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UNIVERSIDADE TÉCNICA DE LISBOA

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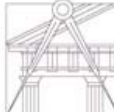

Advanced Masters in Structural Analysis of Monuments and Historical Constructions (AMSAMHC)

2007/2008 2nd Seminar

Architectural Heritage Conservation: Digital Photogrammetry and 3D Laserscanning Applications

AMSAMHC 2007/2008 - 2nd Seminar

"Architectural Heritage Conservation: Digital Photogrammetry and 3D Laserscanning applications"



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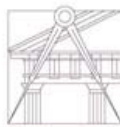

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Architectural Heritage Conservation: Digital Photogrammetry and 3D Laserscanning Applications

1. Previous considerations
2. Photogrammetry and 3D Laserscanning principles and definitions
3. An example of Photogrammetry
4. Two examples of 3D Laserscanning
5. FCT: PTDC/AUR - 66476 - 2006: *“Contributions to Architectural Heritage Conservation: Documentary methodology based in terrestrial digital photogrammetry and 3D laser scanning”*

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1. Previous considerations: The Charts

“In all works of preservation, restoration or excavation, there should always be precise documentation in the form of analytical and critical reports, illustrated with drawings and photographs. Every stage of the work of clearing, consolidation, rearrangement and integration, as well as technical and formal features identified during the course of work, should be included. This record should be placed in the archives of a public institution and made available to research workers. It is recommended that the report should be published.”

(extracted from Venice Chart, art. 16, 1964)

“Before any intervention, existing conditions in the site should be carefully documented.”

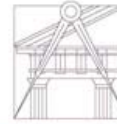
(extracted from point 5 of Washington Chart, 1987)

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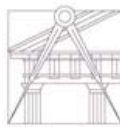

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1. Previous considerations: The Charts

“THE REASONS FOR RECORDING

- 1. The recording of the cultural heritage is essential;*
- 2. Recording should be undertaken to an appropriate level of detail in order to:*
- 3. Recording of the cultural heritage should be seen as a priority, and should be undertaken especially:*
 - a) When compiling a national, regional, or local inventory;*
 - b) As a fully integrated part of research and conservation activity;*
 - c) Before, during and after any works of repair, alteration, or other intervention, and when evidence of its history is revealed during such works;*
 - d) When total or partial demolition, destruction, abandonment or relocation is contemplated, or where the heritage is at risk of damage from human or natural external forces;*
 - e) During or following accidental or unforeseen disturbance which damages the cultural heritage;*
 - f) (...) “*

(extracted from *Principles for the Recording of Monuments, Groups of Buildings and Sites*, 1996)



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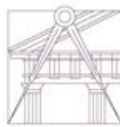

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1. Previous considerations: Architectural survey

- Architectural survey is a resulting product of its own time, of Theory and Criticism of Architecture and of the available instrumentation and technology.
- “(...) measurement, geometric clarification, historical knowledge, but i above all, it is a reading operation, a discretization of the architectural form and of graphical transcription of its formal qualities”
(Docci e Maestri, 2004)
- It is an instrument that serve as basis for those whom, in several ways, work on architectural pre-existences.
- It is always more than a simple measurement action of a building, or an urban context, it is a complex operation that should be carried out with rigour, ethics, and taking into account the purposes for which it is destined to.
- It should be clear and objective and should, ideally, adopt an universal graphical notation.

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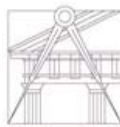

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1. Previous considerations: Surveying models

- **Iconic model** – It is a general synthetic analysis of the construction from a volumetric and geometric point of view, it can be appropriate to historical and stylistic analysis.
- **Distributive model** – It is a natural consequence of the previous model. On this model space articulation is emphasized. It's of great importance to the rehabilitation project and to function redistribution.
- **Constructive model** – It can be considered as an analysis of the building as a concrete and material reality. It should take into account the following:
 - Focus on the external structure, internal structure and decorative structure
 - The terrain is the first building material and that has implications in the upper construction.
 - Constructive elements should be individualized, identified and hierarchized.
 - Constructive logics and structural models should be made explicit (for example the relation between geometry and material properties).
 - It should allow a first approach to the quantification of the building statics.
 - The present deformations should be considered and registered.
 - Constructive logics should be made explicit.

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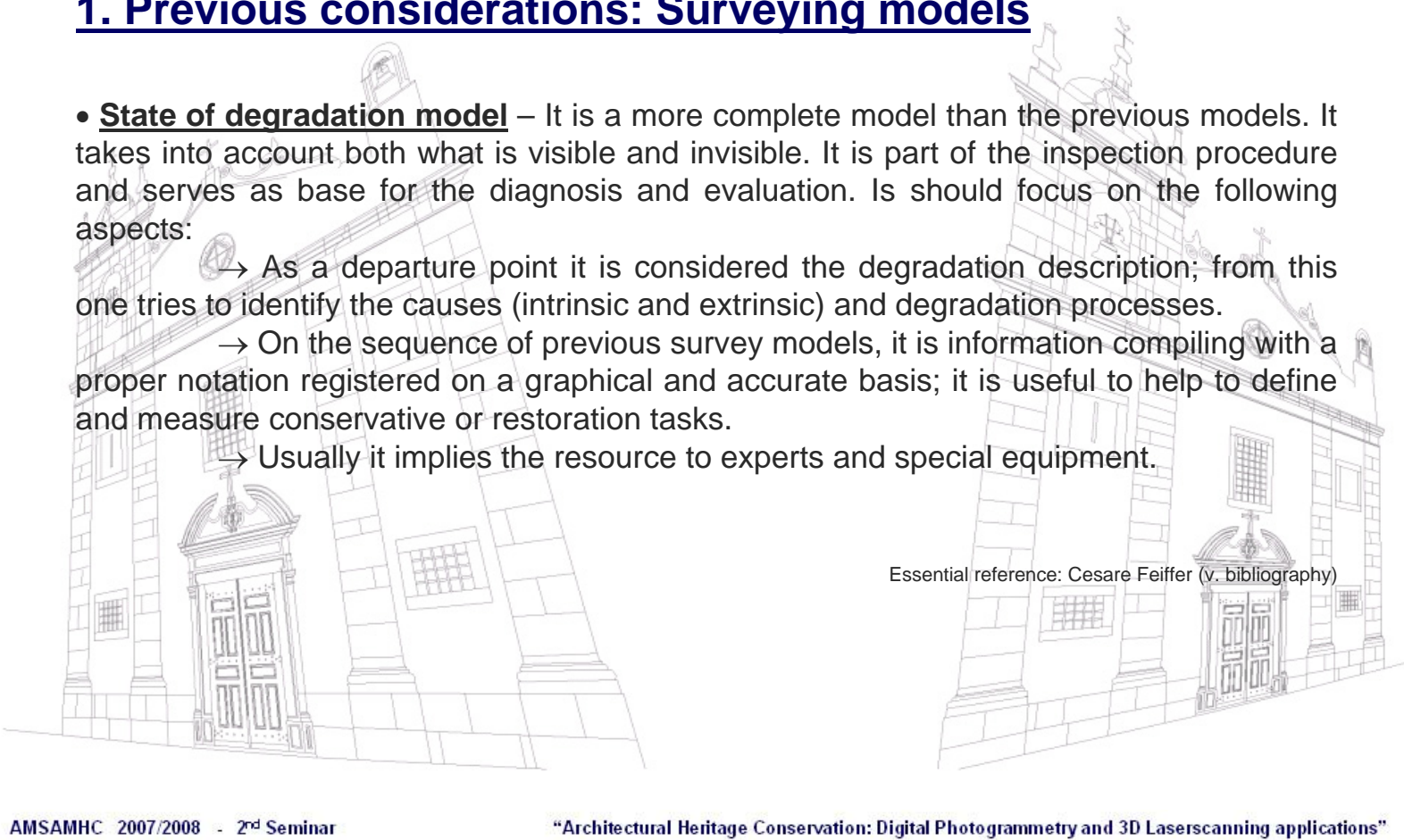
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1. Previous considerations: Surveying models

- **State of degradation model** – It is a more complete model than the previous models. It takes into account both what is visible and invisible. It is part of the inspection procedure and serves as base for the diagnosis and evaluation. It should focus on the following aspects:
 - As a departure point it is considered the degradation description; from this one tries to identify the causes (intrinsic and extrinsic) and degradation processes.
 - On the sequence of previous survey models, it is information compiling with a proper notation registered on a graphical and accurate basis; it is useful to help to define and measure conservative or restoration tasks.
 - Usually it implies the resource to experts and special equipment.

Essential reference: Cesare Feiffer (v. bibliography)





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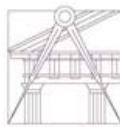

1. Previous considerations: Surveying purposes

- Conservation and Rehabilitation
- Stratigraphic and archaeological analysis
- Historic a Architectural analysis
- Inventory
- Juridical disputes
- Cartography
- Property evaluation
- Didactics

Commonly we tend to accept that if the building is hand surveyed using a pencil and metric tape or digitally recorded using a total station or a 3D scanner is ,in principle, largely irrelevant. Nevertheless, depending on the surveying goals one may consider different options (that mean different costs, different duration, different accuracy) that lead us to what we can call as Surveying Precision Levels that usually are not formally defined. It would be of interest that one could have such a reference frame to serve, for example, for contractual purposes, such as it is defined by the RCHME in its , “Historic Buildings Recording Survey levels”

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2. Photogrammetry principles and concepts

- “ Traditionally, *photogrammetry*, has been defined as the process of deriving (usually) metric information about an object through measurements made on photographs of the object. (...)
The fundamental task of photogrammetry is to rigorously establish the geometric relationship between the image and the object as it existed at the time of the imaging event. Once this relationship is correctly recovered, one can then derive information about the object strictly from its imagery. This relationship can be established by various means, which can be broadly classified into two categories: *analogical*, using optical, mechanical, and electronic components; or *analytical*, where the modelling is mathematical and the processing is digital.”
(...)
One can trace the earliest roots of photogrammetry to the Renaissance painters, particularly Leonardo da Vinci, who studied the principles involved in the geometric analysis of pictures in the late 1400s. The next significant development was projective geometry, which forms the mathematical basis for photogrammetry from passive imaging systems; notables include Desargues, Pascal, and Lambert, from the mid-1600s to the mid-1700s. (...)”

in Introduction to modern photogrammetry (v. bibliography)

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2. Photogrammetry principles and concepts

- 3 X 3 rules for photogrammetric documentation

This set of rules was presented for the first time by Peter Waldhausl and Cliff Ogleby in 1988 CIPA conference that took place in Sofia.

1. Three geometric rules

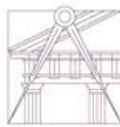

- To get metric control data; at least one measurement and one direction.
- To get full recovering around the object, not forgetting the roof. Each point must appear at least in 3 photographs. Adjacent images must overlap at least 50%.
- To take stereo pairs for restitution considering details of interest; for these a control measurement must be taken.

2. Three photographic rules

- Internal camera geometry must remain constant (do not zoom in or out); keep a constant focus (in infinite if possible); do not crop the images to use.
- Select an homogeneous light electing the best hour in the day.
- Always work with the bigger picture formats available; use the maximum resolution that camera can offer us.

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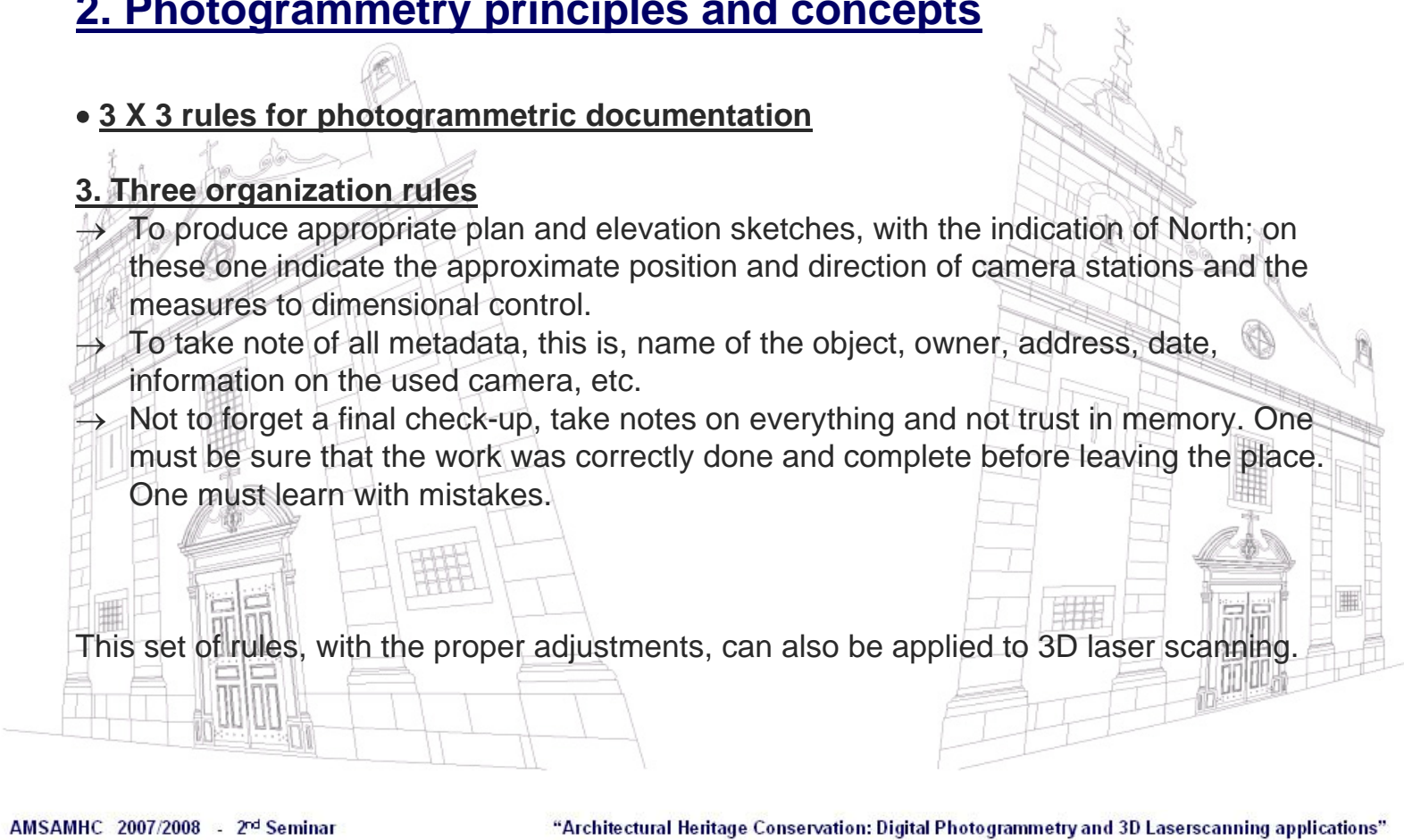
2. Photogrammetry principles and concepts

- 3 X 3 rules for photogrammetric documentation

3. Three organization rules

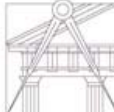

- To produce appropriate plan and elevation sketches, with the indication of North; on these one indicate the approximate position and direction of camera stations and the measures to dimensional control.
- To take note of all metadata, this is, name of the object, owner, address, date, information on the used camera, etc.
- Not to forget a final check-up, take notes on everything and not trust in memory. One must be sure that the work was correctly done and complete before leaving the place. One must learn with mistakes.

This set of rules, with the proper adjustments, can also be applied to 3D laser scanning.



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2. Photogrammetry principles and concepts

- **Four orientations in photogrammetry**
 - 1. Internal orientation**

It is the process that allows to estimate the lens focal distance, the size of projection surface (ex. CCD sensor size), the parameters of geometric distortion caused by lens imperfections. It allows to reconstruct the bundle of rays geometry from the centre of projection. This process can be automatized with proper software. It is also referred as camera calibration.
 - 2. Relative orientation**

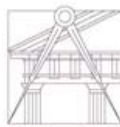

It is the process that allows to establish the geometric spatial relative relation between two photographs. From this one can stereoscopically visualize a 3d model or produce one.
 - 3. External orientation**

It is the process that allows to put in relation the picture coordinate system with the object coordinate system.
 - 4. Absolute orientation**

It is the process of external orientation of a model with a defined relative orientation.

