,003
	D4_373	0,002	-0,001	-0,002	0,002	0,003
	D4_374	0,002	-0,002	-0,002	0,003	0,004
	D4_829	0,004	-0,002	-0,001	0,004	0,004
				mean difference		0,004
				Mean difference of the two parts		0,005
	not_used_point	DX(m)	DY(m)	DZ(m)	horizontal distance (m)	slope distance (m)
north_part_2	D4_011	0,003	-0,002	-0,004	0,004	0,005
				mean difference		0,005

Table_8: Precision of the mesh as it is measured by checking the position of control points

Merging the meshes

After being created and edited the meshes, they were merged in *Rapidform.* Finally they were used 12 meshes that were representing the biggest part of the church. For the orientation of the meshes were used control points at the same coordinate system. So for merging the meshes, it was necessary only to introduce them at *Rapidform* avoiding the time consuming procedure of finding common points between them. At the common parts the visual adjustment was sufficient good.

It should be mentioned that due to the many meshes the procedures of the software were very slow creating problems to the good observation of them. Moreover the texture does not have a good resolution.

Images_76 & 77: The merged mesh from different points of view

4.2. Orthophotos

The orthophotos in general follow the meshes as far as the accuracy (completeness, geometric accuracy, noise). Where there is no information at the meshes, the software can not use the photogrammetric formulas and do not create the orthophoto. Also for areas that the mesh has a bad geometric result, the error of it is transfermed at the final orthophoto.

Below are represented the generated orthophotos by *Image Master* with tables that show the differences between the original projected at the projection plan coordinates (k) of the control points and the coordinates (k΄) that their images have (Dk = k΄ -k). This difference demostrates in away the geometric accuracy of the result.

Eastern wall

Image_78: Orthophoto of the eastern wall

wall	point	DX(m)	DY(m)	horizontal distance (m)
eastern	D4_C924	-0,02	0,007	0,021
	D4_C925	-0,018	0,002	0,019
	D4_C926	-0,018	0,004	0,018
	D4_C927	-0,023	0,016	0,028
	D4_C929	-0,015	0,005	0,016
	D4_C934	-0,001	0,007	0,007
	D4_C935	0	0,008	0,008
	D4_C359	-0,014	0,005	0,015
	D4_C352	0,004	0,005	0,006
			mean difference	0,015
	Not used points			
	D4_C931	-0,015	0,005	0,016
	D4_C356	0,002	0,002	0,003
	D4_C357	0,01	,.0076	,.0122
			mean difference	0,014

Table_9: Precision of the eastern orthophoto as it is measured by checking the position of control points

The mean error for this wall it is bigger than the acceptable. The used control point D4_927 has a difference from its position almost 3cm. Having in mind that the checking by control points only gives an estimation of the accuracy, it is notable that the geometric error can be even bigger at other parts of the image.

The surface of the wall is enough regular and the texture too. Moreover there was a good distribution of the control points at the object, so this inaccuracy was not expected. The calibration is considered to be good as the other projects have sufficient results. So, a possible explanation was the human error during the photogrammetric procedure (marking the points at the images) or during the measurments of the control points. Another explenation is that the used method with the used data was not the suitable for this wall. It is proposed this wall to be worked with different photos, more control points, even different methods (e.g. laser scanning) and compare the results.

