



## Digitisation of monuments for restoration and conservation

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## OUTLINE

- Introduction
  - Heritage Recording
  - Imaging
  - Photogrammetry
- Digitisation performance by photogrammetric approaches
  - Based on number of imagery
    - Single image
    - Stereo-imagery
    - Multi-image
  - Alternatives for non-planar targets
  - Multispectral information
- Learning by practical examples for heritage recording
  - Multispectral photogrammetry
  - Photogrammetry + laser scanning + thermography
- Conclusions

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## Introduction

- Documentation is a challenge and needs the synergy from multiple sources
  - Art historians, archaeologists, architects, engineers...
- Basic requirements
  - Archive, inventory and repository
  - Planning, management, response and recovery
  - Assessment of risk
  - Extraction of useful information in order to take (current and future) appropriate decisions for conservation, restoration, rehabilitation or reconstruction
- Types of documentation
  - Historic documentation
  - Chemical documentation
  - Structural documentation
  - Metric documentation
  - ...

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## Introduction

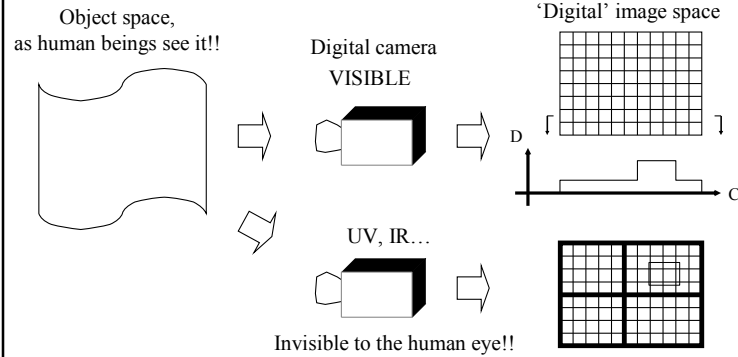
- Metric documentation for documentation and monitoring of cultural heritage
  - On-surface
    - Drawings/sketches
    - Photographs
    - Total stations/GNSS
    - Photogrammetry
    - Laser scanning
    - GIS/AIS/CAD/DB/WWW
  - Under-surface (in combination with structural documentation)
    - Ultrasounds
    - Geophysical studies
      - Electric
      - Magnetic
      - Radar (GPR)
    - Thermography

CIPA movie

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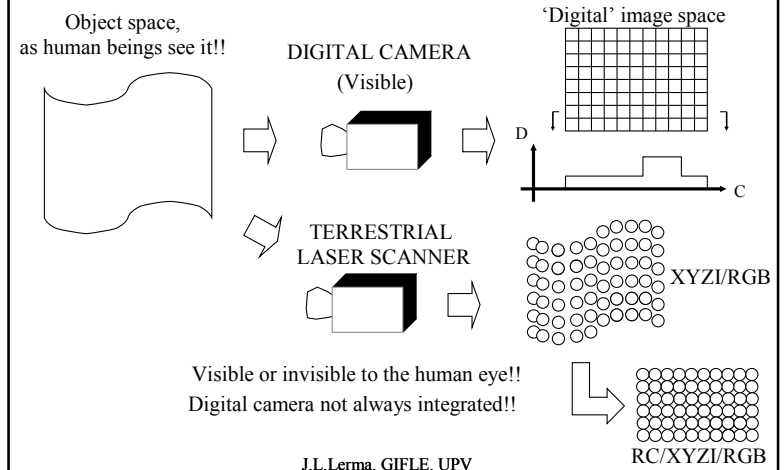
## Imaging

- Visible vs non-visible imaging



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## Imaging vs range measurements



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## PHOTOGRAMMETRY

- Definition

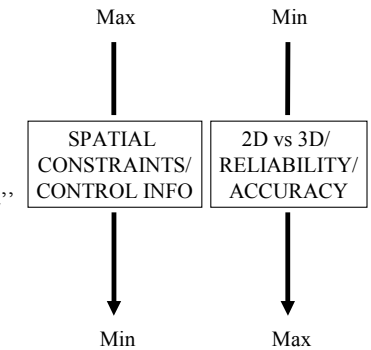
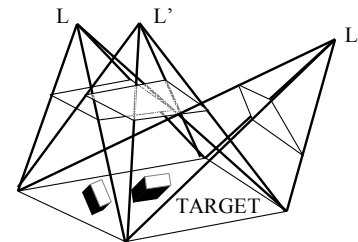
- “The science or art of obtaining reliable measurements by means of photographs” (Manual of Photogrammetry, 3<sup>rd</sup> Ed.)
- “Art, science and technology of obtaining reliable information about physical objects and the environment through the process of recording, measuring, and interpreting photographic images and patterns of electromagnetic radiant energy and other phenomena” (Manual of Photogrammetry, 4<sup>th</sup> Ed.)

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## Photogrammetric Performance

- Based on number of imagery:

- Single image
- Stereo-imagery
- Multi-image



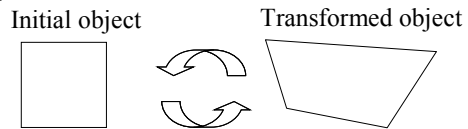
COSTS: Automatic performance!!