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2. 3D laser scanning principles and concepts

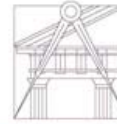
- **Terrestrial laser scanning:** “Any ground based device that uses laser to measure the three-dimensional coordinates of a given region of an object surface automatically, in a systematic order at a high rate in (near) real time. This includes scanners used to fixed objects, such as buildings and monuments, and scanners used to scan small objects and artefacts (sometimes referred to as close range laser scanning)”.
In An addendum to the Metric Survey Specifications for English Heritage
- **Point cloud:** “A collection of XYZ coordinates in a common coordinate system that portrays to the viewer an understanding of the spatial distribution of a subject or site. It may also include additional information such as an intensity or RGB value. Generally a point cloud contains a relatively large number of coordinates in comparison with the volume the cloud occupies, rather than a few widely distributed points”.
In An addendum to the Metric Survey Specifications for English Heritage
- **Point density:** “The average distance between XYZ coordinates in a point cloud. This is commonly represented in two forms, spatial and angular.”
In An addendum to the Metric Survey Specifications for English Heritage

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2. 3D laser scanning principles and concepts

- **Scan**: “Scan refers to a single session of data collection at a single scan origin and scan orientation. The verb scan is the act of using a terrestrial laser scanner”.

In An addendum to the Metric Survey Specifications for English Heritage

- **Registration**: “The process of transforming point clouds onto a common coordinate system.”

In An addendum to the Metric Survey Specifications for English Heritage

- **Scan origin**: “The origin of the arbitrary coordinate system in which scans are performed (normally set as 0, 0, 0). When the scan origin is transformed into the site coordinate system it is known as the scan position”.

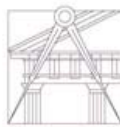

In An addendum to the Metric Survey Specifications for English Heritage

- **Scan position**: “The location, in a known coordinate system, from which a single scan is performed. .”

In An addendum to the Metric Survey Specifications for English Heritage

- **Scan artefacts**: “Irregularities within a scan that are result of the scanning process rather than features on subject itself. These can be geometric or radiometric in nature.”

In An addendum to the Metric Survey Specifications for English Heritage



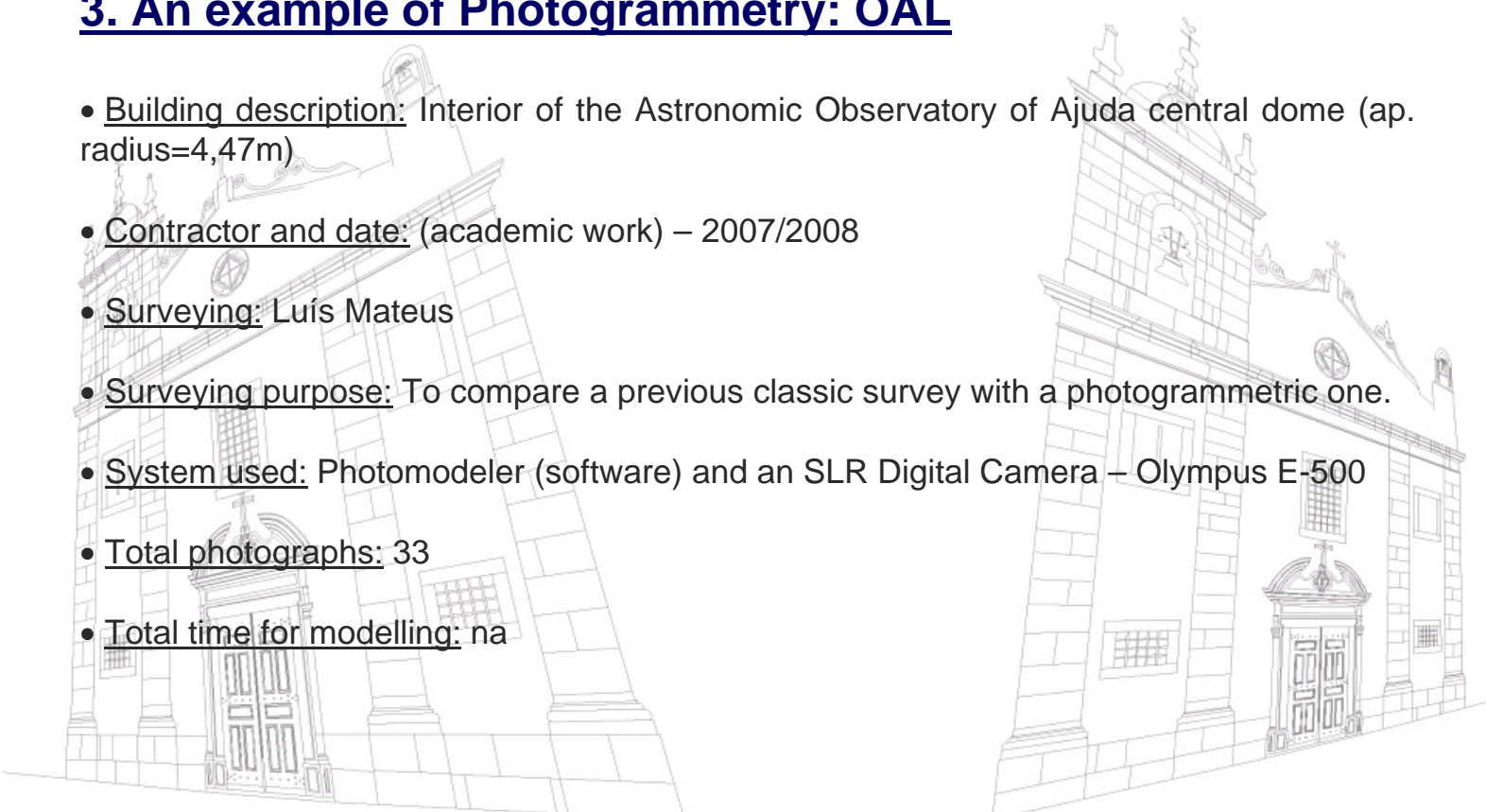
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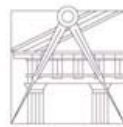
3. An example of Photogrammetry: OAL

- Building description: Interior of the Astronomic Observatory of Ajuda central dome (ap. radius=4,47m)
- Contractor and date: (academic work) – 2007/2008
- Surveying: Luís Mateus
- Surveying purpose: To compare a previous classic survey with a photogrammetric one.
- System used: Photomodeler (software) and an SLR Digital Camera – Olympus E-500
- Total photographs: 33
- Total time for modelling: na



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3. An example of Photogrammetry: OAL

- Camera calibration (Olympus E-500)

Focal Length
Value: 14.442208 mm
Deviation: Focal: 0.001 mm

Xp - principal point x
Value: 8.826455 mm
Deviation: Xp: 0.002 mm

Yp - principal point y
Value: 6.542933 mm
Deviation: Yp: 0.002 mm

Fw - format width
Value: 17.743933 mm
Deviation: Fw: 5.2e-004 mm

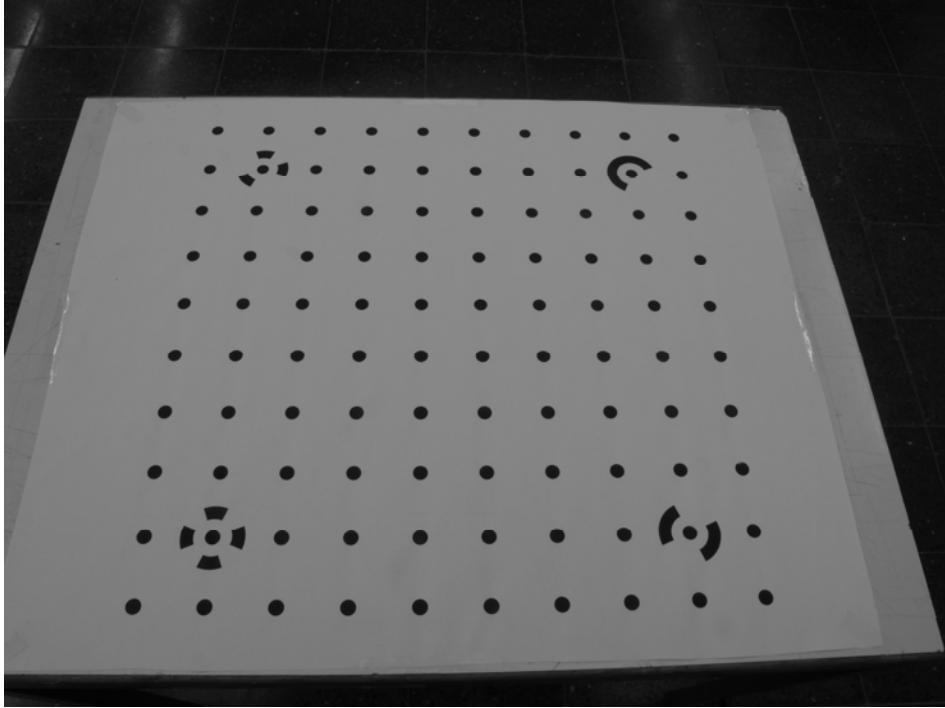
K1 - radial distortion 1
Value: 6.699e-004
Deviation: K1: 1.4e-006

K2 - radial distortion 2
Value: -1.409e-006
Deviation: K2: 1.4e-008

K3 - radial distortion 3
Value: 0.000e+000

P1 - decentering distortion 1
Value: 6.937e-006
Deviation: P1: 2.1e-006

P2 - decentering distortion 2
Value: -4.126e-005
Deviation: P2: 2.2e-006

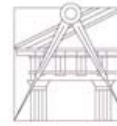


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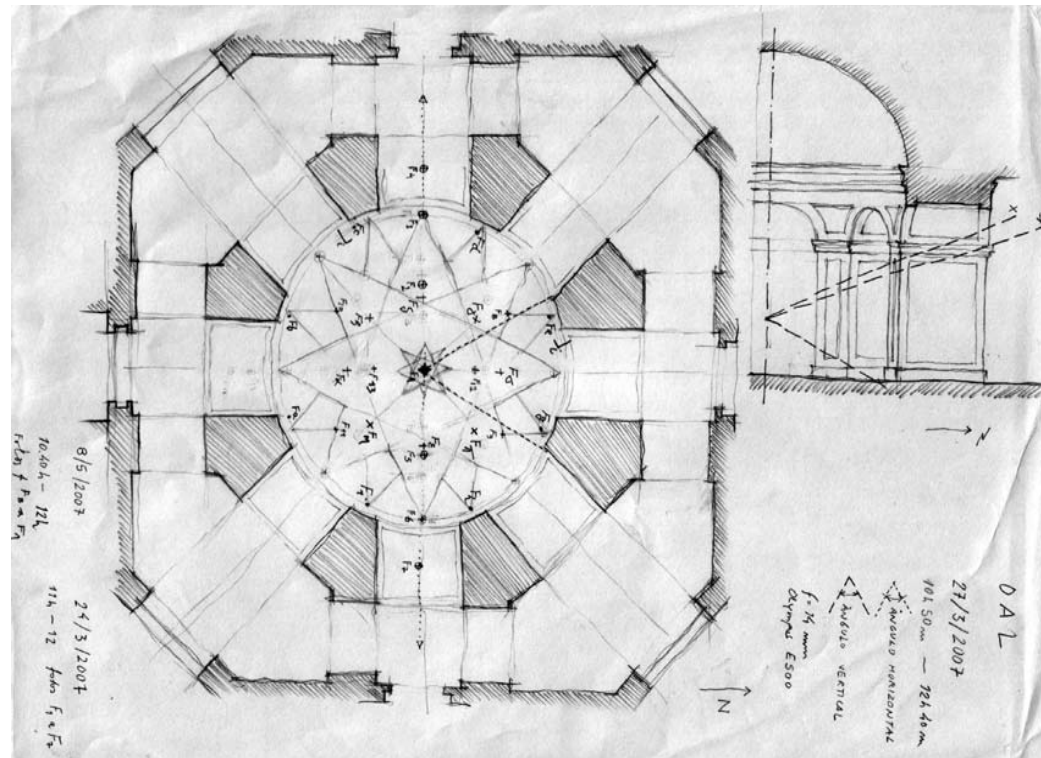




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3. An example of Photogrammetry: OAL

- Data acquisition planning





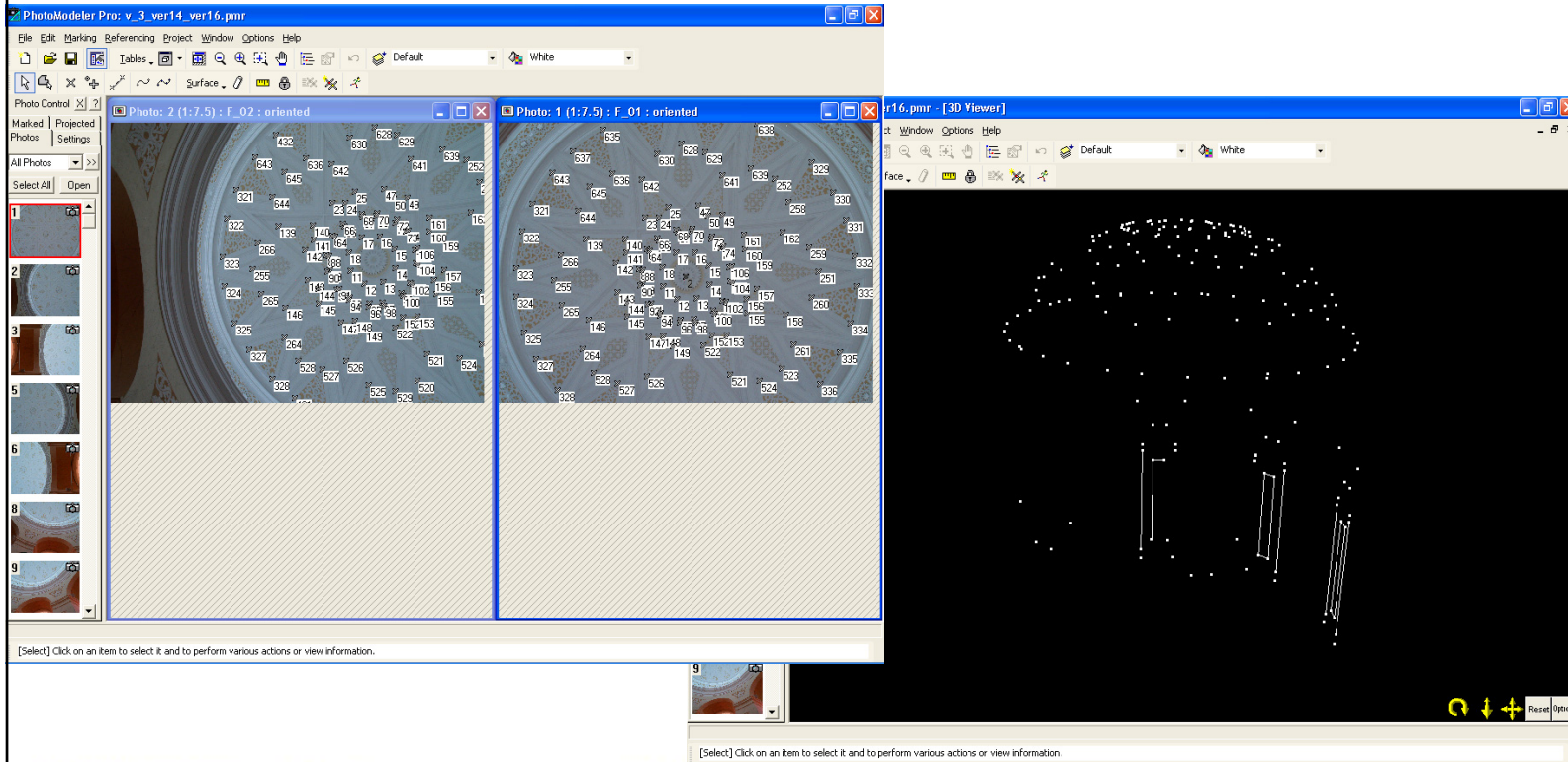
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3. An example of Photogrammetry: OAL

- 3D modelling



PhotoModeler Pro: v.3.16

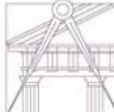

Photo: 2 (1:7.5) : F_02 : oriented

Photo: 1 (1:7.5) : F_01 : oriented

r16.pmr - [3D Viewer]