<u>Southern wall</u>

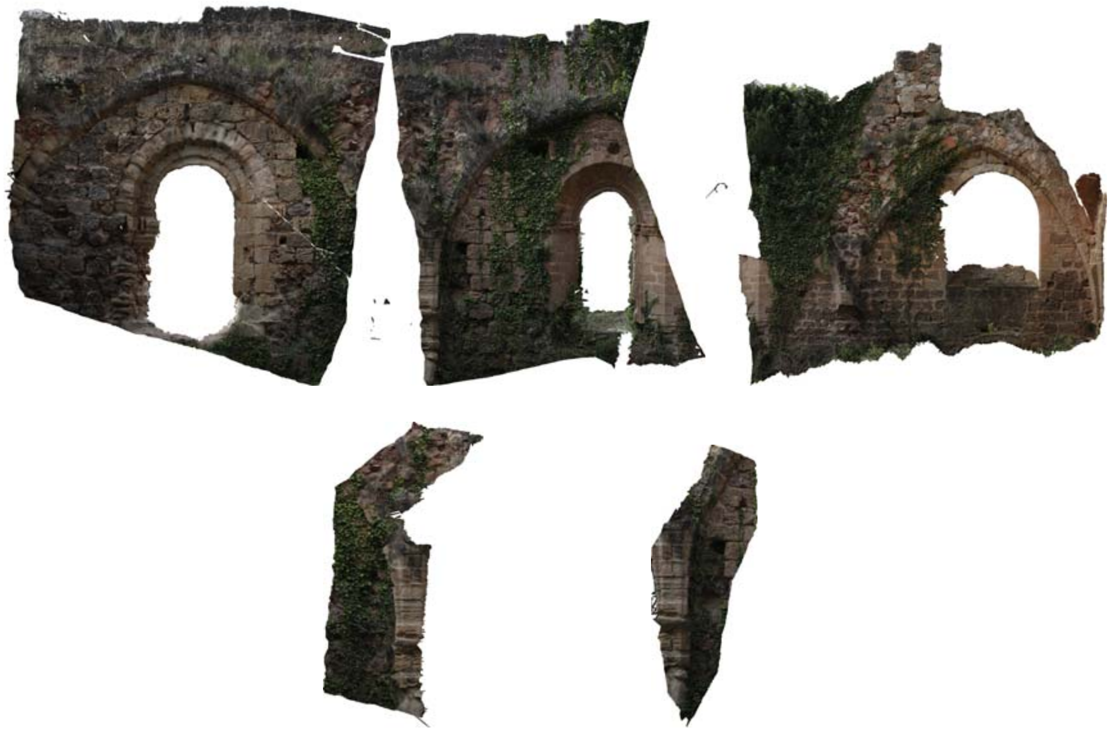


Image_79, 80, 81 & 82: Orthophotos of the southern wall

wall	point	DX(m)	DY(m)	horizontal distance (m)
southern_part_1	D4_C906	-0,004	-0,003	0,005
	D4_C907	0,002	0,002	0,003
	D4_C911	0,002	-0,003	0,004
	D4_C036	-0,005	-0,002	0,006
	D4_C914	-0,001	-0,001	0,001
	D4_C902	-0,006	-0,009	0,011
	D4_C903	-0,001	-0,005	0,005
	D4_C008	-0,004	0,001	0,004
	D4_C004	-0,002	0,001	0,002
	D4_C041	-0,006	-0,003	0,006
	D4_C010	-0,002	-0,002	0,003
			mean difference	0,005
southern_part_2	D4_C915	0,005	-0,005	0,007
	D4_C916	-0,006	-0,004	0,007

	D4_C920	-0,025	-0,016	0,029
	D4_C039	0,000	-0,003	0,003
	D4_C799	0,026	-0,002	0,026
	D4_ 040	0,003	-0,007	0,007
			mean difference	0,013
southern_part_3	D4_C302	-0,002	0,001	0,002
	D4_C313	0,000	-0,008	0,008
	D4_C306	0,007	-0,011	0,013
	D4_C307	0,019	0,003	0,019
	D4_C308	0,023	0,000	0,023
	D4_C923	-0,002	-0,007	0,008
southern_column	D4_C037	-0,008	-0,002	0,008
			mean difference	0,012
		Mean differences of all the parts		0,010
	Not used points			
southern_part_1	D4_C043	-0,002	0,001	0,002
	D4_C044	0,002	-0,002	0,002
	D4_C035	-0,004	0,001	0,004
	D4_C909	0,005	0,003	0,004
	D4_C910	0,001	-0,003	0,003
	D4_C913	-0,003	0,002	0,004
	D4_C038	-0,006	-0,002	0,006
			mean difference	0,004
southern_part_2	D4_C917	-0,020	0,004	0,020
	D4_C918	-0,010	0,001	0,010
			mean difference	0,015
southern_part_3	D4_C305	0,002	-0,007	0,007
	D4_C921	-0,031	-0,008	0,027
	D4_C922	-0,031	-0,008	0,032
			mean difference	0,022
		Mean difference of all the meshes		0.013

Table_10: Precision of the southern orthophoto as it is measured by checking the position of control points

The biggest error is for point D4_C922 (mre than 3 cm) and is more than the acceptable. This wall has anaceptable accuracy at its bigger part. The western part (part_1) has satisfactory mean error 0.005m.