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## Single Image: Rectification

- Generalities
  - There is a projective relationship between features on a planar surface and homologous features on another planar surface

- Transformation



- Control information

- 4 Control Points, min.
- (1 Hz + 1 V) distances + 1 rotation, min.
- Visual. Without metric control!!

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## Single Image: Rectification

- Advantages

- Direct and simple procedure
- Economic and relatively quick procedure for producing a record of planar surfaces
- Requires cheap equipment and software

- Disadvantages

- Undulating surfaces
- 2D measurements only: positions, distances and areas
- No depth info
- Lack of stereoscopy
- Manual procedure (most of the times)

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## Single Image: Rectification

- Applications

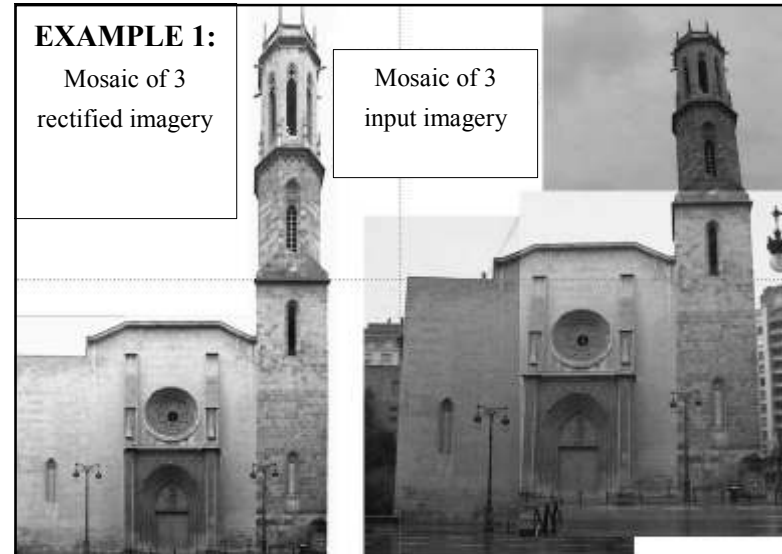
- Metric rectification of perspective images on planar targets
- Scaled imagery for plots and measurements
  - Architectural façades
  - Archaeological walls
  - Mosaic and tiled floors and ceilings
- Warping image texture to 3D models
- 2D/3D multimedia products
  - Backgrounds
  - Walks through
  - Videos

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### EXAMPLE 1:

Mosaic of 3  
rectified imagery

Mosaic of 3  
input imagery



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## EXAMPLE 2: Graphic documentation of streetscapes

PHOTGRAMMETRIC DOCUMENTATION FOR MUHARRAQ AND MANAMA  
URBAN DESIGN PILOT PROJECTS, UNDP Project in Bahrain

Input images



Output mosaic



More info about the documentation process, please visit: <http://jllerma.webs.upv.es/BahrainProject.htm>

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## EXAMPLE 3: 3D Reconstruction after metric documentation



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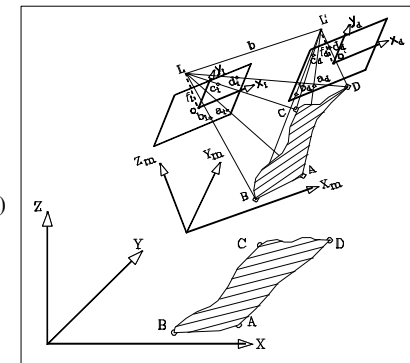
## Photogrammetric Performance

- Photogrammetric alternatives for non-planar targets
- What happens if the targets are not planar at all?
  - Single image → Not appropriate
  - Stereo-imagery → Possible
    - Stereo plotting
    - Stereo matching
  - Multi-image → Recommended. Option A
    - Self-calibration bundle block adjustment
    - ORTHOWARE (Metria Digital, S.L.)
  - Multi-image + laser scanning → Recommended. Opt. B

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## Stereo-imagery

- Classic photogrammetric method:
  - Classic ≠ Analogue nor manual
- Classic photogrammetric requirements:
  - Overlap imagery ( $p \geq 60\%$ )
  - GCP ( $\geq 3$  per pair)
  - Orientation
    - Interior
    - Relative
    - Absolute

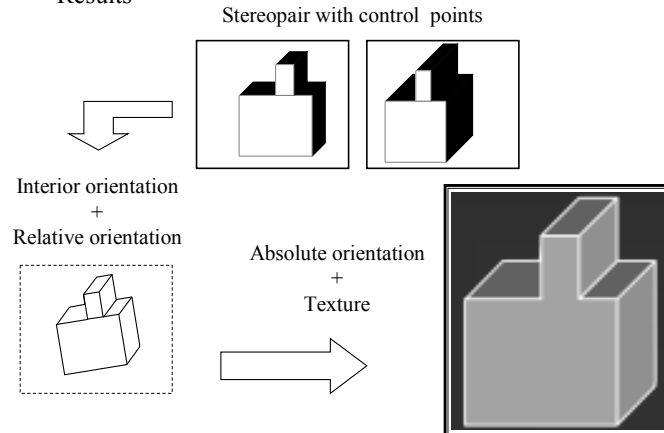


(Fig. 5-6, Lerma 2002)