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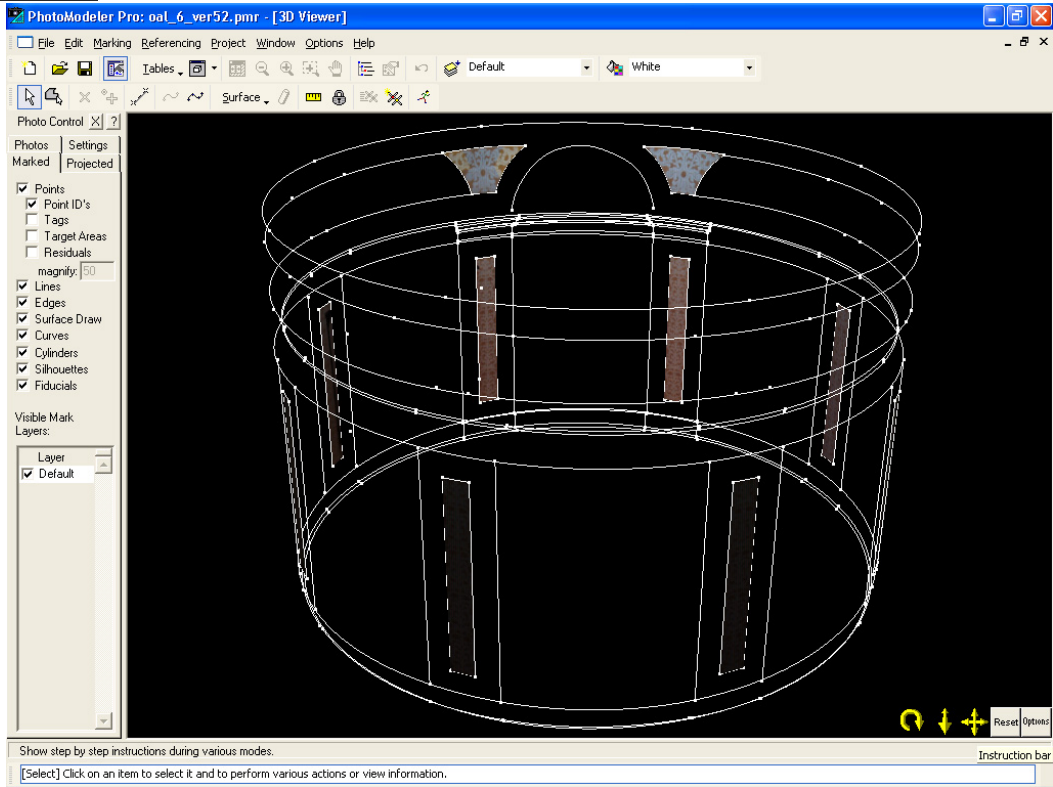
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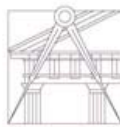

3. An example of Photogrammetry: OAL

- 3D modelling



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4. Two examples of 3D Laserscanning: building in Lisbon

- Building description: A 200m² three-storey 19th century building at the centre of Lisbon.
- Contractor and date: The owner (a real estate agency) - 2007
- Surveying: Company 3DTotal (<http://www.3dtotal.pt>)
- Surveying purpose: To produce metric survey drawings (plans, elevations and sections) to a 1/100 scale that should be provided to the architecture office to serve as basis for a rehabilitation project.
- System used: Phase based laser scanner, Z+F – IMAGER 5006 (http://www.zf-laser.com/e_imager5006.html)
- Total scan positions: 83
- Total time for scanning and registration: 1 day + 3 days
- Total time to draw plans, sections and elevations: 10 days (85 hours)

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<p><u>4. Two examples of 3D Laserscanning: building in Lisbon</u></p>		
		
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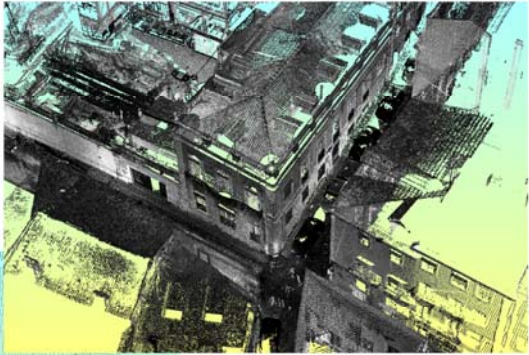
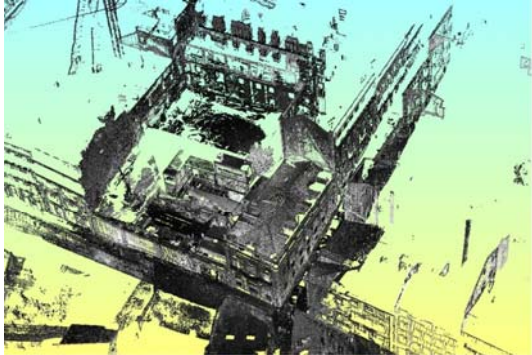


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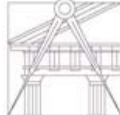

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4. Two examples of 3D Laserscanning: building in Lisbon



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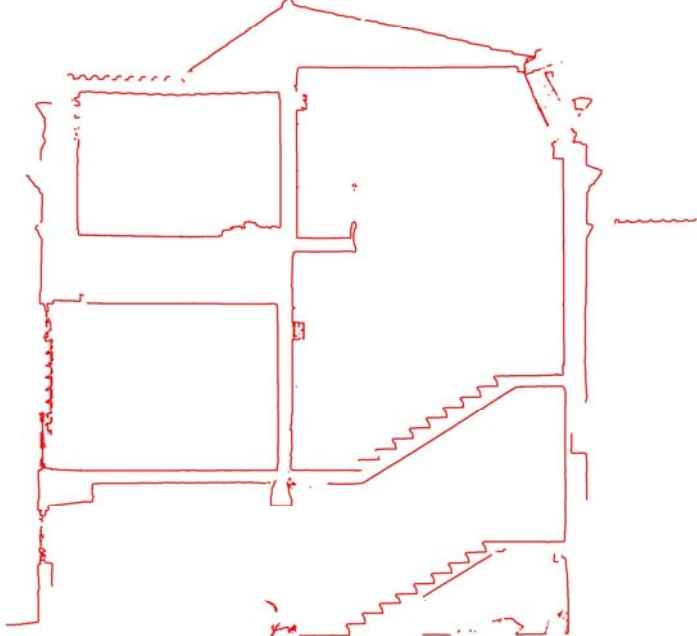


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4. Two examples of 3D Laserscanning: building in Lisbon



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4. Two examples of 3D Laserscanning: building in Lisbon



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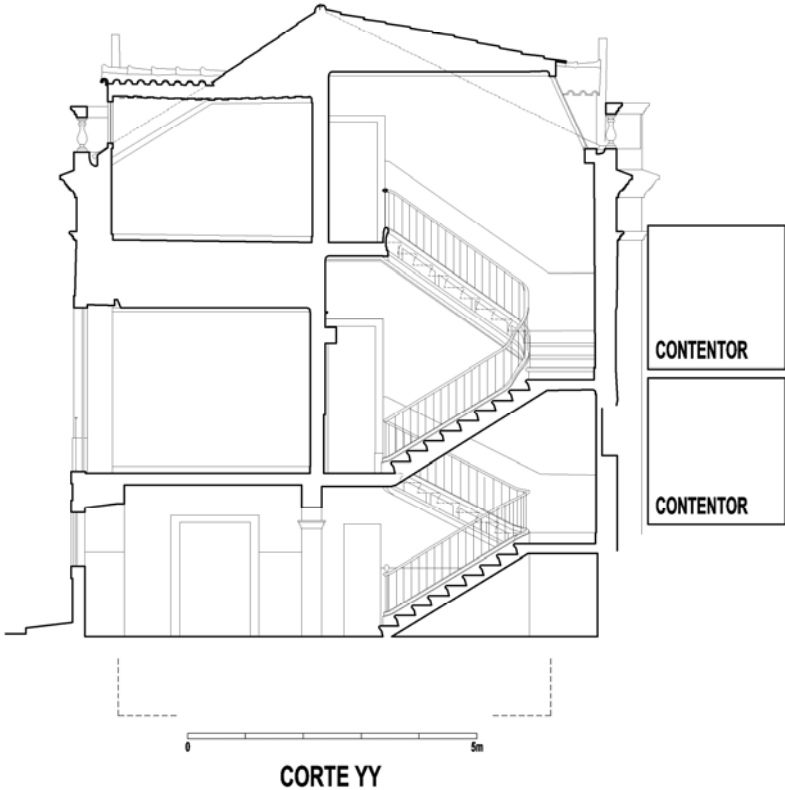


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4. Two examples of 3D Laserscanning: building in Lisbon



CORTE YY

0 5m

CONTENTOR

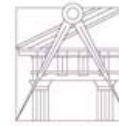
CONTENTOR

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"Architectural Heritage Conservation: Digital Photogrammetry and 3D Laserscanning applications"



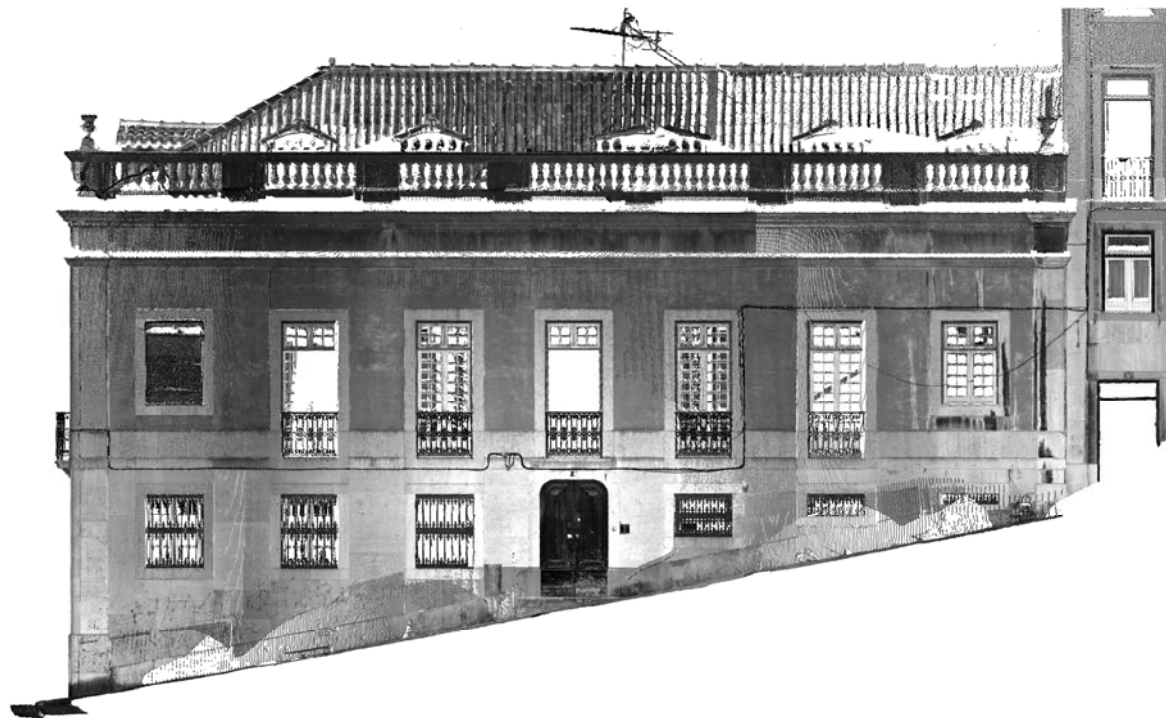
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4. Two examples of 3D Laserscanning: building in Lisbon






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4. Two examples of 3D Laserscanning: building in Lisbon



ALÇADO 1

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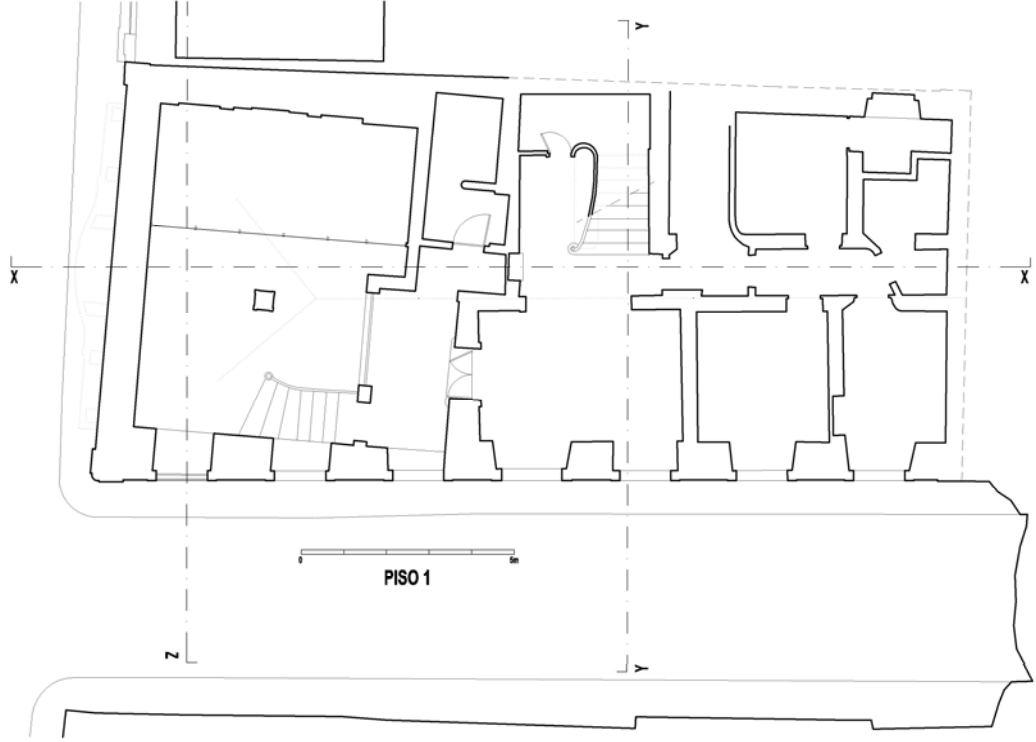


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4. Two examples of 3D Laserscanning: building in Lisbon



PISO 1

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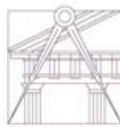

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4. Two examples of 3D Laserscanning: building in Lisbon



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4. Two examples of 3D Laserscanning: church in Spain

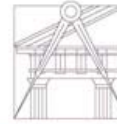
- Building description: Romanic 13th century Church of Santiago Apostol in Villamorón (ap. 544m² – 32m x 17m) – Burgos – Spain
- Contractor and date: The company RODIO - 2005
- Surveying: Laboratorio de Fotogrametría Arquitectónica de la Escuela Técnica Superior de Arquitectura de la Universidad de Valladolid
(http://www.uva.es/cocoon_uva/impe/uva/navDirectorio?idMenuIzq=3257&idSeccion=3257&idMenus=)
- Surveying purpose: To produce a report on the structural deformations of the Church
- Main surveying system: Time of flight laser scanner, ILRIS 3d - OPTECH
(<http://www.optech.ca/>)
- Complementary surveying system: PENTAX AL 320 level

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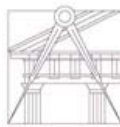



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4. Two examples of 3D Laserscanning: church in Spain






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4. Two examples of 3D Laserscanning: church in Spain

- Adopted methodology:
 - **Introduction:** Formal and material description of the church; description of the scope of work (to establish the direction of the inclinations of structural elements and measure them with respect to vertical everywhere there are significant fissures and formal alterations) ; general description of the state of the building deformation (detachments and fissures) based on visual inspection.

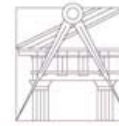


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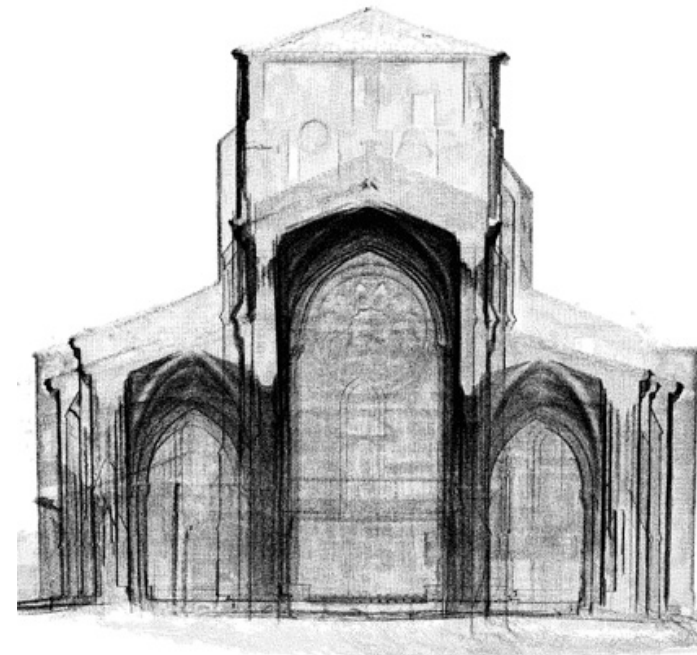


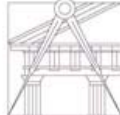

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4. Two examples of 3D Laserscanning: church in Spain

- Adopted methodology:
 - Scanning of 3D coordinates of points (clouds of points) and registration into a single 3d model.