As for the completeness, the model it is quite satisfactory. Five meshes were created in order to achieve the more coverage of the wall.

Western wall

Images_83 & 84 : Orthophotos of the western wall.

wall	punto	DX(m)	DY(m)	horizontal distance (m)
western	D4_C837	-0,003	-0,001	0,003
	D4_C834	-0,003	0,001	0,003
	D4_C838	-0,001	-0,003	0,003
	D4_C832	-0,005	0,002	0,006
	D4_C003	-0,002	0,002	0,003
	D4_C840	-0,005	0,000	0,005
	D4_C841	0,007	-0,005	0,005
	D4_C843	-0,003	-0,003	0,004
	D4_C842	-0,002	0,001	0,002
	D4_C844	-0,006	0,001	0,006
	D4_C042	0,000	-0,001	0,001
	D4_C902	0,000	-0,001	0,001
	D4_C903	0,001	-0,001	0,002
			mean difference	0,0032
	Not used points	DX(m)	DY(m)	horizontal distance (m)
	D4_C845	0,000	-0,007	0,007

Table_12: Precision of the northern orthophoto as it is measured by checking the position of control points

The error that the checking of control points at the first orthophoto (image_83) gives, is quite small regarding with the accuracy that the scale of the orthophoto requires

(1.25 cm). The maximum error is at the point D4_845 (0.007m) that was not used at the procedure of the orientation. It should be mentioned that the checking is not absolutely representative as it is being done only with one non used point. We should have measured more control points or at least, some of the measured ones should not have been used for the orientation. As for the second orthophoto (image_84), it is not checked by control points as at this part do not appear none of them. It is only checked by its adjustment and relative position with the first orthophoto.

These two orthophotos cover almost all the part of the western wall. It is missing the upper southern part, that it is almost all covered by plants.

So as far as our creteria about the orthophotos, completeness and geometric accuracy, this part is represented enough well.

<u>Northern wall</u>

Images_85 & 86: Orthophotos of northern wall

As it is shown at the table_12, the precision that both these photos have is quite good regarding with the required one (1,25 cm for the scale 1:50). The point D4_372 that was not used to the procedure of orientation has the bigger error (1cm). For the common parts of the meshes it was chosen the mesh on which the control points had the better accuracy .

At these orthophotos there is a problem as far as the radiometric homogeneity concerned. As it can be noticed, there is a line appeared at the orthophoto that divides the photo at two areas with different brightness. This problem can be solved by editing the photos at an image editing sofware (e.g. *Photoshop*).

Another proposal is to change the selected initial image from which *Image* Master is going to take the colour information for the creation of the orthophoto. This was tried but due to the fact that there was no initial image that contained all the sellected part of the mesh that was going to be used in order to make the orthophoto, the result had again radiometric differences.

These differences do not influence the metric accuracy of the final result.

Wall	point	DX(m)	DY(m)	horizontal distance (m)
norte_part_1	D4_636	0,006	-0,001	0,006
	D4_936	0,004	-0,002	0,004
	D4_822	0,003	-0,003	0,005
	D4_824	0,005	-0,001	0,005
	D4_823	0,003	0,001	0,003

	D4_367	0,002	0,001	0,003
	D4_368	-0,002	0,001	0,002
	D4_011	-0,003	-0,003	0,004
			mean difference	0,004
norte_part_2	D4_831	-0,003	-0,001	0,003
	D4_374	-0,005	0,002	0,009
	D4_829	-0,004	-0,002	0,005
	D4_828	-0,004	-0,002	0,005
	D4_827	-0,001	-0,001	0,002
	D4_826	-0,001	-0,004	0,004
	D4_825	0,000	-0,004	0,004
	D4_830	-0,004	-0,001	0,004
			mean difference	0,004
	Not used points			
	D4_372	-0,006	0,008	0,010

Table_12: Precision of the northern orthophoto as it is measured by checking the position of control points

Chapter_5: Conclusions – Proposals

This project covers sufficiently the aims of its planning that was to documentate the church of the Monastery of San Prudencio.

