

VSM 2002
25-27 September 2002
Hilton Hotel, Gyeongju, Korea

Virtualizing a Byzantine Crypt by Combining High-resolution Textures with Laser Scanner 3D Data

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Outline

- Introduction
- Project motivation and requirements
- 3D Model building steps
- Results
- Movie: Carpiniana
- Conclusions



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<http://siba2.unile.it>



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SIBA Coordination is the structure of the University of Lecce that co-ordinates, manages and develops the Telematic Information System for Research and Education.

It moreover coordinates the development of the University libraries computerization and of the relations with other national and international Universities and Research Centres for the achievement of information systems and other shared projects.



Digital scan back
(max res. 7520x6000 px)



Instantaneous digital back
(max res. 3000x2000 px)



3D Soisic Mensi Scanner
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For some time now, SIBA Coordination is therefore involved in the development of methodologies for the use of digital technologies within the cultural heritage field by means of the use of innovative technological and computerized systems.



SIBA Laboratories

- Server Laboratory
- Laboratory for the acquisition and processing of bibliographical and documentary information
- Laboratory for the digital acquisition and processing of images
- GIS Lab (Geographic Information Systems)
- 3D Lab (acquisition and processing of three-dimensional images)
- Multimedia Laboratory including an audio-video recording studio
- Didactical laboratory equipped for recording and simultaneous translation

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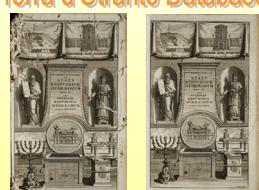
NRC · CNRC

It realized various projects of major national and international interest for the preservation and assessment of the cultural heritage.

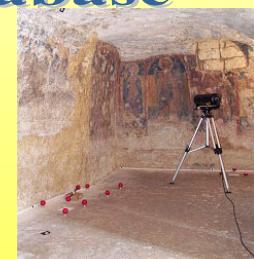
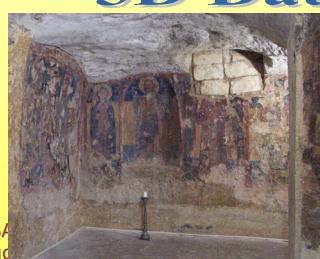
PUL
Papyrological Universitatis Luptensis



TOD
Terra d'Otranto Database



3D Database



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The screenshot shows a Microsoft Internet Explorer window with the following details:

- Title Bar:** Progetto Coordinato Catania - Lecce - Microsoft Internet Explorer
- Address Bar:** Indirizzo: http://siba3.unile.it/ctle/
- Content Area:**
 - S.I.B.A. Logo:** A blue square logo with white text "S.I.B.A.".
 - Page Header:** Coordinamento Servizi Informatici Bibliotecari di Ateneo
Università degli Studi di Lecce
 - Project Logo:** A blue circular logo for the "Progetto Coordinato delle Università di Catania e Lecce". It features the logos of the two universities and the European Union flag.
 - Project Name:** Progetto Coordinato delle Università di Catania e Lecce
 - Logos of Partners:** Logos for Università degli Studi di Catania, Università degli Studi di Lecce, M.U.R.S.T., and Unione Europea F.E.S.R.
 - Navigation:** Buttons for "Presentazione del Progetto" (Presentation of the Project) and "Programma Operativo" (Operational Program).
- Bottom Bar:** Includes the S.I.B.A. logo, the URL "http://siba3.unile.it/ctle/", and logos for NRC and CNRC.

Coordinated project of Catania and Lecce Universities I17,I18,I21

- The project foresees the digital acquisition and processing of bibliographic and documentary information
- Digital reproduction of archaeological objects and finds of particular importance
- Acquisition and processing of images and three-dimensional models and environments, for restoration and virtual reconstruction.



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3D Database Project

Objectives

Digital acquisition, processing, virtual restoration and three-dimensional reconstruction of archaeological finds, architectural structures, sites and objects of high historical and artistic value, as well as the preservation, enhanced knowledge and increased accessibility.