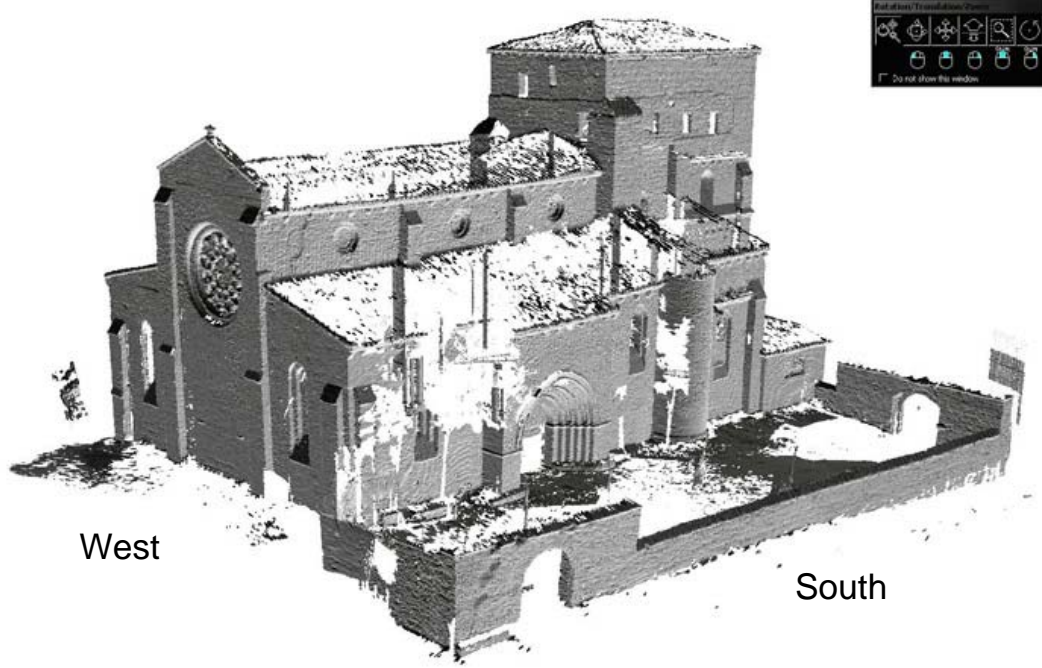
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4. Two examples of 3D Laserscanning: church in Spain

- Adopted methodology:
 - Scanning of 3D coordinates of points (clouds of points) and registration into a single 3d model.





West

South

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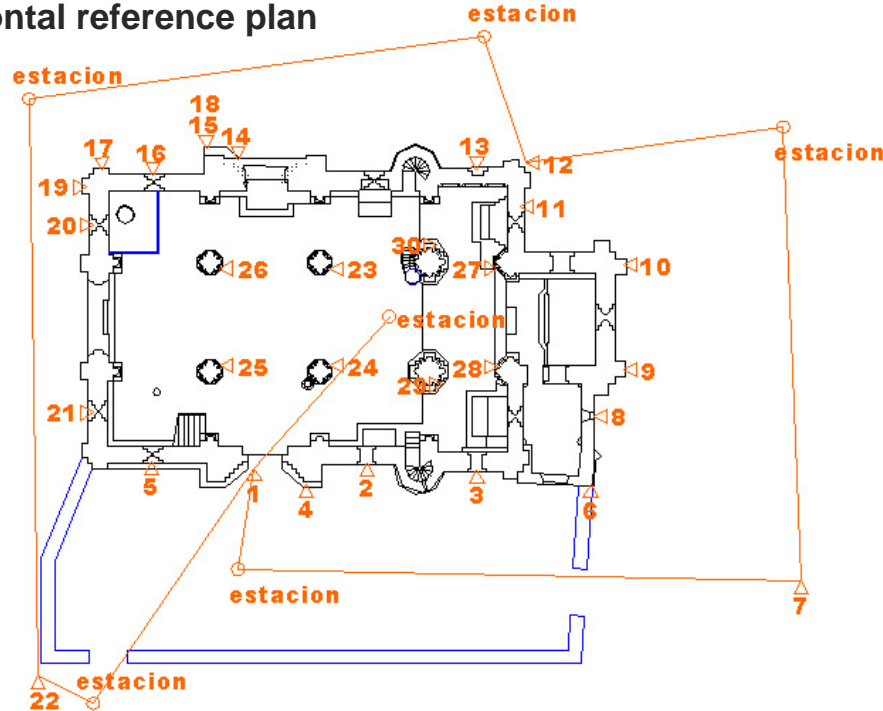

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4. Two examples of 3D Laserscanning: church in Spain

- Adopted methodology:
 - Precision geometric levelling as basis for an accurate orientation of the 3D model with respect to an horizontal reference plan

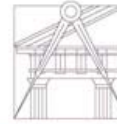


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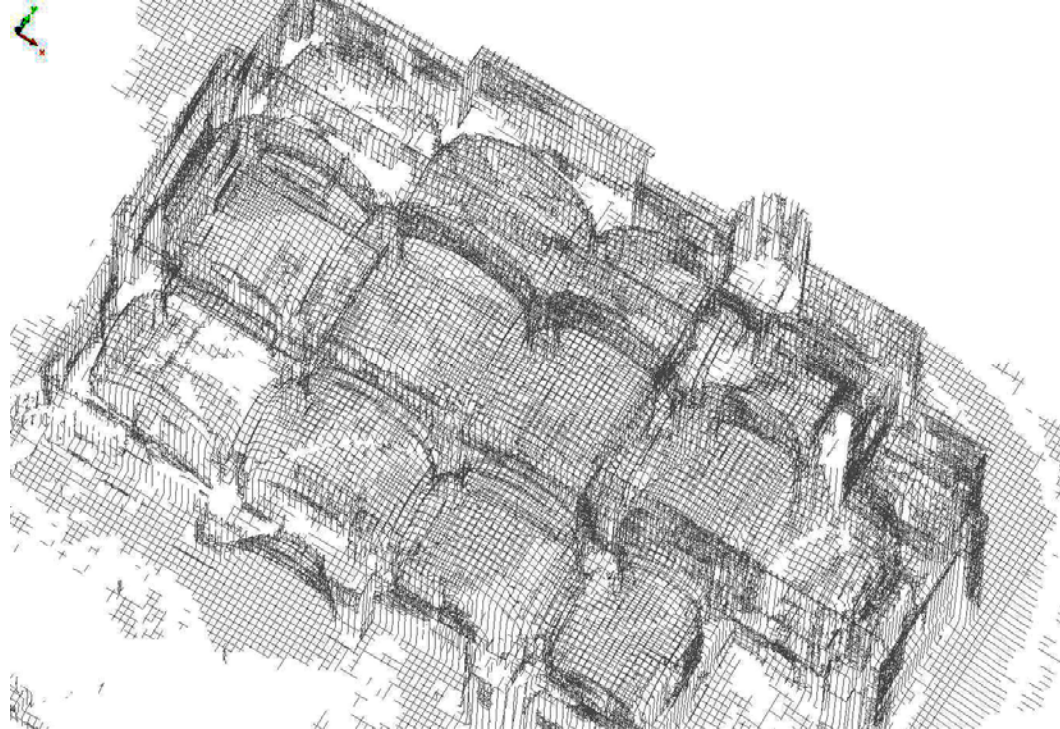
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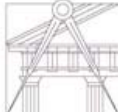

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4. Two examples of 3D Laserscanning: church in Spain

- Adopted methodology:

→ Section extraction from the registered clouds of points





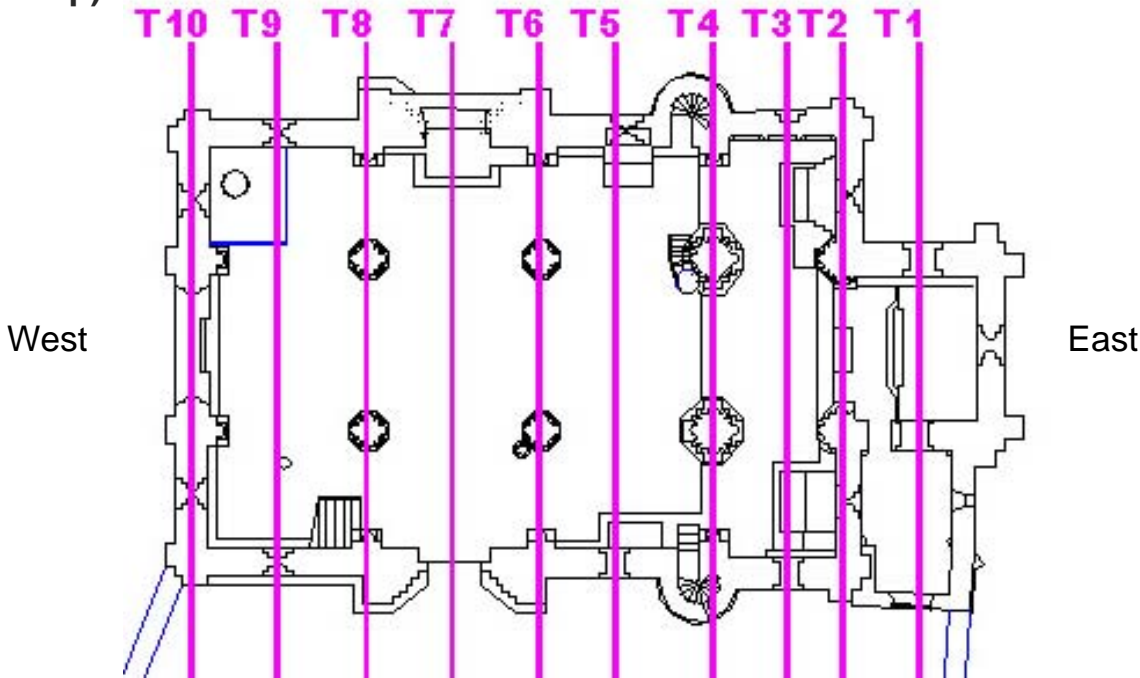
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4. Two examples of 3D Laserscanning: church in Spain

- Adopted methodology:
 - Deformation evaluation (from the most significant sections obtained in previous step)



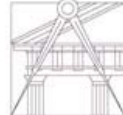

West

East

T10 T9 T8 T7 T6 T5 T4 T3 T2 T1

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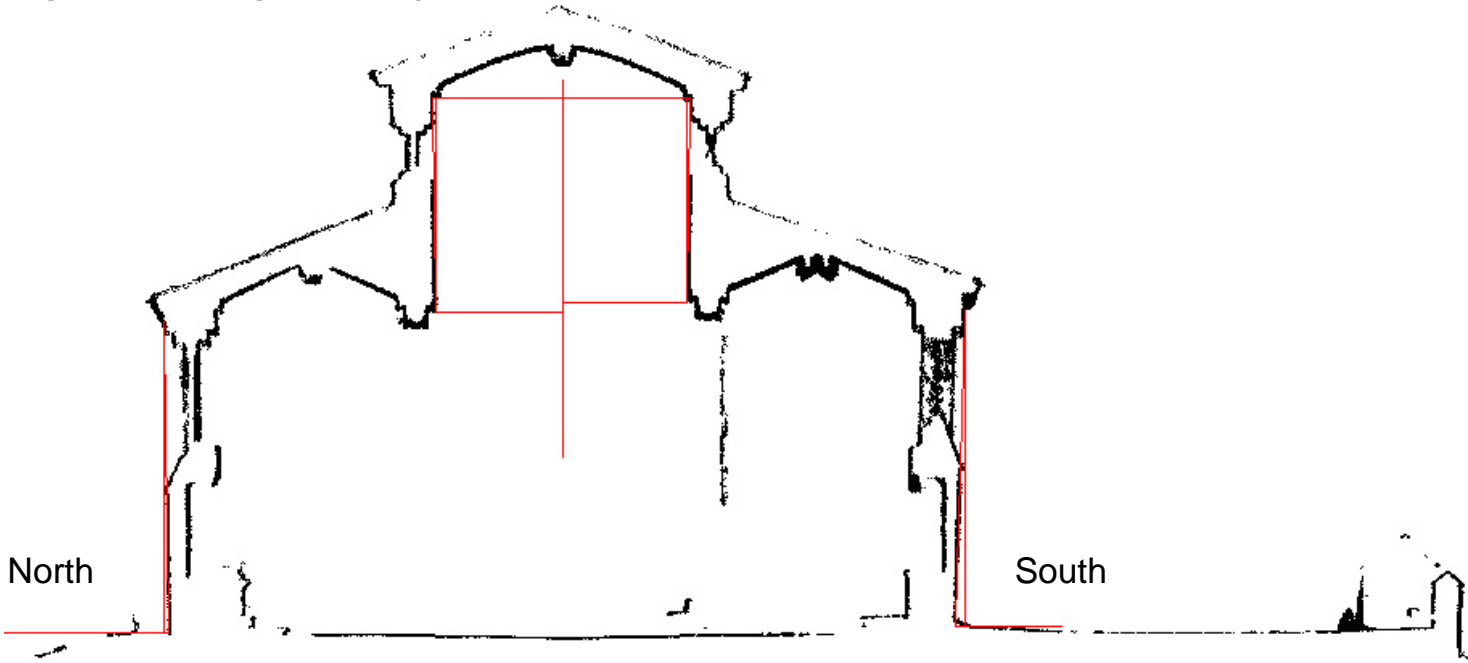
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4. Two examples of 3D Laserscanning: church in Spain

- Adopted methodology:
 - Deformation evaluation (from the most significant sections obtained in previous step – ex. T5)

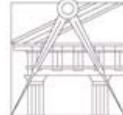



North

South

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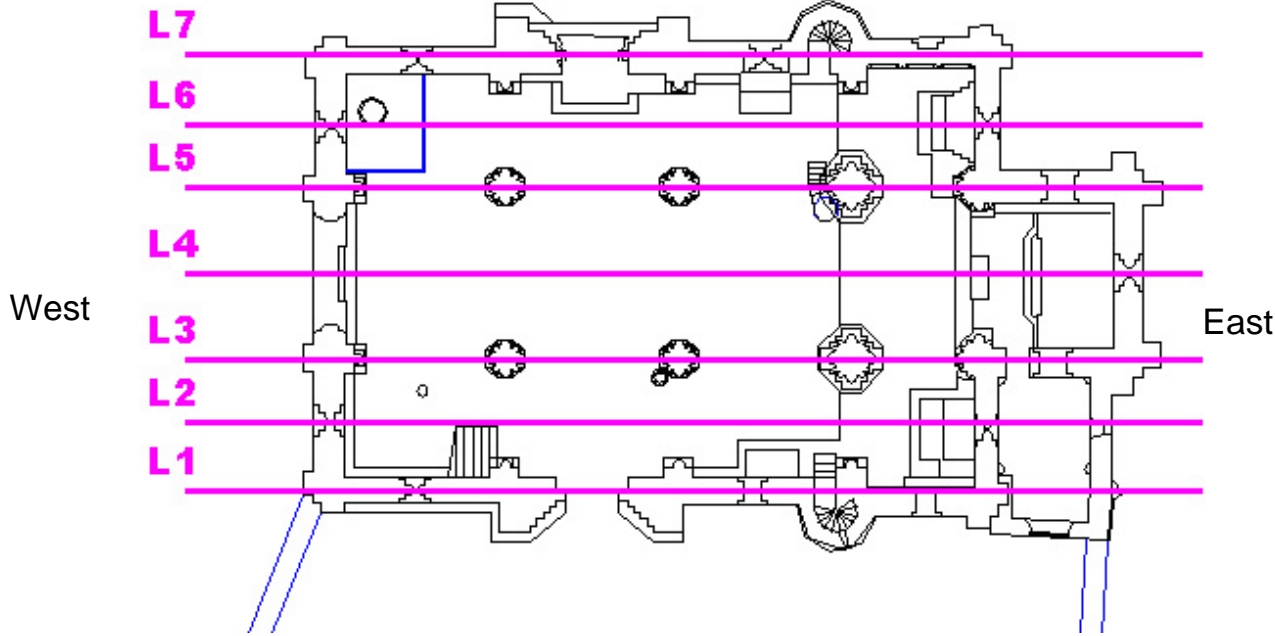
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4. Two examples of 3D Laserscanning: church in Spain

- Adopted methodology:
 - Deformation evaluation (from the most significant sections obtained in previous step)