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## Stereo-pairs: Shift from 2D images to 3D object

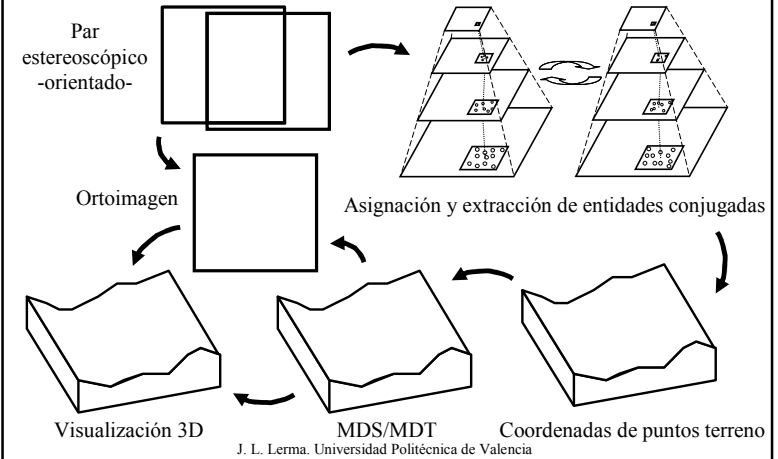
- Results



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## Stereo-pairs: Matching

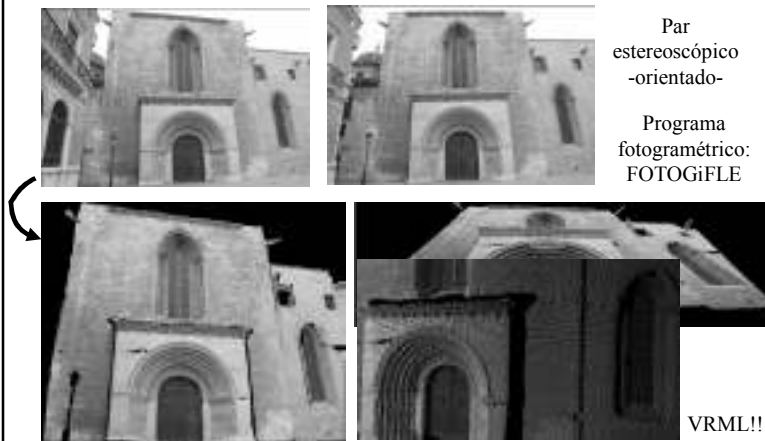
- Work-flow to build up fully automatic 3D models and orthoimagery



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## PARES DE IMÁGENES: Correspondencia automática

- Flujo de trabajo para generar en modo automático MDS/MDT Y ORTOIMÁGENES



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## MULTI-IMAGERY:

### Self-calibration bundle block adjustment

- Most useful and extended method in photogrammetry
- Benefits:
  - Block adjustment
  - Non-metric, semimetric or metric cameras
  - 3D model measurements
  - Accuracy, reliability, redundancy...
- Disadvantage:
  - Automatic measurements are not often implemented in off-the-self software
  - If not automatic, strong photogrammetric knowledge is recommended to overcome difficult set ups
    - Weak geometry
    - Block with different non-calibrated cameras

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## MULTI-IMAGERY: Self-calibration bundle block adjustment

- EXAMPLE: Interior of a Seconded room in the Cathedral of Valencia
  - Block: 31 images
  - Non-calibrated zoom SLR camera
  - Plotting, sections and elevations required at large scale before starting conservation works
  - 3D model → Multimedia video to be projected outside due to visitors' inaccessibility

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## MULTI-IMAGERY: Self-calibration bundle block adjustment

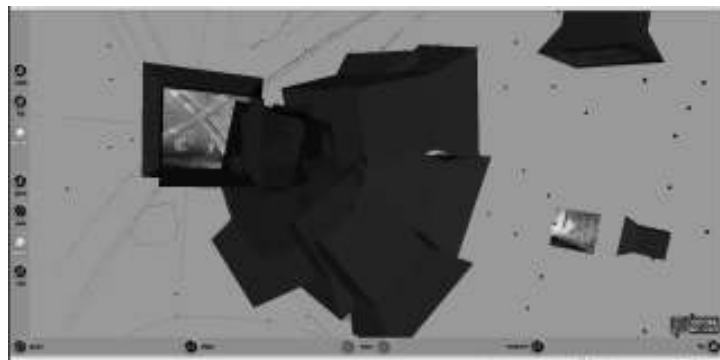
- EXAMPLE: Interior of a Seconded Room in the Cathedral of Valencia. XV century



Photogrammetric Software: FotograUPV

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## MULTI-IMAGERY: Self-calibration bundle block adjustment