As for the simple representation that its results (3Dimensional textured models and orthophotos) can offer, independently from geometric accuracy and interessted only in a satisfactory visual result they are absolutely acceptable results that could be used in many ways.

As it is already analyzed, the desirable metric accuracy of the orthophotos was 1 cm in order to be compatible with the permitable error of the scale 1: 50. This was not succeded at all the orthophotos, something that reduces the quality of all the results as we are obligated to keep as final accuracy, the worst one. But accompanied the results with this diploma –thesis that describes the distribution of the error, pointing out the areas that exceeded with big error all the orthophoto and the areas that have the sufficient accuracy, they can be a useful tool at archaiologists, architects and to whom is interested to take metric data from them.

Some conclusions that result from this project and can be proposals for similar projects are mentioned below:

<u>Field work</u>

- It should be paid a lot of attention during the planning of the work and take the suitable data. More photos that cover all the object with the needed geometry should have been taken, having in mind not only the part of the object that it is going to be projected at the projection plan, but also the completeness of the 3 Dimensional model that should include all the object from every point of view. For example the areas at the bottom part of the arc (western wall) and the curve of the window (southern wall) could be represented with a few more photos.

- As for the western part of the northern wall, that at the end its documentation was unsuccessful, it results that the biggest problem was not the lack of the control points but the surface and the texture of it. As solutions to this kind of walls are proposed measurements of control points without targets with the help of a total station that have integrated a camera The photos that the camera takes can be used for making automatically sketches on which the control points can be appeeared in a zoom size better than at the manual sketches that the surveyer can do. Moreover, it would be interesting to try to take many pairs of this wall from all the basic possible points of view. For achieving this, a lifting machine or other equipment that can lift (remote control helicopter, balloon) the camera at the desirable height could be used.

- In cases that it is needed the interior of the holes at the eastern wall (measuring its depth, observating its rocks etc), they should be used special light conditions.

- The plants at the bottom of the walls should have been cleaned before of the collection of the data as they leaded at the end at lack of information.

- They should have been measured more control points for checking the final result. In some cases in order to orientate the model it was needed to be used at the orientation almost all the control points we had. So at the end it was not able to be checked our results by not used at the orientation points.

Office work

- Part of this project was the small investigation of the abilities of two photogrammetric softwares (*Image Master* and *Photomodeler Scanner 6*. So it was necessary to get familiar with the two programs, something that leaded to a lot of consumed time for obtaining almost the same result by two different sources. For educational reasons, these procedures leaded to experience not only of using just photogrammetric software but also to have better contact with the sciense of photogrammetry, by trying to understand the procedures that each software uses. But for similar professional work it is not proposed the management of the same data by two softwares. It should be done a research before the planning of the work that should lead to the better decision as far as the better program or combination of programs used. This also would lead to better obtained data at the field work.

- As far as the merging of the models concerned, it has to be mentioned that the more the meshes, the slower is the software (*Rapidform*). So it is proposed for cases like this that a lot of meshes need to be merged, to ´´clean´´ the meshes as much possible. It is recommended the best removing of noise, the elimination of triangles that are not useful (e.g. flat areas) and generally to make the model the most easily manageable.

General experience obtained by elaborating my diploma thesis at a foreigh laboratory (ERASMUS program)

Closing, this diploma thesis did not offer only surveying – photogrammetric knowledge but also gave me the opportunity to get to know the culture, the customs, the traditions, the language and people from another country, something that can be considered also as a very important educational obtaining.