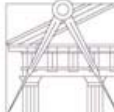



West East

L7
L6
L5
L4
L3
L2
L1

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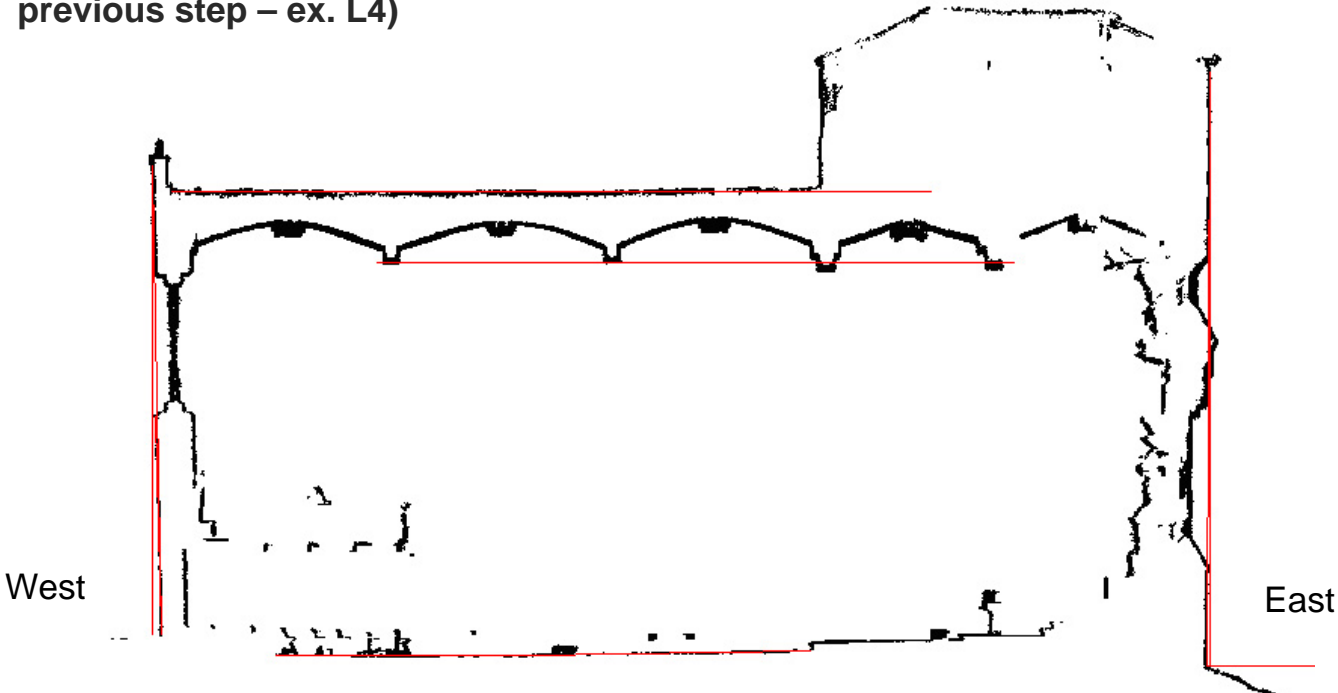
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4. Two examples of 3D Laserscanning: church in Spain

- Adopted methodology:
 - Deformation evaluation (from the most significant sections obtained in previous step – ex. L4)





West

East

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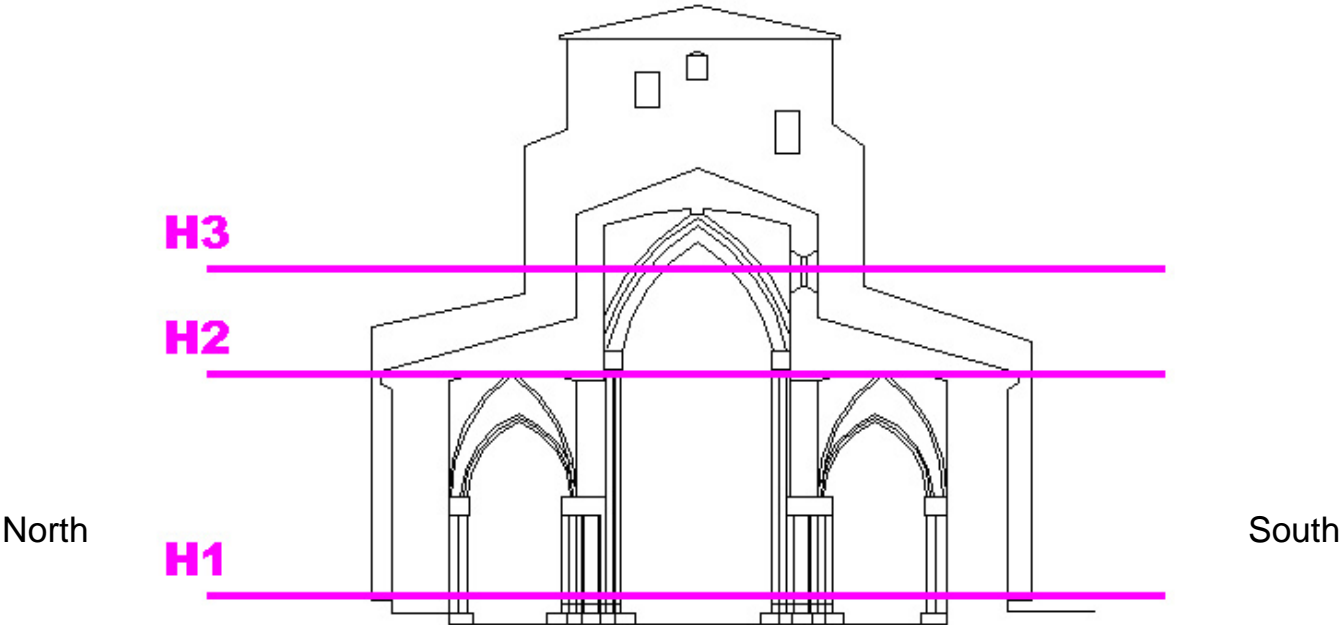
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4. Two examples of 3D Laserscanning: church in Spain

- Adopted methodology:
 - Deformation evaluation (from the most significant sections obtained in previous step)





North

South

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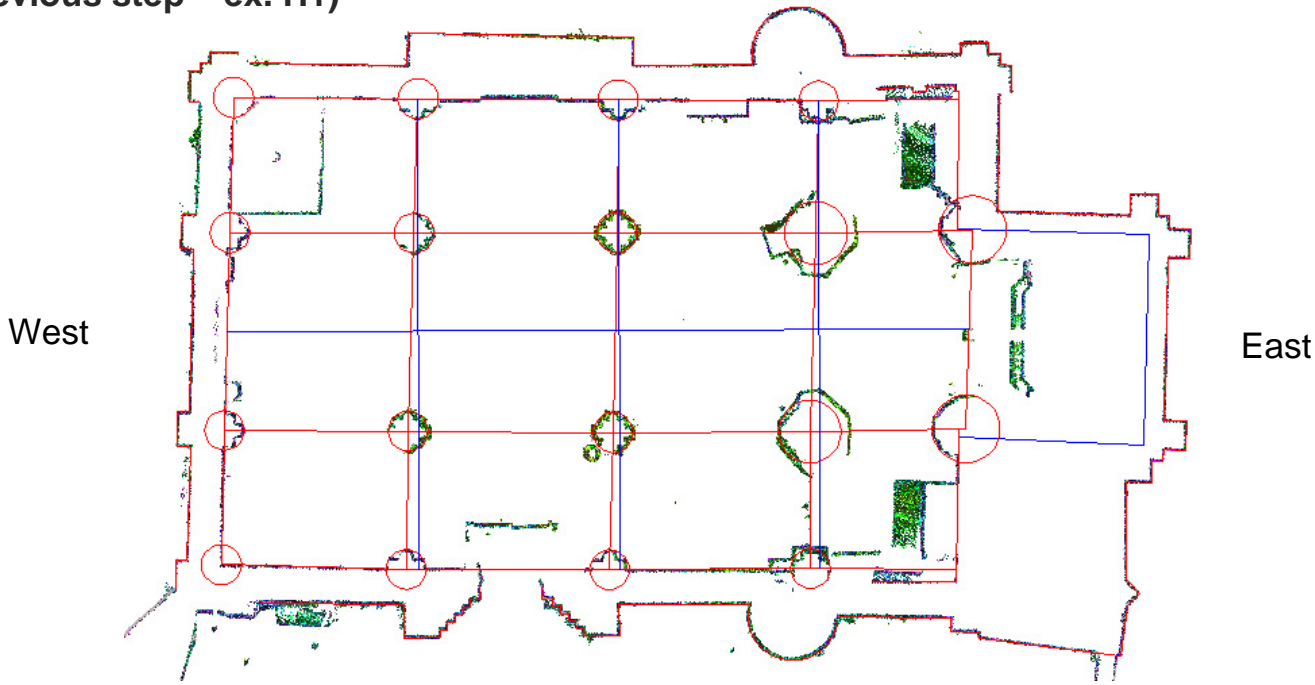
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4. Two examples of 3D Laserscanning: church in Spain

- Adopted methodology:
 - Deformation evaluation (from the most significant sections obtained in previous step – ex. H1)





West

East

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4. Two examples of 3D Laserscanning: church in Spain

- Adopted methodology:
 - **Interpretation of the results**

The sections analysed show the deformations graphically and allow their accurate measurement. From these measurements comparison it is possible to say in what direction they occur and where they are more expressive.

In this case it was possible to conclude that the bigger deformations occurred from the longitudinal axis to the south and in an orthogonal direction on the west wall.

As possible causes one can refer a possible sliding of the building structure that may have caused the arch shaped deformation in the south wall.

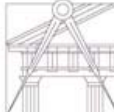

The rupture of some structural elements of the roof may also have contributed to this deformation.

Also the existence of a roman cistern under the ground level may be a possible cause for this deformation. (...)

This graphical analysis itself doesn't allow one to conclude about the causes that produce them or if the deformations are stabilized. Complementary analysis have to be carried out!

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5. FCT: PTDC/AUR - 66476 - 2006: “Contributions to Architectural Heritage Conservation: Documentary methodology based in terrestrial digital photogrammetry and 3D laser scanning”

- **Research team:**

Researchers – FAUTL:

José Aguiar (director) 20% (architecture - conservation)
Francisco Agostinho 10% (architecture – graphical computation)
Luís Mateus 70% (architecture – geometry and CAD)
Víctor Ferreira 10% (architecture – graphical computation)
Cristina Henriques 25% (geography)

Researchers – U.Minho:

Luís Fontes 25% (archaeology of architecture)
Paulo Bernardes 25% (mathematics – graphical computation)
Natália Botica 25% (geography – SIG)

Researchers – U.Coimbra:

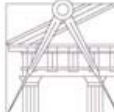

Helena Catarino 10% (archaeology)
Sónia Filipe 20% (archaeology of architecture)

Researchers – IGESPAR:

Maria Ramalho 10% (archaeology o architecture)
Manuel Lacerda 10% (architecture)

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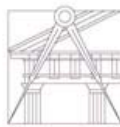

5. FCT: PTDC/AUR - 66476 - 2006: “Contributions to Architectural Heritage Conservation: Documentary methodology based in terrestrial digital photogrammetry and 3D laser scanning”

- **General description:**

<u>Main scientific area:</u>	Architecture and Urbanism
<u>Secondary scientific area:</u>	History, Anthropology and Cultural Heritage
<u>Partners:</u>	Faculty of Architecture of UTL (principal contractor) University of Minho – Archaeology group University of Coimbra IGESPAR (Portuguese Institute for Architectural Heritage Management)
<u>Consultant:</u>	Juan José Fernández Martín (University of Valladolid)
<u>Starting date:</u>	October de 2007
<u>Finishing date:</u>	September de 2010
<u>Total researchers:</u>	12
<u>Scholars:</u>	2

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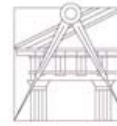
- **Technical addendum / abstract:**
 - 1) Within the context of accurate metric information need for rehabilitation or conservation architectural design, comes the idea to investigate documentary processes that support themselves in modern recording techniques and technologies, such as digital photogrammetry and 3d laser scanning, both high and low cost.
 - 2) Once it is a interdisciplinary area one tried to organize a research team of multiple resources, from architecture, archaeology, graphic computation, geometry, mathematics, SIG.
 - 3) It is an investigation about methods and techniques of recording and information management, specially pointed out to Architectural Conservation and Rehabilitation. On this sense, its possible to complement other information systems more qualitative in nature (such as IPPAR information system)
 - 4) Living in a time where the change of paradigm is more and more evident, in what concerns how data is collected and managed in Architectural Conservation, one will try to establish reference frameworks and guidelines that take into account what are the needs, the technologies available, the products to be produced, costs, that can serve as basis for planning conservative actions.

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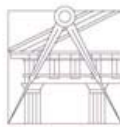

• Technical addendum / abstract:

- 5) The study cases must correspond to situations where it is foreseen that a concrete conservation measure is to be taken. These can change during the research. For now we consider the following cases: São Frutuoso of Montélios Chapel in Braga, Valflores Palace in Loures, Santa Clara a Velha Church in Coimbra, several areas in Coimbra uptown. It can be both isolated objects or urban sets of buildings. It is important to focus several scales to deal with different kind of problems.



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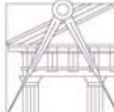

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- **Technical addendum / objectives:**
 - 1) To create the basis for a minimum system of surveying and documentation of architectural heritage based both in low cost photogrammetry and 3d laser scanning for potential achieving to plans, sections and elevations, or 3d models, to support restoration actions whenever needed.
 - 2) To explore the possibilities of joint between digital photogrammetry and 3d laser scanning in order to investigate methodological implications both in analysis and diagnosis processes and architectural design process.
 - 3) To implement an Information System that allows the management of qualitative a geometric data (2D and 3D) about Architectural Heritage. This should serve as base to the implementation of conservative measures, as base to the widespread and study of architectural heritage, and complement other existing Information Systems.
 - 4) To explore research opportunities that come up in the boundaries of traditional scientific areas.

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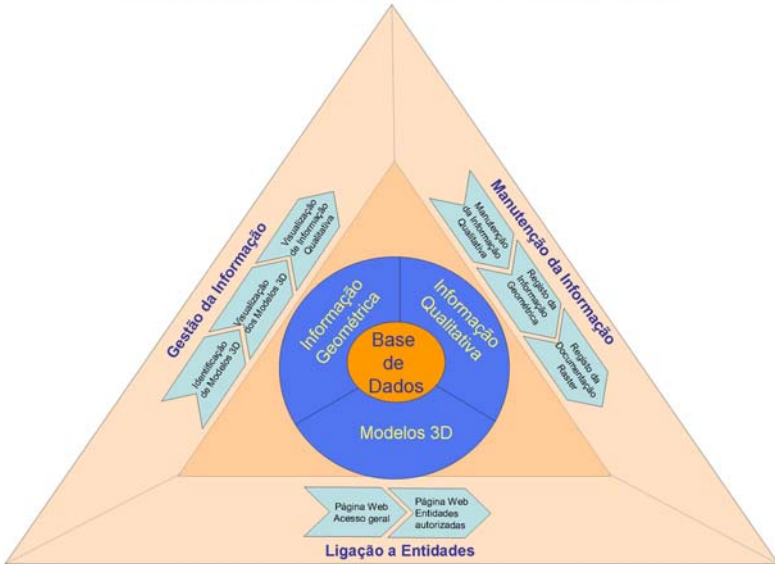
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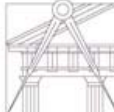

5. FCT: PTDC/AUR - 66476 - 2006: “Contributions to Architectural Heritage Conservation: Documentary methodology based in terrestrial digital photogrammetry and 3D laser scanning”

- Technical addendum / Information System:
Sistema de Informação de Conservação Arquitectónica e Urbana



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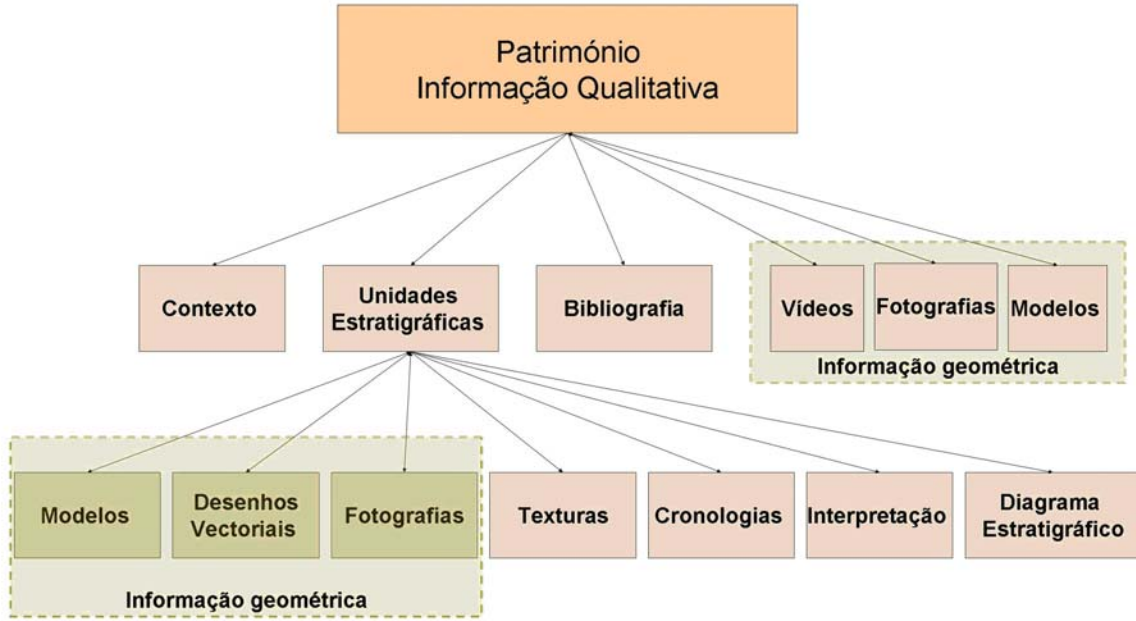
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- Technical addendum / Information System:

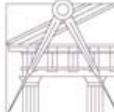



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graph TD; A[Património Informação Qualitativa] --> B[Contexto]; A --> C[Unidades Estratigráficas]; A --> D[Bibliografia]; A --> E[Vídeos]; A --> F[Fotografias]; A --> G[Modelos]; E & F & G --> H[Informação geométrica]; C --> I[Modelos]; C --> J[Desenhos Vectoriais]; C --> K[Fotografias]; I & J & K --> L[Informação geométrica]; C --> M[Texturas]; C --> N[Cronologias]; C --> O[Interpretação]; C --> P[Diagrama Estratigráfico];
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The diagram illustrates the structure of the Information System. At the top is 'Património Informação Qualitativa'. It branches into 'Contexto', 'Unidades Estratigráficas', 'Bibliografia', and a group of 'Vídeos', 'Fotografias', and 'Modelos' which are collectively labeled as 'Informação geométrica'. 'Unidades Estratigráficas' further branches into 'Modelos', 'Desenhos Vectoriais', and 'Fotografias' (also labeled as 'Informação geométrica'), and 'Texturas', 'Cronologias', 'Interpretação', and 'Diagrama Estratigráfico'.