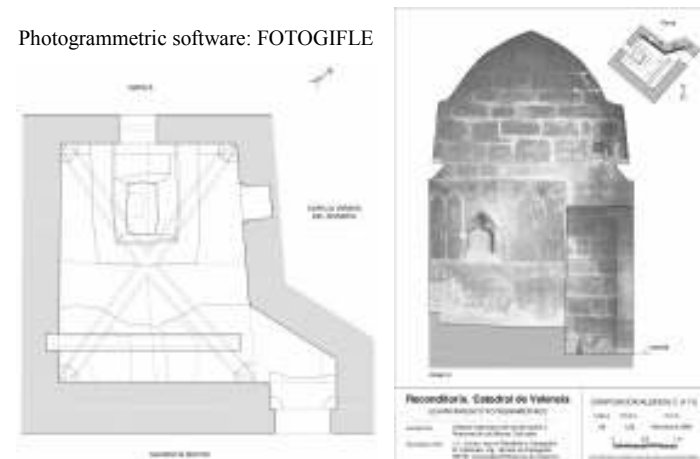


Photogrammetric Software: FotograUPV

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## Mapping before restoration

Photogrammetric software: FOTOGIFLE



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## MULTI-IMAGERY: ORTHOWARE

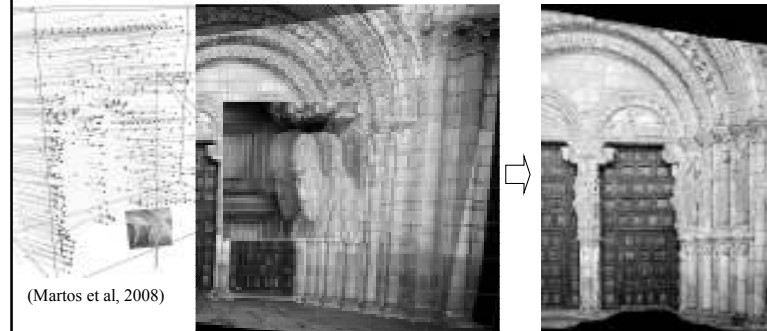
- Aim
  - Building up orthoimagery from calibrated cameras
- Requirements:
  - Many pictures
  - Some distance measurements and one level line
  - Standard PC or laptop
  - Easy to use to everybody: users, providers, non-experts
  - Fast and easy quality control
- Without conventional requirements
  - Surface model
  - Control points, but recommended

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## EXAMPLE WITH ORTHOWARE:

### Romanesque front door of Saint Vicente

- Project initialisation
- Exterior orientation of the block
- Image correction till finishing image blending
- Orthoimage



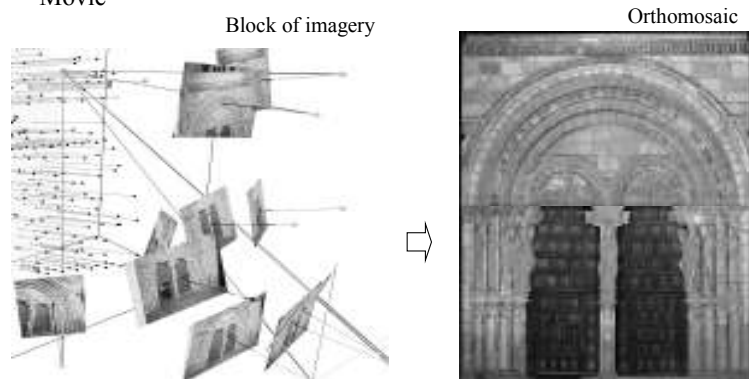
(Martos et al, 2008)

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## EXAMPLE WITH ORTHOWARE:

### Romanesque front door of Saint Vicente

- Orthoimage ↔ Image in orthogonal projection ↔ Scale
- Orthoimage + Orthoimage + ... ↔ Orthomosaic
- Movie



(Martos et al, 2008)

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## EXAMPLE WITH ORTHOWARE:

### San Julián de los Prados (Santullano) –West façade

- Input images
- Orthomosaic



(Metria Digital, 2008)

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## Terrestrial laser scanning

- When should we use it?
  - Complex scenarios in 3D
  - Comprehensive data collection
  - Lack of texture
  - No ambient light requirement
- Advantages:
  - Massive information XYZI/RGB
  - Volumetric information
  - Field of view (panoramic)
  - Fast automatic data acquisition
- Disadvantages:
  - High cost
  - Portability and size (equipment)
  - Massive information
  - Management and processing