The first problems related to the adjustment in a new enviroment and the ones related to the totally unknown, until know, Spanish language were surpassed with the great helping of the professors and the students of the Laboratory of Geometric Documentation of Heritage.

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2) http://www.international.icomos.org/natcom_eng.htm
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3) http://www.spanishlinguist.com/extra/spain_regions_map.html
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1) Properties of Leica TCR 307

LEICA TCR 307. TECHNICAL SPECIFICATIONS

Technical data	TC/TCR 302	TC/TCR 303	TC/TCR 305	TC/TCR 307
Telescope				
Magnification	30x			
Field of View	1° 30′ (26m at 1km)			
Reticle Illumination	Bright / Dim Selectable			
Angle Measurement				
Method	Absolute, Diametrical	Absolute	Absolute	Absolute
Display least count	1″(0.1mgon)	1″(0.5mgon)	1″(0.5mgon)	1″(0.5mgon)
Accuracy (DIN 18723, ISO 12857)	2″(0.6mgon)	3″(1mgon)	5″(1.5mgon)	7″(2mgon)
Compensator				
System	Integrated electronic dual axis, Liquid			
Working Range	± 4′			
Setting Accuracy	0.5″	1″	1.5″	2″
Distance Measurement **Infrared (IR) Coaxial**				
Range[1] to 1 Leica GPR1 prism	3000m	3000m	3000m	2500m
Range[1] to 1 Leica GMP102 prism	1200m			
Range[1] to Retro Tape (60mm x 60mm)	250m			
Accuracy (Fine/Rapid/Tracking)	2mm + 2ppm / 5mm + 2ppm / 5mm + 2ppm			
Measuring Time (Fine/Rapid/Tracking)	< 1s / < 0.5s / < 0.3s			
Visible Laser[2] (RL) Coaxial				
Range[1] to suitable surface without reflector (Short mode) – White side of grey card	80m			
Range[1] to Leica GPR1 prism (Long mode)	5000m			
Accuracy (Short/Long/Tracking)	3mm + 2ppm / 5mm + 2ppm / 5mm + 2ppm			
Measuring Time (Short/Long/Tracking)	3s + 1s / 10m (>30m) / 2.5s / 1s + 0.3s / 10m (>30m)			
Spot size at 50m	12mm elliptical			
Laser Class	2/II			
System				
Data storage: Internal memory	4000 data records			
Data storage: External	Connect to external data recorder via Interface port			
Serial Interface	RS232			
Data exchange	GSI / IDEX / Definable Formats			
On-board Programs	Surveying / Set Out / Tie Distance / Area / Free Station			
Built-in Functions	REM / REC / IR-RL Switch / Delete Last Record			
Display	LCD 8 lines x 24 characters / 40mm x 65mm with built-in illumination			
Keyboard	12 keys (Alphanumeric input) optional 2nd keyboard			
Laser Plummet				
Type	Laser Pointer with adjustable intensity			
Accuracy	± 0.8mm at 1.5m			
Operation Environment				
Operation temperature	–20°C to 50°C			
Protection to IEC529 (Dust and water)	IP54			
Humidity	95% RH, non condensing			
Storage temperature	–40°C to 70°C			
Dimensions and Weights				
Gross dimensions (L x W x H)	151mm x 203mm x 316mm			
Weight (instrument only)	4.5kg	4.2kg	4.2kg	4.2kg
Power Supplies				
Battery (Standard)	NiMH / Standard Camcorder			
Voltage/Capacity	6V / 1800mAH (GEB111)			
Continuous use – angle mode	>4 hours			
No. of measurements with distance	>1000			
Recharging time	1 hour			
Optional power supplies (Adapter required)	NiMH 6V / 3.6Ah (GEB121) / 6x LR6 AA 1.5V Alkaline cells			

[1]) Average atmospheric conditions; slight haze or some clouds, slight heat shimmer
[2]) Only valid for TCR models