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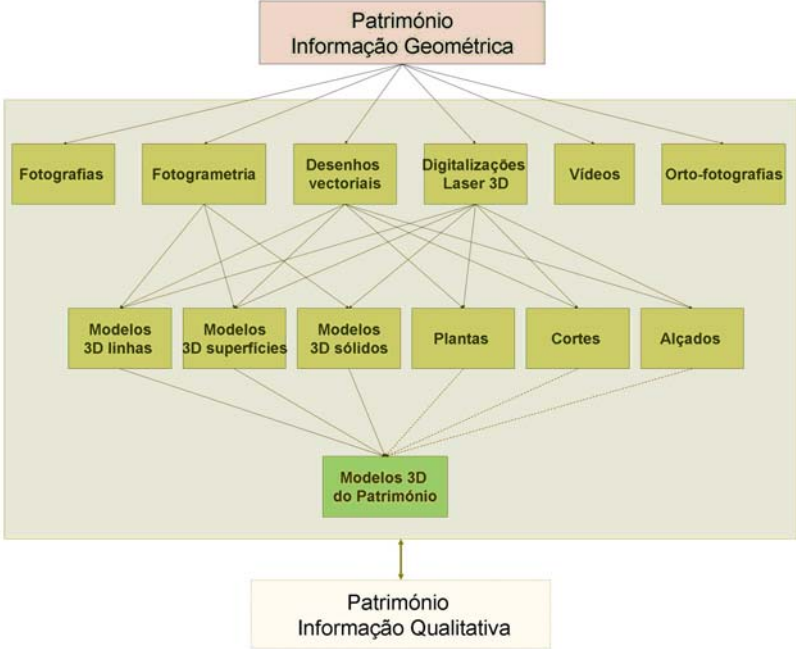
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5. FCT: PTDC/AUR - 66476 - 2006: “Contributions to Architectural Heritage Conservation: Documentary methodology based in terrestrial digital photogrammetry and 3D laser scanning”

- Technical addendum / Information System:



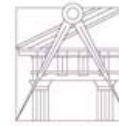
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graph TD; A[Património Informação Geométrica] --> B[Fotografias]; A --> C[Fotogrametria]; A --> D[Desenhos vectoriais]; A --> E[Digitalizações Laser 3D]; A --> F[Vídeos]; A --> G[Orto-fotografias]; B --> H[Modelos 3D linhas]; B --> I[Modelos 3D superfícies]; B --> J[Modelos 3D sólidos]; B --> K[Plantas]; B --> L[Cortes]; B --> M[Alçados]; C --> H; C --> I; C --> J; C --> K; C --> L; C --> M; D --> H; D --> I; D --> J; D --> K; D --> L; D --> M; E --> H; E --> I; E --> J; E --> K; E --> L; E --> M; F --> H; F --> I; F --> J; F --> K; F --> L; F --> M; G --> H; G --> I; G --> J; G --> K; G --> L; G --> M; H --> N[Modelos 3D do Património]; I --> N; J --> N; K --> N; L --> N; M --> N; N --> O[Património Informação Qualitativa];
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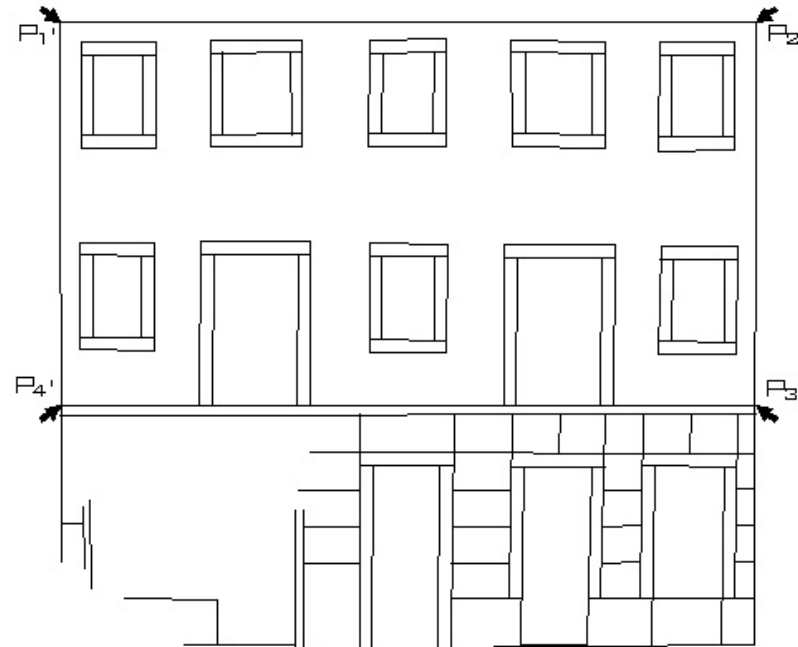



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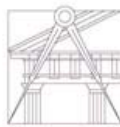
5. FCT: PTDC/AUR - 66476 - 2006 - (low cost photogrammetry)

• 1st Part – Drawing rectification





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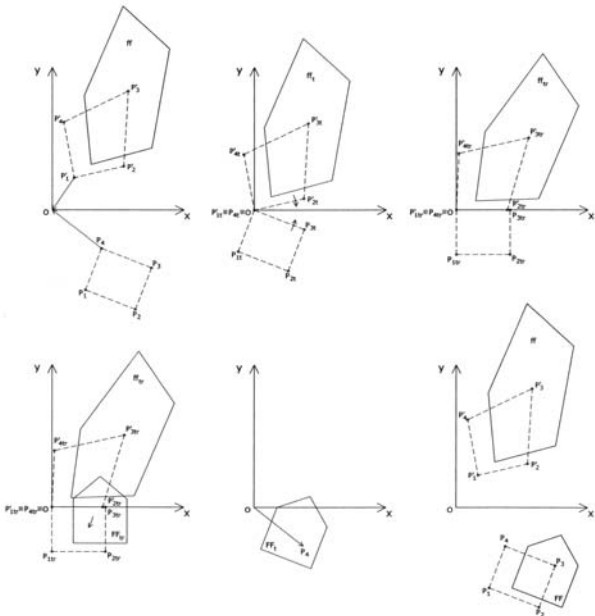


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5. FCT: PTDC/AUR - 66476 - 2006 - (low cost photogrammetry)

$$X_u = \frac{e_1 x_n + f_1 y_n + g_1}{e_0 x_n + f_0 y_n + 1}$$

$$Y_u = \frac{e_2 x_n + f_2 y_n + g_2}{e_0 x_n + f_0 y_n + 1}$$


$$g'_1 = X_{1tr}$$

$$g'_2 = Y_{1tr}$$

$$f'_2 = \frac{Y_{1tr} x_{4tr} - Y_{1tr} x_{3tr}}{x_{3tr} y_{4tr} - y_{3tr} x_{4tr}}$$

$$e'_2 = \frac{Y_{1tr} y_{3tr} - Y_{1tr} y_{4tr}}{x_{3tr} y_{4tr} - y_{3tr} x_{4tr}}$$

$$e'_1 = \frac{e'_2 X_{2tr}}{Y_{2tr}} + \frac{X_{2tr} (Y_{1tr} - Y_{2tr})}{x_{2tr} Y_{2tr}} - \frac{X_{1tr} - X_{2tr}}{x_{2tr}}$$

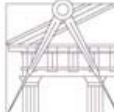

$$f'_1 = -\frac{e'_1 x_{4tr} + X_{1tr}}{y_{4tr}}$$

$$e'_1 = \frac{e'_2 X_{2tr}}{Y_{2tr}} + \frac{X_{2tr} (Y_{1tr} - Y_{2tr})}{x_{2tr} Y_{2tr}} - \frac{X_{1tr} - X_{2tr}}{x_{2tr}}$$

$$f'_1 = -\frac{e'_1 x_{4tr} + X_{1tr}}{y_{4tr}}$$

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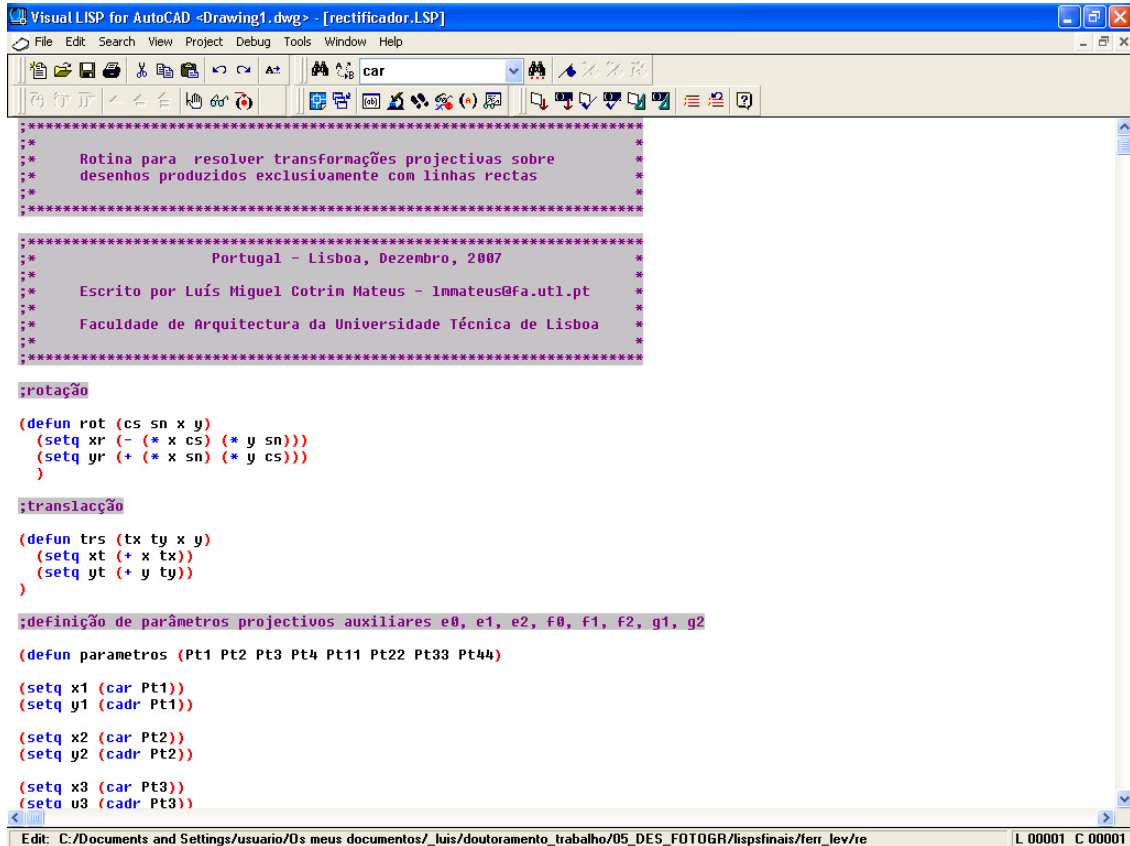


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5. FCT: PTDC/AUR - 66476 - 2006 - (low cost photogrammetry)



```
Visual LISP for AutoCAD - <Drawing1.dwg> - [rectificador.LSP]
File Edit Search View Project Debug Tools Window Help

*****
* Rotina para resolver transformações projectivas sobre *
* desenhos produzidos exclusivamente com linhas rectas *
*****

*****
* Portugal - Lisboa, Dezembro, 2007 *
* Escrito por Luís Miguel Cotrim Mateus - lmmateus@fa.utl.pt *
* Faculdade de Arquitectura da Universidade Técnica de Lisboa *
*****

;rotação

(defun rot (cs sn x y)
  (setq xr (- (* x cs) (* y sn)))
  (setq yr (+ (* x sn) (* y cs)))
)

;translação

(defun trs (tx ty x y)
  (setq xt (+ x tx))
  (setq yt (+ y ty))
)

;definição de parâmetros projectivos auxiliares e0, e1, e2, f0, f1, f2, g1, g2

(defun parametros (Pt1 Pt2 Pt3 Pt4 Pt11 Pt22 Pt33 Pt44)

  (setq x1 (car Pt1))
  (setq y1 (cadr Pt1))

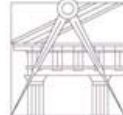

  (setq x2 (car Pt2))
  (setq y2 (cadr Pt2))

  (setq x3 (car Pt3))
  (setq u3 (cadr Pt3))

  Edit: C:/Documents and Settings/usuario/0s meus documentos/_luis/doutoramento_trabalho/05_DES_FOTOGRAFIA/lispfinais/ferr_lev/re L 00001 C 00001
```

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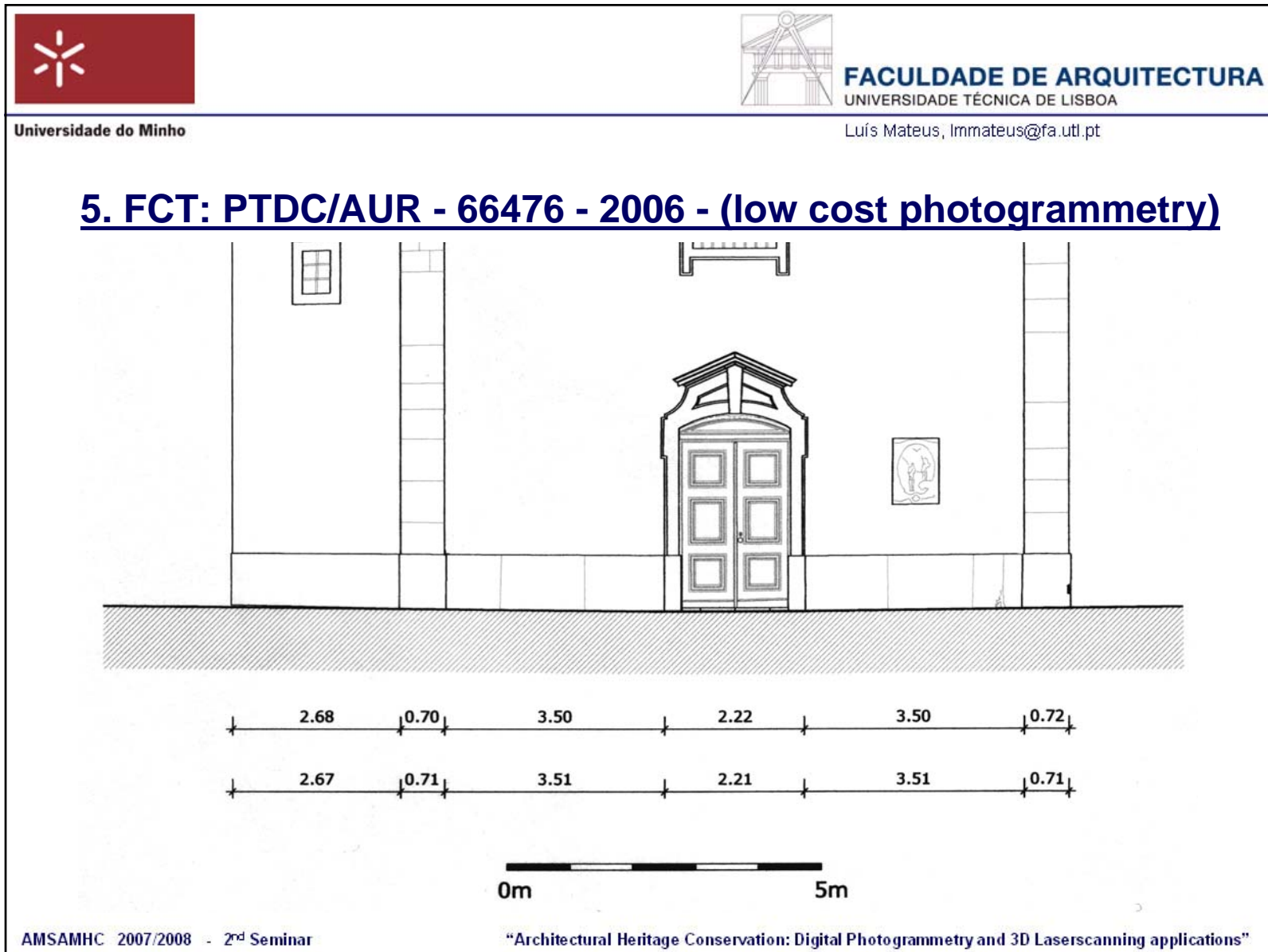
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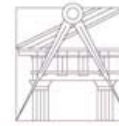
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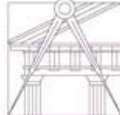