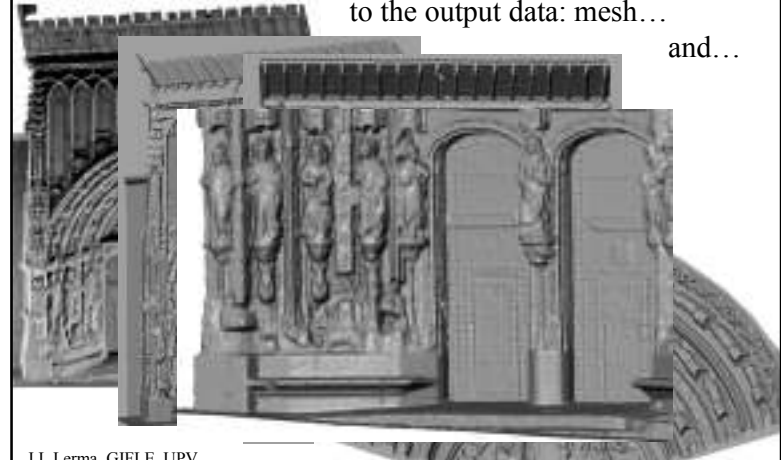


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Data acquisition: High altar, Cathedral of Valencia

## Terrestrial laser scanning

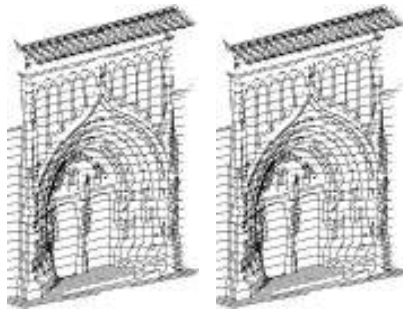
- From the input data (point clouds) to the output data: mesh... and...



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## Terrestrial laser scanning

- Mapping
  - Orthoimagery (bottom and front); Contours;
  - Sections...



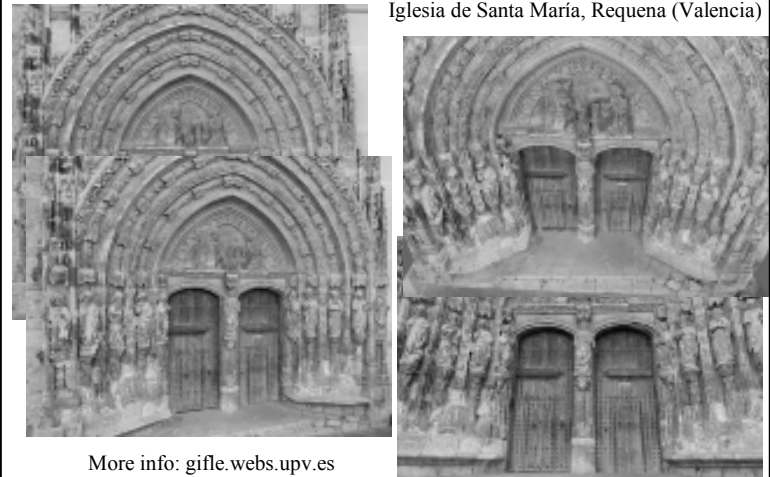
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## Terrestrial laser scanning + Photogrammetry

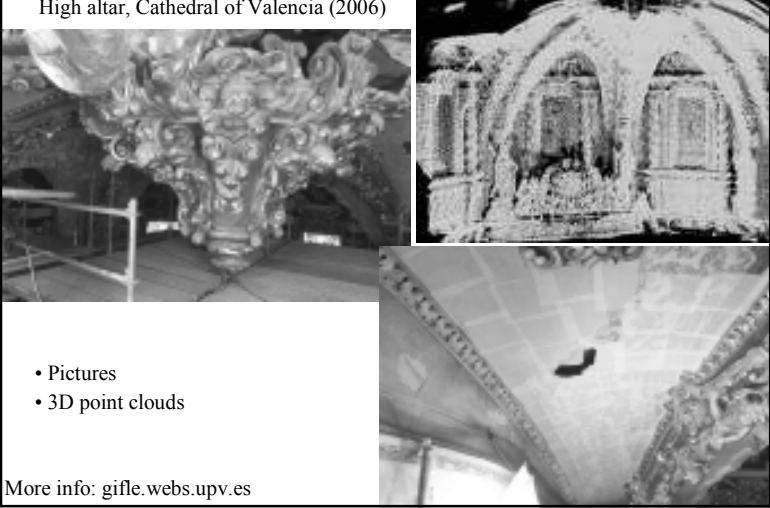
- Full analysis in 3D + texture

Iglesia de Santa María, Requena (Valencia)



More info: [gifle.webs.upv.es](http://gifle.webs.upv.es)

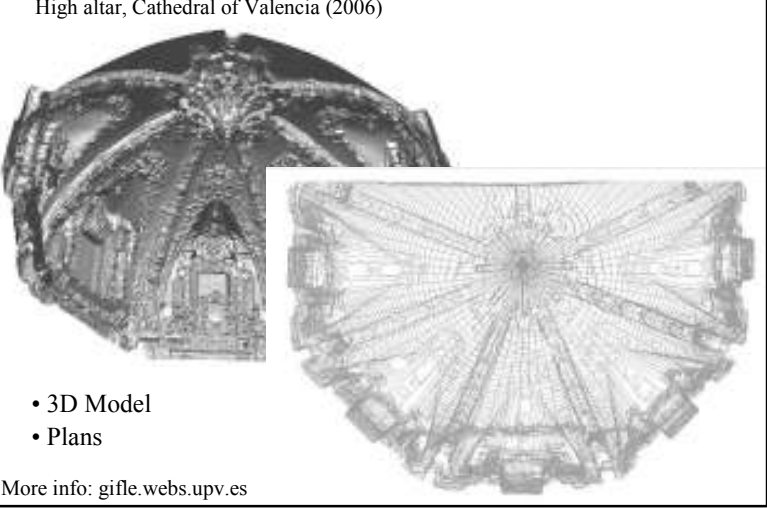
**Digitization:** Terrestrial laser scanning + Photogrammetry  
 High altar, Cathedral of Valencia (2006)