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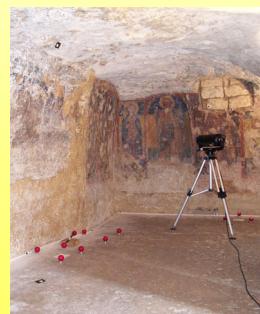


3D Database Project

3D ARCHAEO



3D BYZANTINE



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3D ARCHAEO

Digital acquisition and construction of three-dimensional models of archaeological finds, environments and sites of the Salento Peninsula.

Therefore the creation of several databases, as for instance the 3D **stelae** and **cippus** database and others, concerning in particular the archaeological excavations of Cavallino (LE), is expected.



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3D BYZANTINE

Digital acquisition and construction of three-dimensional models of structures and environments of subterranean and sub divo Byzantine churches of the Salento Peninsula.

3D Crypts

3D Sub Divo



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3D BYZANTINE

Crypts in the Salento Peninsula



Nardò (LE)



Supersano (LE)



Veglie (LE) **NRC · CNRC**

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"3D Database" Project

3D ARCHEO

3D BIZANTINO

3D Sub Divo

3D Crypts

Digital acquisition and reconstruction of three-dimensional models of structures and environments of subterranean and sub divo Byzantine churches of the Salento Peninsula.



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M.I.U.R.



Unione Europea
F.E.S.R.

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3D BIZANTINO: 3D Crypts

Santa Cristina Crypt, Carpignano (Italy):
View of 2 entrances leading to the crypt



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Project Motivation

Site documentation in case of loss or damage

- Complete high-resolution 3D model (shape and appearance) of present state
- The old pillar inside the Crypt is cracked
- Water infiltration from raw sewage is entering the Crypt through the walls.

Virtual tourism & Study

- Interaction without risk of damage
- *Virtual restoration*: frescoes & original setting
- Educational resource

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Project Requirements

Control of the whole modeling process: work can be performed by non-experts

- 3D acquisition & accuracy verification
- 2D camera calibration
- Texture mapping

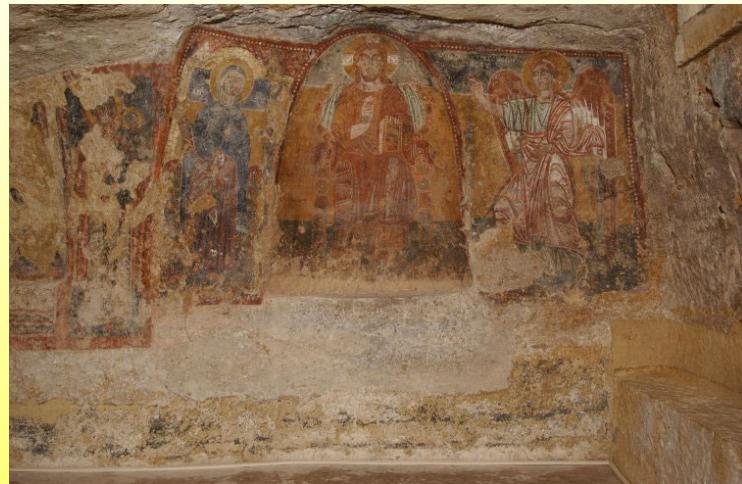
As a user: Practical, Effective & Convivial

- Based on commercial tools
- **High** geometric accuracy and photo-realism
- Images must editable easily without re-doing the texture mapping, e.g. virtual restoration

Some photographs



Some photographs



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From Preparation to Actual Models

- Pick proper techniques: Photogrammetry, Laser scans...
- *Determining standoff distance, uncertainty, resolution!*

$$Z \sim 2.5 \text{ m}, \sigma_z \sim 0.4 \text{ mm}, \Delta x, \Delta y \sim 5 \text{ mm}$$