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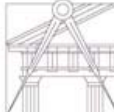

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0 5m

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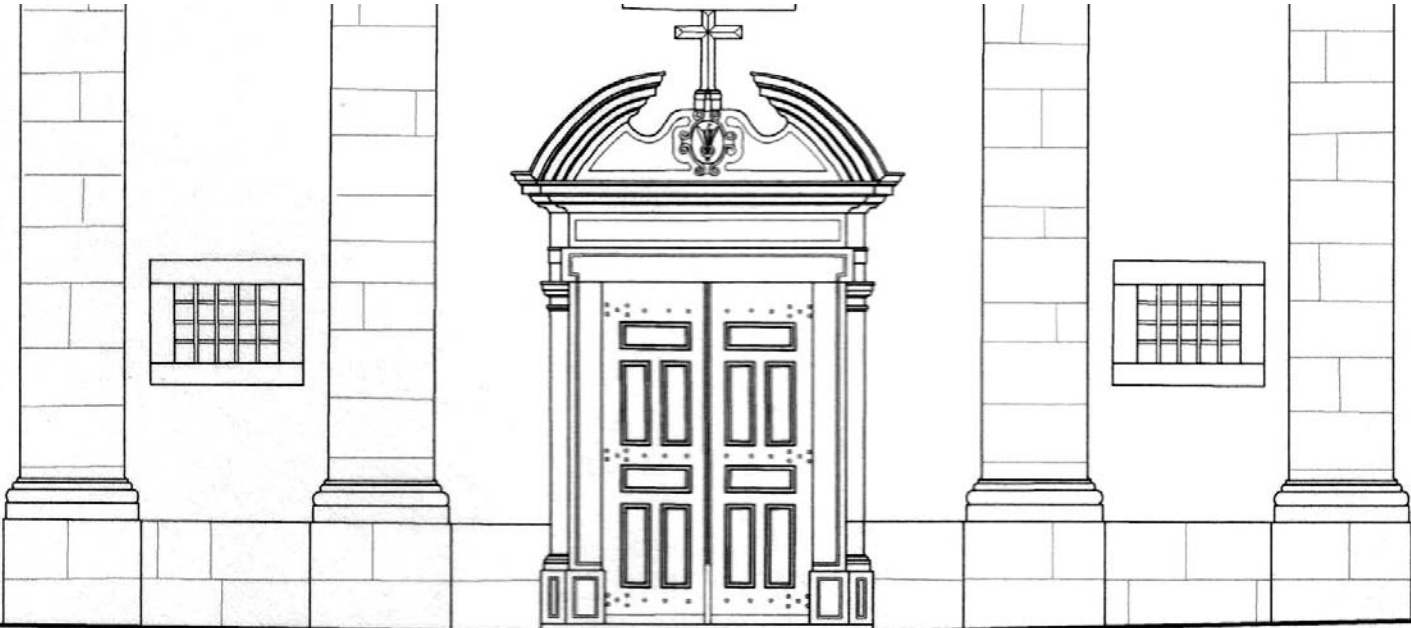


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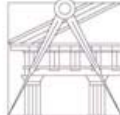

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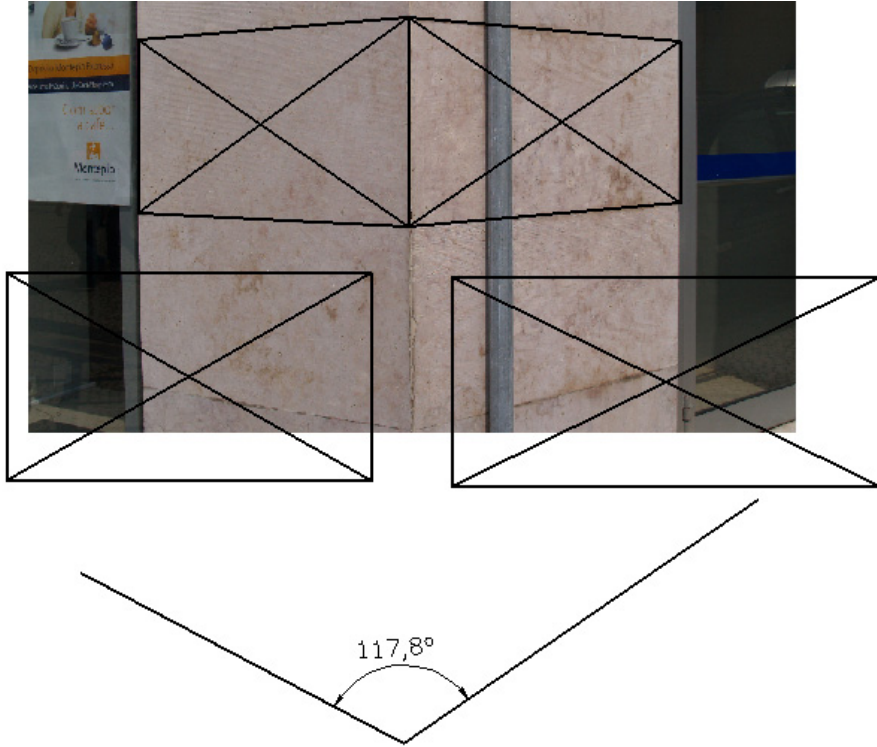
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5. FCT: PTDC/AUR - 66476 - 2006 - (low cost photogrammetry)



- 2nd Part – Angle calculation between façades



The image shows a photograph of a wall with a book titled 'Controlo de Qualidade' by Metropolis. Overlaid on the photograph are three rectangular frames, each with a diagonal crosshair, representing camera positions for photogrammetry. Below the photograph is a geometric diagram showing two lines meeting at a vertex, forming an angle labeled $117,8^\circ$.

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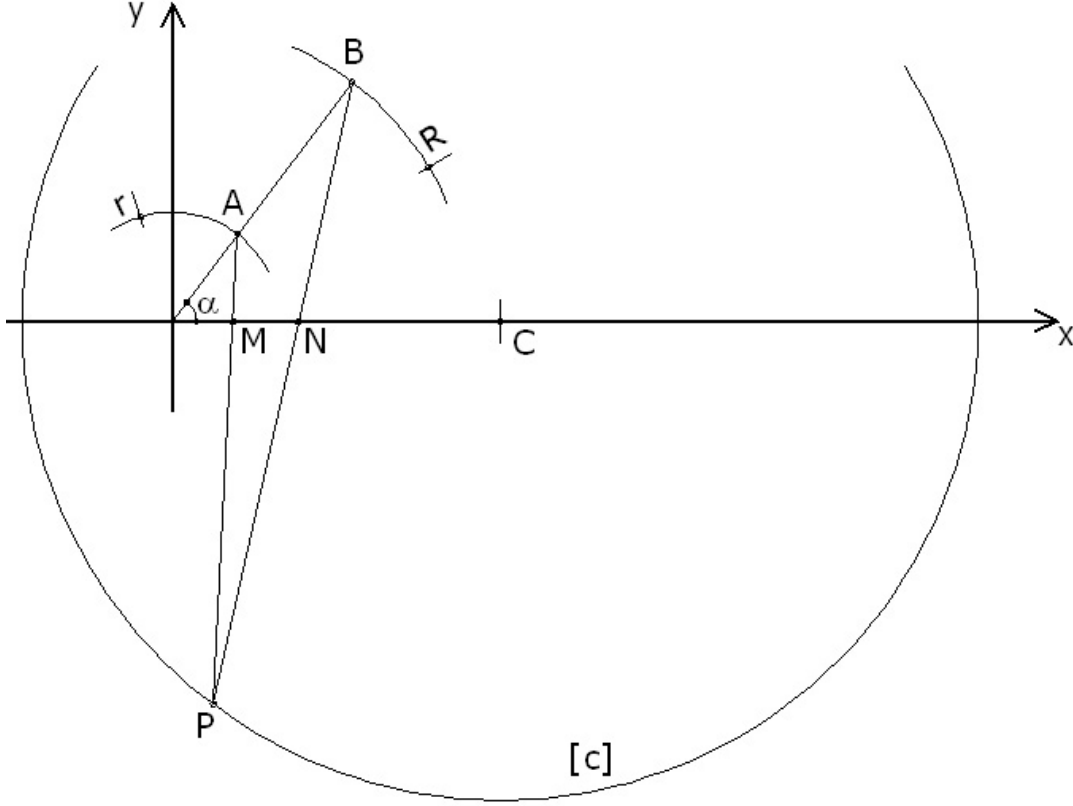


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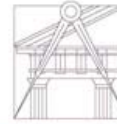


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5. FCT: PTDC/AUR - 66476 - 2006 - (low cost photogrammetry)

$$A = (r \cos \alpha; r \sin \alpha)$$

$$B = (R \cos \alpha; R \sin \alpha)$$

$$M = (d; 0)$$

$$N = (D; 0)$$

$$P = (X_p; Y_p)$$

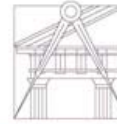
Os alinhamentos $A.M.P$ e $B.N.P$ podem ser traduzidos pelas seguintes igualdades:

$$\begin{vmatrix} r \cos \alpha & d & X_p \\ r \sin \alpha & 0 & Y_p \\ 1 & 1 & 1 \end{vmatrix} = 0$$

$$\begin{vmatrix} R \cos \alpha & D & X_p \\ R \sin \alpha & 0 & Y_p \\ 1 & 1 & 1 \end{vmatrix} = 0$$



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5. FCT: PTDC/AUR - 66476 - 2006 - (low cost photogrammetry)

$$Y_p = \frac{Rr(d - D)}{Rd - rD} \sin \alpha$$


$$X_p = \frac{Rr(d - D)}{Rd - rD} \cos \alpha + \frac{Dd(R - r)}{Rd - rD}$$

Estes expressam as equações paramétricas de uma circunferência $[c]$ de centro $C = \left(\frac{Dd(R - r)}{Rd - rD}; 0 \right)$ e raio

$$R_{[c]} = \left| \frac{Rr(d - D)}{Rd - rD} \right|.$$



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5. FCT: PTDC/AUR - 66476 - 2006 - (low cost photogrammetry)

```

;*****
;*
;*  Rotina para determinar o ângulo que fazem duas fachadas
;*  aproximadamente planas através de uma foto de esquina
;*  tirada com o eixo da objectiva na horizontal
;*
;* *****
;*****
;*
;*  Portugal - Lisboa, Dezembro, 2007
;*
;*  Escrito por Luís Miguel Cotrim Mateus - lmmateus@fa.utl.pt
;*
;*  Faculdade de Arquitectura da Universidade Técnica de Lisboa
;*
;* *****
;*****
; distância "dist" de um ponto "Pt1" a uma recta "Pt1.Pt2"
(defun dptr (Pt1 Pt2 Pt3)
  (setq x1 (car Pt1))
  (setq y1 (cadr Pt1))
  (setq x2 (car Pt2))
  (setq y2 (cadr Pt2))
  (setq x3 (car Pt3))
  (setq y3 (cadr Pt3))
  (setq x4 (+ x1 (- y2 y3)))
  (setq y4 (+ y1 (- x3 x2)))
  (setq Pt4 (list x4 y4))
  (setq Pin (inters Pt4 Pt1 Pt2 Pt3 nil))
  (setq dist (distance Pt1 Pin))
)
; intersecção de uma recta (w,z).(w3,0) com uma circunferência de raio R de centro na origem (0,0)
(defun RxC (w z w3 R)
  (setq a (+ 1 (* (/ (- w3 w) z) (/ (- w3 w) z))))
  (setq b (* -2 w3 (/ (- w3 w) z)))
  (setq c (- (* w3 w3) (* R R)))
  ; ponto 1
  (setq Yu1 (/ (+ (- b) (sqrt (- (* b b) (* 4 a c)))) (* 2 a)))
  (setq Xu1 (- w3 (* Yu1 (/ (- w3 w) z))))
  (setq Pu1 (list Xu1 Yu1))
  ; ponto 2
  (setq Yu2 (/ (- (- b) (sqrt (- (* b b) (* 4 a c)))) (* 2 a)))
    
```

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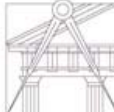

5. FCT: PTDC/AUR - 66476 - 2006 - (low cost photogrammetry)



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67



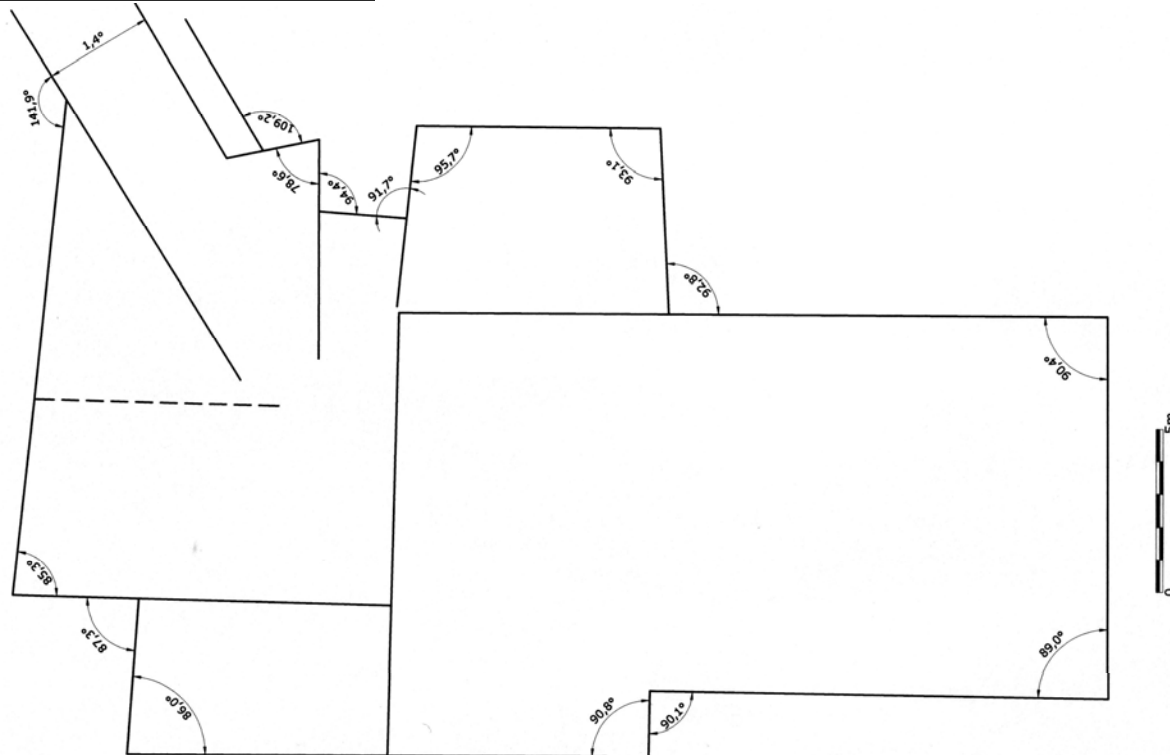
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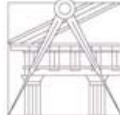