- Pictures
- 3D point clouds

More info: [gifle.webs.upv.es](http://gifle.webs.upv.es)

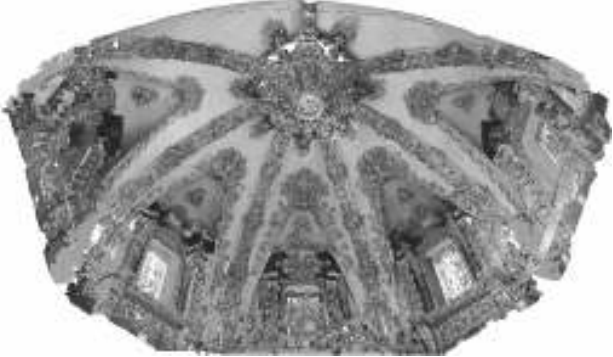
**Digitization:** Terrestrial laser scanning + Photogrammetry  
 High altar, Cathedral of Valencia (2006)



- 3D Model
- Plans

More info: [gifle.webs.upv.es](http://gifle.webs.upv.es)

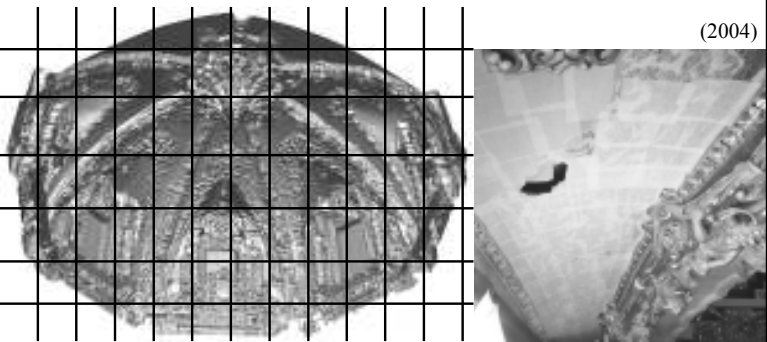
**Digitization:** Terrestrial laser scanning + Photogrammetry  
 High altar, Cathedral of Valencia (2006)



- Full 3D analysis in colour
- Movies
- Replicas (plots) in 3D
- Didactic material

More info: [gifle.webs.upv.es](http://gifle.webs.upv.es)

**Digitization:** Terrestrial laser scanning + Photogrammetry  
 High altar, Cathedral of Valencia (2006)



- Deconstruction
- Why?
  - Physical/digital archive
  - Demolishment!?
  - Restoration

(2004)

More info: [gifle.webs.upv.es](http://gifle.webs.upv.es)

## CATHEDRAL OF VALENCIA

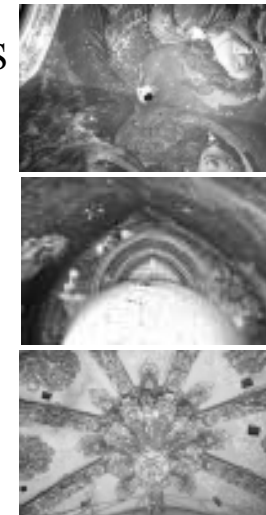
- ❑ During conservation works on the Baroque style in the high altar, June 2004, project coordinators found what had been written in the Records
- ❑ Unique Renaissance frescos over the Baroque vault!! Only visible through a tiny hole



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## RENAISSANCE FRESCOES

- ❑ Frescoes were painted by two Italian master painters, Francesco Pagano and Paolo de San Leocadio, in 1474
- ❑ They depicted angels playing instruments against a golden raised starry blue-sky background
- ❑ Frescoes were well preserved because they were covered up during the construction of the Baroque vault, dating back to the last third of the 17th century



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## VIRTUAL RECONSTRUCTION by imagery

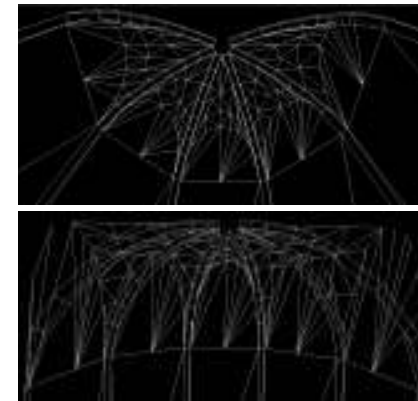
- ❑ Renaissance fresco mosaic: 1/(2\*7)