2) Budget of the specific documentation Church of the Monastery of San Prudencio

DIRECT COSTS	UNITES	COST/DAY	DAYS	TOTAL COST €
Staff on field (level 2, field))	1	132,58	2	265,16
Staff on field (level 7, field)	1	90,20	2	180,40
Staff at office (level 2, office)	1	132,58	10	1325,79
Instruments		62,63	2	125,26
Auxiliary materials		0,61	2	1,22
Transportation		91,58	2	183,16
Food				40,00
Total Direct Costs (DC)				2120,99
GENERAL COSTS (GC)				
Office		80,94	12	971,28
DC + GC				3092,27
UNEXPECTED COSTS (10%)				309,23
TOTAL				3401,49
Industrial Benefit (15%)				510,22
TOTAL (without taxes)				3911,72
Taxes				704,11
TOTAL (with taxes 18%)				**4615,82**

Table_1: Budget of the documentation (3D model and orthophotos) of the Church of the Monastery of San Prudencio

The above table is a result of the parameters that are presented at the following tables.

WORK			
LEVEL		**2**	**7**
Description		**Surveyor Engineer**	**Oficial 1ª**
Working hours			
	hours of agreement (1)	1806	1806
	hours of not working (unexpected) (2)	0	0
	TOTAL (h) (3)	**1806**	**1806**
CW	sal. + ant. + plus		
	Salary (4)	17038,62	10961,53
	antiquity (5)	2555,79	1644,23
	Plus Convenio (6)	2048,90	2048,9
	TOTAL (€) (7)	**21643,31**	**14654,66**
NCW			
	Insurance (8)	300,00	300,00
	TOTAL (€) (9)	**300,00**	**300,00**
Price	(10+11+12)		
	GC (10)	5107,82	3458,50
	Accidents and sickness (11)	1515,03	1025,83
	(12)	1363,53	923,24
	TOTAL (€) (13)	**7986,38**	**5407,57**
Annual Cost	CW+ NCW + price		
	TOTAL (€) (14)	**29929,70**	**20362,23**
Cost/hour	Annual Cost / working hours		

	TOTAL (€) (15)	**16,57**	**11,27**
Cost/day	cost per day*everyday working (8h)		
	TOTAL (€) (16)	**132,58**	**90,20**

(1) Hours/year, according to the current data.	
(2) Hours that were agreeded to be worked but due to unexpected problems, thy were not.	
(3) Total working hours = (1) - (2)	
(4) Contractual Wages of 2009 for categories of professions	
(5) Estimated antiquity of work = 9 years (mean value in Spain) --> Increase 15% of (4)	
(6) Plus of the Contractual Wages	
(7) Total Contractual Wages (PC) = (4) + (5) + (6)	
(8) Insurance estimated from the worker	
(9) Total Non Contractual Wages (NCW) = (8)	
(10) General contingencies (GC) = Type * Base	
	Type = 23.60% (all the categories) | Base = (7)
	established in the Manuall de Wages
(11) Accidents and sickness = Tipo * Base	
	Tipo = 7.00% (category of field - Surveyor Engineer and Oficial 1ª -) | Base = (7)
	Tipo = 1.00% (categoría de oficina - Telefonista -) | Base = (7)
(12) Unemployed + Wage Guarantee Fund + Profesional Training= Type * Base	
	Type = 5.50% + 0.20% + 0.60% = 6.30% (all the categories) | Base = (7)
(13) Total Price = (10) + (11) +(12)	
(14) Annual cost per categor = (7) + (9) + (13)	
(15) Cost per hour per category = (14) / (3)	
(16) Cost per day per category = (15) * everyday workingl (8h)	