5. FCT: PTDC/AUR - 66476 - 2006 - (low cost photogrammetry)

- 3rd Part – Angle registration



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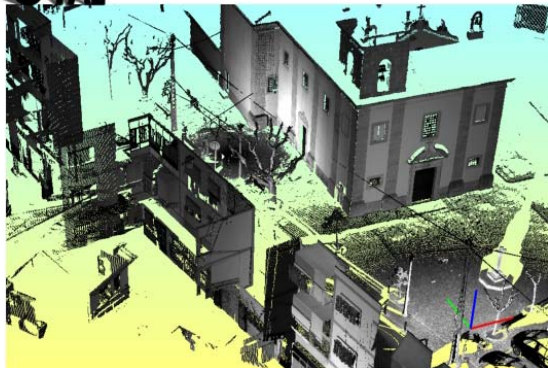
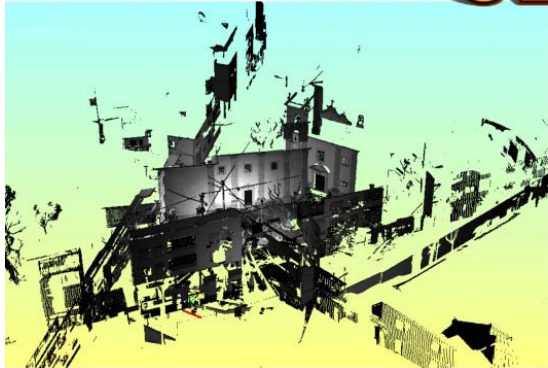

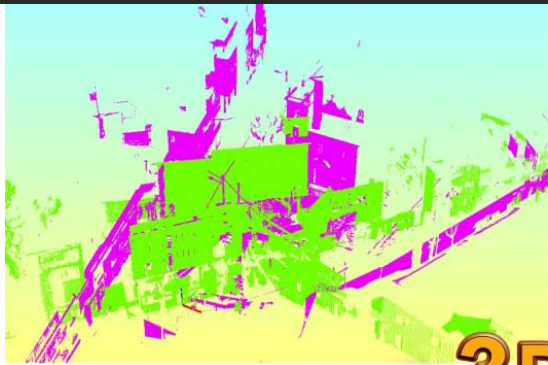
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- 4th Part – Evaluation with 3d laser scanning



3D TOTAL

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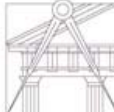

5. FCT: PTDC/AUR - 66476 - 2006 - (low cost photogrammetry)



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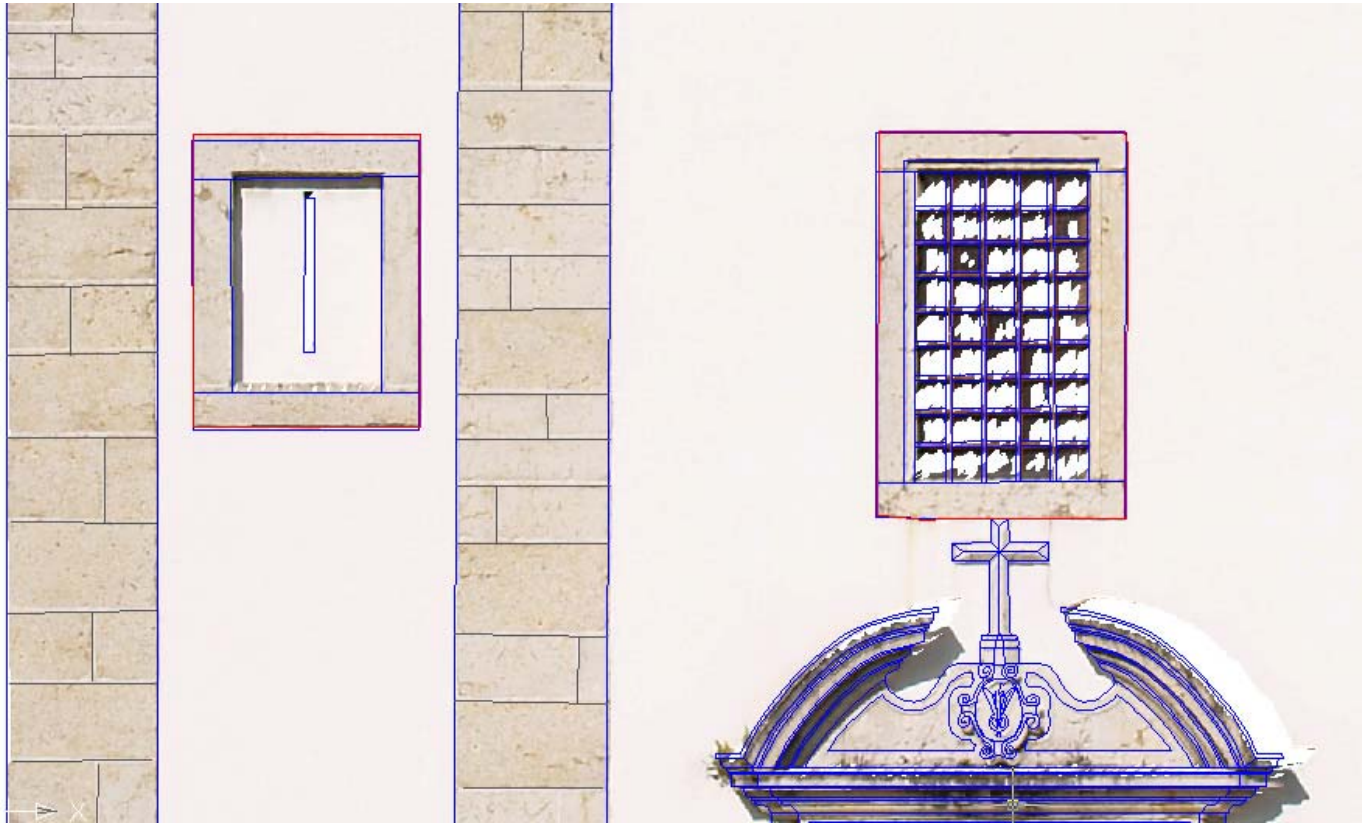


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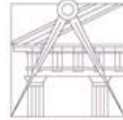

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5. FCT: PTDC/AUR - 66476 - 2006 - (low cost photogrammetry)



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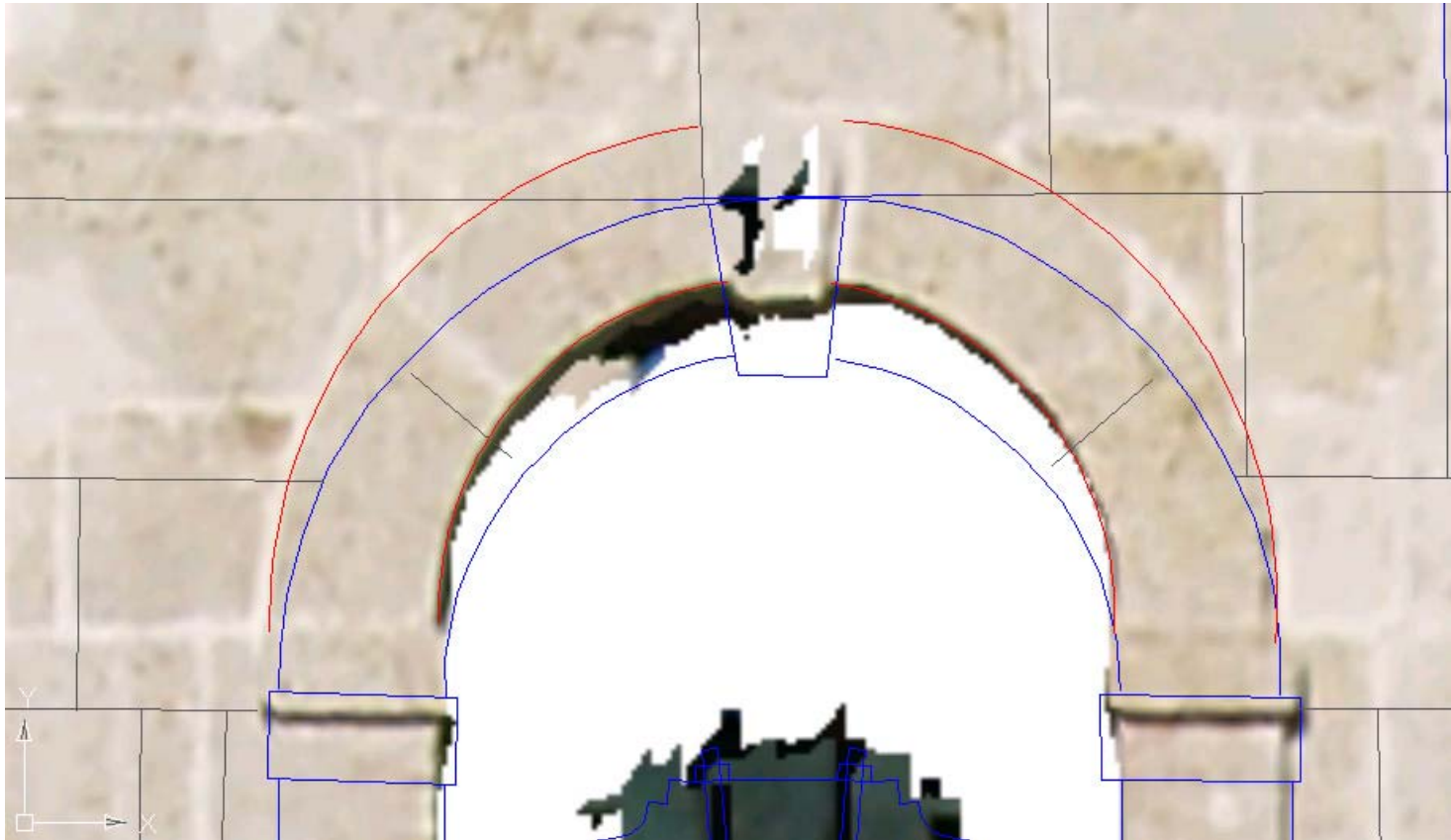


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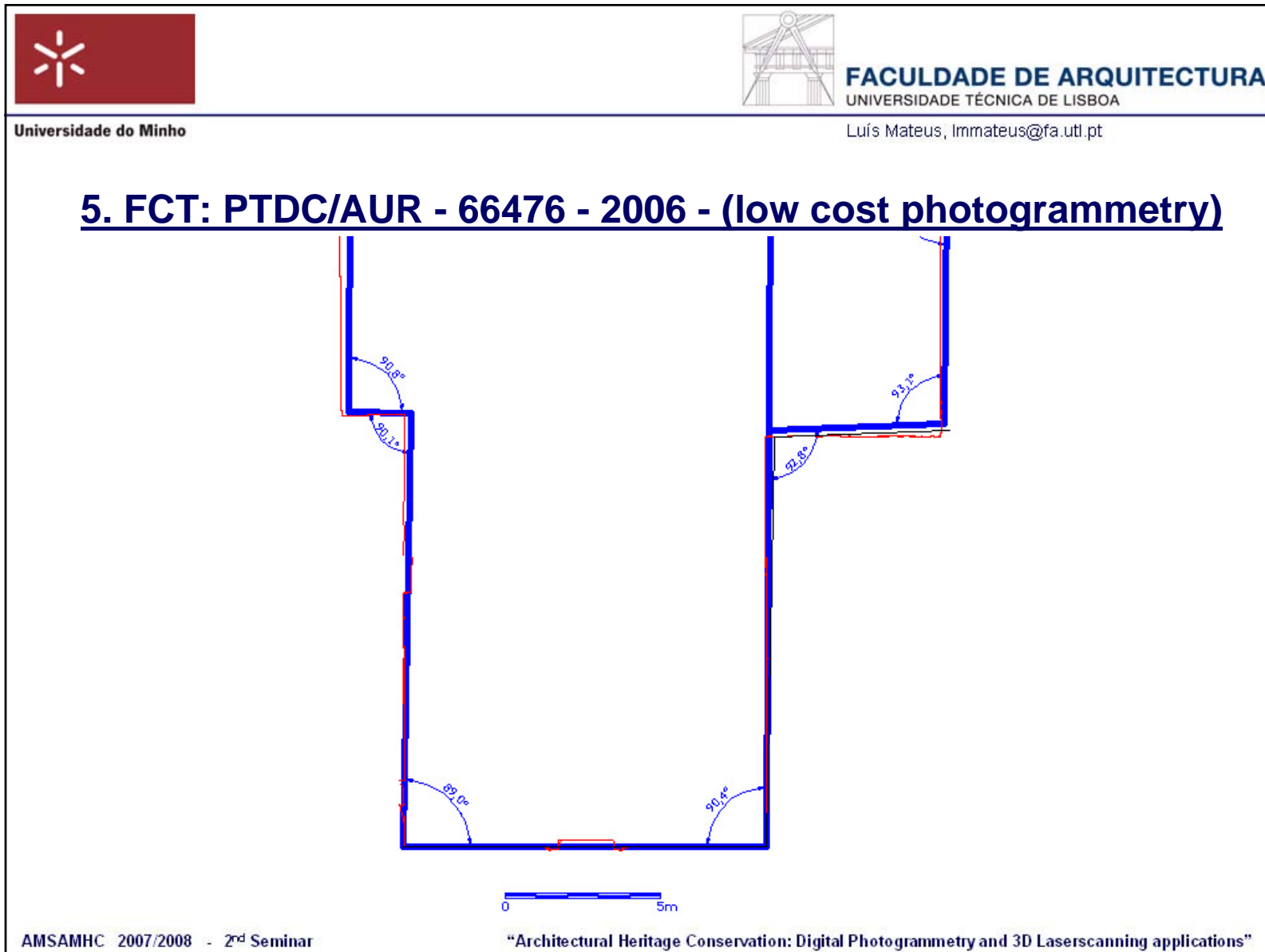
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<h2><u>References</u></h2>		
<p>AutoLISP Programmers Reference - Autocad release 12, Neuchatel: Autodesk BV, 1992. 251p. ISBN 2-88447-004-2</p>		
<p>CRAMER, Johannes and BREITLING, Stefan – Architecture in existing fabric – 2007, ISBN: 9 783764 377526</p>		
<p>ENGLISH HERITAGE METRIC SURVEY TEAM, Metric Survey Specifications for English Heritage, English Heritage – National Monuments Record Centre, Great Western Village, 2003, 111 p. ISBN 1-873-59257-4 (and addendums)</p>		
<p>FEIFFER, Cesare – Il progetto di conservazione. Milão: Franco Angeli Libri s.r.l., 1989. 595p. ISBN 88-204-3055-X</p>		
<p>LILLESAND, Thomas M. & Kiefer, Ralph W. 1994, Remote Sensing and Image Interpretation, 5^a edição, John Wiley & Sons, Nova Iorque, 2004. 752 p. ISBN 0-471-15227-7</p>		
<p>MAESTRI, Diego; DOCCI, Mario – Manuale di rilevamento architettonico e urbano. 8^a edição. Roma: Editori Laterza, 2005. 343 p. ISBN 88-420-4341-9</p>		
<p>MARINO, Luigi 1994, Il Rilievo per il Restauro – Ricognizioni-Misurazioni-Accertamenti-Restituzione-Elaborazione, 4^a edição, Hoepli, Milão</p>		
<p>MIKHAIL, Edward M., Bethel, James S. & McGlone J. Chris 2001, Introduction to Modern Photogrammetry, John Wiley & Sons, Nova Iorque, 479 p. ISBN 0-471-30924-9</p>		
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<h2><u>References (internet)</u></h2>		
<p>CIPA: International Committee for Documentation of Cultural Heritage http://cipa.icomos.org/</p>		
<p>DAVAP: Documentación, Análisis y Visualización Avanzada del Patrimonio (Universidad de Valladolid) http://www3.uva.es/davap/</p>		
<p>ISPRS, International Society for Photogrammetry and Remote Sensing , 2006, in: http://www.isprs.org/</p>		
<p>ICOMOS, <i>International Charters for Conservation and Restoration</i>, 2006, in: http://www.international.icomos.org/home.htm</p>		
<p>IPPAR, Instituto Português do Património Arquitectónico, 2006, in: http://www.ippar.pt</p>		
<p>DGEMN, Direcção Geral dos Edifícios e Monumentos Nacionais, 2006, in: http://www.monumentos.pt</p>		
<p>Link to some documents referred: http://www.fa.utl.pt/~lmmateus/ferr_lev/ferr_lev.zip</p>		
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