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## Draping onto a 3D model

- ❑ Simplified 3D modelling of the Gothic vault



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## VISUALIZATION AND INTERACTION



**Baroque + Gothic +  
Renaissance frescoes**



**Gothic +  
Renaissance frescoes**

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## HELPING TO START RESTORATION



**Baroque + Renaissance**

Sol. 1

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## HELPING TO START RESTORATION



**Baroque + Renaissance + Key on**

Sol. 2

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## HELPING TO START RESTORATION



**Baroque + Renaissance + Key off**

Sol. 3

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## AFTER RESTORATION (2007)

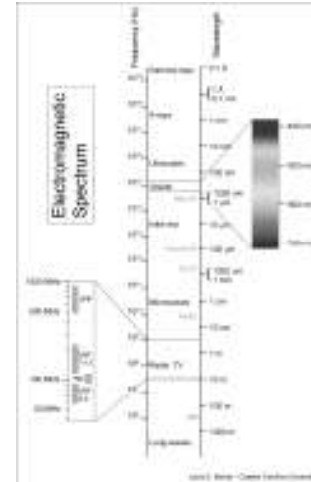


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## Multispectral information

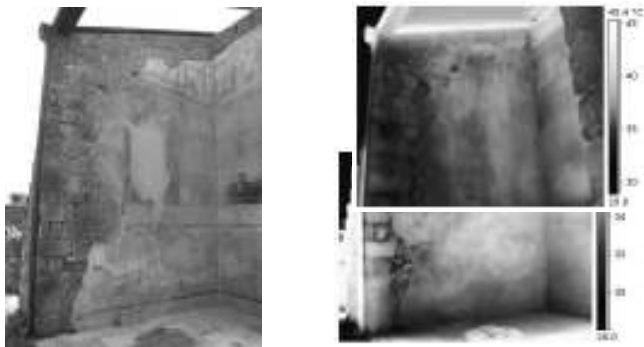
- Electromagnetic spectrum
  - Is the range of all possible electromagnetic radiation frequencies
  - The spectrum of an object is the characteristic distribution of its electromagnetic radiation
- Why should we have to collect info out of the visible region?

[http://en.wikipedia.org/wiki/Electromagnetic\\_spectrum](http://en.wikipedia.org/wiki/Electromagnetic_spectrum)  
(April 18, 2009)



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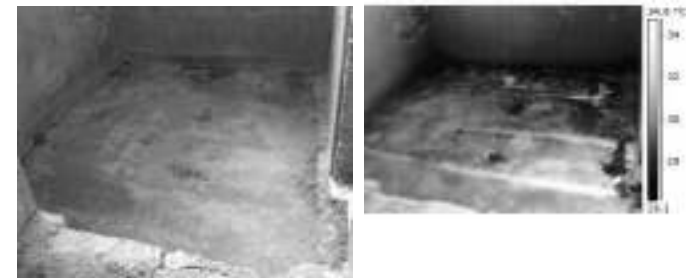
## Analysis on Architectural Walls, Floor and Ceiling



Casa di Arianna, Pompei (Italy)  
*Lalarium Room*

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## Analysis on Walls and Ground



Casa di Arianna, Pompei (Italy)  
*Oecus Room*

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## Analysis on Architectural Façades

VIS



IRT



Basílica de la Virgen  
Pza. de L'Almoina  
(Valencia)

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## Analysis on Architectural Façades

VIS



IRT



Basílica de la Virgen  
Pza. de la Virgen  
(Valencia)

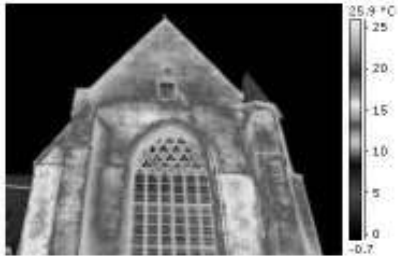
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## Analysis on Architectural Façades

VIS



IRT



St Jacobs, Leuven (Belgium)

Animation

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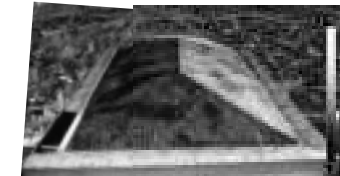
## Analysis on roof an ceiling

Monzon Castle: Temple (Huesca)

VIS



IRT



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And...

- Much more...

But

- Plans and metric info with semantic info are required for:
  - Systematic analysis, archiving, monitoring and management

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## Multispectral processing

- Input **B** **G** **R** **NIR**



- Output



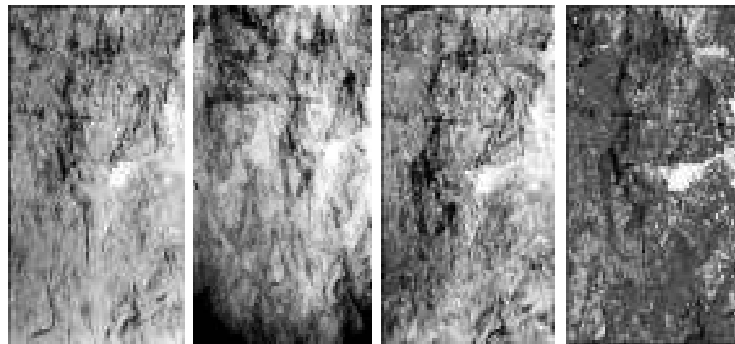
Clase	Precisión de productor	Precisión de usuario
Pilastra	80,32%	86,13%
Pilastra2	75,66%	54,50%
Enfoscado	88,79%	94,68%
Roca	92,71%	87,43%
Madera	70,71%	96,14%