Table_2: Salary of the staff

INSTRUMENT											
Instrument / Model	**GPS (1)**	**Battery and Charger of GPS (1)**	**Total Station (1)**	**Tripod (1)**	**Prism (1)**	**Battery and Charger of Total Station (1)**	**Photographic Camera(1)**	**Lens of Camera (1)**	**Battery and Charger of Camera (1)**	**Memory Card**	**TOTAL € (13)**
Price of buying	12000,00	300,00	12000,00	177,00	175,00	339,00	2000,00	100,00	100,00	115,00	27306,00
Price of selling (2)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Recovery/ year (3)	1799,10	44,98	1799,10	26,54	26,24	50,82	299,85	14,99	14,99	17,24	4093,85
Insurance(4)	179,91	4,50	179,91	2,65	2,62	5,08	29,99	1,50	1,50	1,72	409,39
Revision (5)	1100,00	0,00	110,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1210,00
Certified Calibration	18,00	0,00	18,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	36,00
Transports (6)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Reparation (7)	100,00	0,00	100,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	200,00
Units (8)	2	1	1	2	1	1	1	1	1	2	13,00
TOTAL/ YEAR (10)	**6394,02**	**49,48**	**2207,01**	**58,38**	**28,86**	**55,91**	**329,84**	**16,49**	**16,49**	**37,93**	**9194,40**
Working Days (11)	150	150	150	150	150	150	100	100	100	100	**1300,00**
TOTAL / day (12)	**42,63**	**0,33**	**14,71**	**0,39**	**0,19**	**0,37**	**3,30**	**0,16**	**0,16**	**0,38**	**62,63**

(1) Aproximate data according to the companies of the specific used instruments
(2) It was decided a price = 0, in order to avoit the possible risks
(3) Recovery Years = ((1) - (2)) / Minimum Period (6.67 años)
(4) Insurance = 10% of (3)
(5) it was cosidered that only GPS and Total Station are worthwhile to be revised
(6) The transprts are icluded at the Revision

(7) it was cosidered that only GPS and Total Station are worthwhile to be repaired
(8) Necessary units for a company
(9)Total cost per year = ((3) + (4) + (5) + (6) + (7) + (8)) / (9)
(10) Days that can be used an instrument per year.
(11) Cost of the instrument per day = (10) / (11)
(12) Sum of all the costs

Table_3: Cost of instruments

Route						
Route	**km**	**Total km**	**hours**	**SC día**	**VC km**	**Total Cost**
Vitoria-Clavijo	107	214	1,5	35,94	0,26	91,58

Table_4: Cost of transport

The above table is taking into account the following parameters (table_5)

Vehicle			
	Car		**Renault Trafic Combi**
	Price of buying	without taxes	18275,86
	Price of selling		5000
Standart Costs (SC)	**Recovery**	(buying p-selling price)/minimum price	
		maximum ratio	16%
		Periodo mínimo (100/maximum ratio)	6.25 años
		Recovery / year	2124,14
	Insurance		2000,00
	TIV (1)		16,67
	Imp. Circulación		100,00
	Lighting sign		100,00
Variable Costs (VC)	**Combustible**	price*use*consuming/100	
		price (€/l)	1,40
		consuming (l/100km)	7,9
		use (km/year)	40000
		costs/year (€)	4424,00
	Revision		300,00
	Tyres		100,00
	Repairs		300,00
	Units (2)		1
	All the year		9364,81
	Working days		236
	Total euros / day		39,68
	TOT euros km		0,23
	SC day		35,94
	VC km		0,26
(1) Total TIV (Technical Inspection of Vehicles) = 2 revisions * 50€ / 6 años			
(2) Necessary Units for the project			

Table_5: Parameters of the transport

Office Costs								
Material Costs	**Material**	**Ordenador**	**P+S+P(1)**	**Ploter**	**Software (2)**	**Furniture**		
	Price of buying	1500,00	300,00	2000,00	15275,00	1000,00		
	Price of selling	0,00	0,00		0,00	0,00		
	Maximum Ratio	25%	15%	15%	33%	10%		
	Minimum Period (3)	4	6,67	6,67	3,03	10		**TOTAL**
	Recovery/year (4)	375,00	44,98	299,85	5040,75	100,00		5860,58
	Days	236	236	236	236	236		
	€/day	1,59	0,19	1,27	21,36	0,42		**24,83**
General Costs	**Concepto**	**Renting**	**Communal Costs**	**Insurance**	**Telephone**	**Consumables**		
	€/year	9000,00	2400,00	350,00	490,80	1000,00		13240,80
	Days	236	236	236	236	236		
	€/day	38,14	10,17	1,48	2,08	4,24		**56,11**
(1) Printer+Scanner+Photocopier							**TOTAL €/year**	**19101,38**
(2) Software = Windows+Office+Autocad+PhotoModeler/Image Master+Rapidform							**TOTAL €/day**	**80,94**
(3) = 100/maximum ratio								
(4) = Price of buying-Price of selling / minimum period								