Basilica de la Virgen  
(Valencia)

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## Multispectral processing

- Input
- Output



RGB

NIR

RGB+

Rock Art, Tirig (Castellón)

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## Plans with thorough info

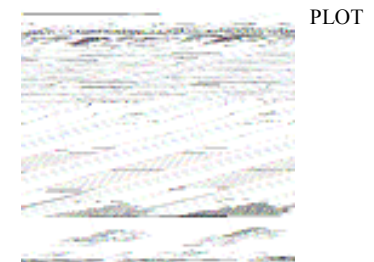


Brickwork façade (UPV)

VIS



IRT

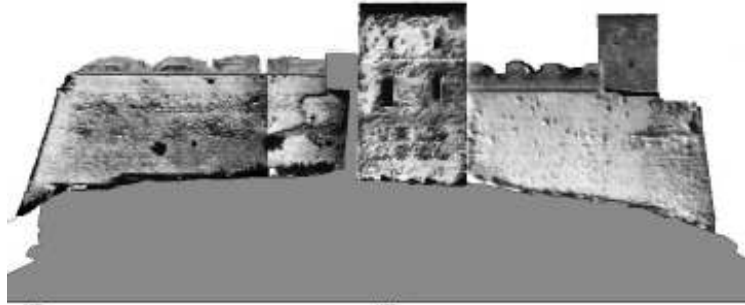


PLOT

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## Plans with multispectral info

Monzon Castle: South (Huesca)



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## Terrestrial laser scanning+Photogrammetry+IRT

- Analysis in 2D/3D

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More info: [gifle.webs.upv.es](http://gifle.webs.upv.es)

Animation

## Conclusions

- Photogrammetry is a well-known technique that offers many possibilities to help conservation experts on cultural heritage:
  - Documentation
  - Mapping
  - Visualization
  - Multimedia products
- It can be used standalone
- There exist simple as well as sophisticated methods
- Nowadays, there is enough easy-to-use software to carry out documentation projects from the scratch
- It can be used in combination of other:
  - Surveying techniques such as a tape, total station, GPS, LIDAR
  - CAD/GIS
  - GPR, thermography... often recommended
- Do not forget the idea of integrating multispectral data as well as other sources of information

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## References

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- Lerma, J.L., *Multiband versus Multispectral Supervised Classification of Architectural Images*. THE PHOTOGRAMMETRIC RECORD, 17(97):89-101, 2001.
- Lerma, J.L., *Fotogrametría Moderna Analítica y Digital*. Universidad Politécnica de Valencia. 550 pag., 2002.
- Manual of Photogrammetry, 5th Edition*. American Society of Photogrammetry and Remote Sensing, 2004.
- Martos, A., Navarro, S., Lerma, J.L., Rodríguez, S., Rodríguez, J. *Orthoware: Software tool for image based architectural photogrammetry*. VSMM 2008 Digital Heritage. Proc. of the 14<sup>th</sup> International Conference on Virtual Systems and Multimedia (Ioannides, M., Addison, A., Georgopoulos, A., Kalisperis, L., Eds.). Full Papers, pp. 32-39, Limassol, Cyprus, 20-25 Oct. 2008.

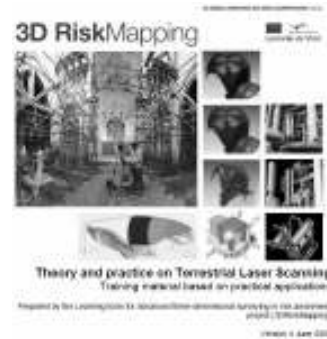
### Webpages:

- CIPA, Heritage Documentation of Cultural Heritage. <http://cipa.icomos.org/>
- ISPRS, International Society for Photogrammetry and Remote Sensing. <http://www.isprs.org>
- Virtual Systems and Multimedia. <http://www.vsmm.net>

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## Terrestrial laser scanning

- Leonardo da Vinci '3D RiskMapping' Project
  - AIM: E-learning material. Free didactic material on TLS
  - **Book (5 languages: English, Spanish, German, Dutch & Romanian):**  
**Theory and practice on Terrestrial Laser Scanning.**  
**Training material based on practical applications**
  - **Data sets**
  - **Movies**
  - **Partners**
    - [KH St Lieven](#)
    - [GlobeZenit](#)
    - [BnS](#)
    - [UPV](#)
    - [BOKU](#)
    - [Delfttech](#)
    - [TU Iasi](#)
    - [PlowmanCraven](#)



Thank you for your attention!!

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