Table_6: Office Costs

The above table is taking into account the prices of the software that are presented below (table_7)

Prices of Software	
Microsoft Windows 7	140,00
Microsoft Office	195,00
AutoCad	4440,00
EOS PhotoModeler	1800,00
Topon Image Master	1500,00
INUS Rapidform	9000,00

Table_7: Prices of the Software

3) Plans

0 0.5 1 2 4m

UNIVERSITY OF BASQUE COUNTRY
LABORATORY OF GEOMETRIC DOCUMENTATION OF HERITAGE
GROUP OF INVESTIGATION OF BUILT HERITAGE

NATIONAL TECHNICAL UNIVERSITY OF ATHENS
FIELD OF SURVEYING ENGINEERING
LABORATORY OF PHOTOGRAMMETRY

MONUMENT: CHURCH OF THE MONASTERY OF SAN PRUDENCIO

LOCATION: CLAVIJO, LA RIOJA, SPAIN

DRAWING: ORTHOPHOTO OF SOUTHERN FACADE

n. of drawing: 1

DATE: JULY 2011

SCALE 1 : 50

STUDENT

GKINTZOU CHRISTINA

SUPERVISORS:

JOSE MANUEL VALLE MELON
ALVARO RODRIGUEZ MIRANDA
ANDREAS GEORGOPOULOS

creepers

wall

0 0.5 1 2m

Universidad del País Vasco Euskal Herriko Unibertsitatea

UNIVERSITY OF BASQUE COUNTRY
LABORATORY OF GEOMETRIC DOCUMENTATION OF HERITAGE
GROUP OF INVESTIGATION OF BUILT HERITAGE

NATIONAL TECHNICAL UNIVERSITY OF ATHENS
FIELD OF SURVEYING ENGINEERING
LABORATORY OF PHOTOGRAMMETRY

MONUMENT:	CHURCH OF THE MONASTERY OF SAN PRUDENCIO
LOCATION:	CLAVIJO, LA RIOJA, SPAIN
DRAWING:	ORTHOPHOTO OF WESTERN FACADE
n. of drawing:	2
DATE:	JULY 2011
SCALE	1 : 50

STUDENT

GKINTZOU CHRISTINA

SUPERVISORS:

JOSE MANUEL VALLE MELON
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ANDREAS GEORGOPOULOS

creepers

wall

0 0.5 1 2m

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GROUP OF INVESTIGATION OF BUILT HERITAGE

NATIONAL TECHNICAL UNIVERSITY OF ATHENS
FIELD OF SURVEYING ENGINEERING
LABORATORY OF PHOTOGRAMMETRY

MONUMENT: CHURCH OF THE MONASTERY OF SAN PRUDENCIO

LOCATION: CLAVIJO, LA RIOJA, SPAIN

DRAWING: ORTHOPHOTO OF NORTHERN FACADE

n. of drawing: 3

DATE: JULY 2011

SCALE 1 : 50

STUDENT

GKINTZOU CHRISTINA

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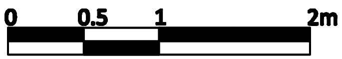
ALVARO RODRIGUEZ MIRANDA

ANDREAS GEORGOPOULOS

creepers

wall



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NATIONAL TECHNICAL UNIVERSITY OF ATHENS
FIELD OF SURVEYING ENGINEERING
LABORATORY OF PHOTOGRAMMETRY

MONUMENT:	CHURCH OF THE MONASTERY OF SAN PRUDENCIO
LOCATION:	CLAVIJO, LA RIOJA, SPAIN
DRAWING:	ORTHOPHOTO OF EASTERN FACADE
n. of drawing:	4
DATE:	JULY 2011
SCALE	1 : 50

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creepers

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