- Time to acquire 2D images, range images and build the 3D models

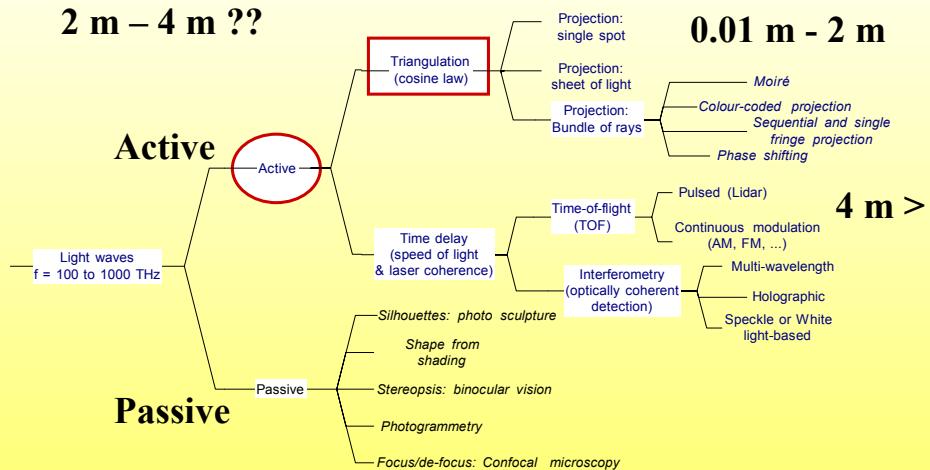
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Measuring 3D shape: Light waves

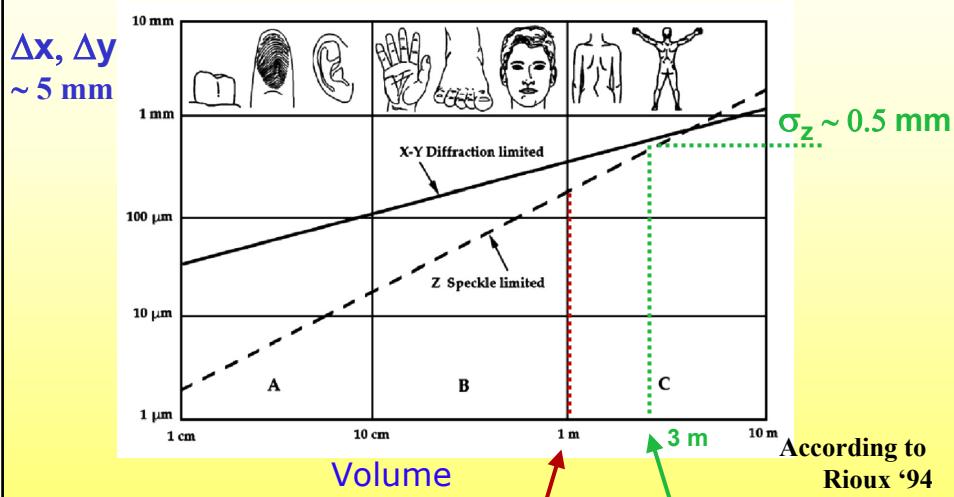
2 m – 4 m ??



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Physical limitations: laser triangulation



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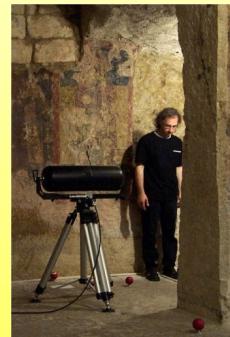


Scanner 3D laser Mensi SOISIC 2000

- ✓ distance range: 0.8 - 10 m
- ✓ uncertainty 0.6 mm at 4 m
- ✓ scanning speed: 100 pt/sec
- ✓ minimal mesh: 0.2 mm per meter
- ✓ field of view (FOV): 46°
- ✓ panoramic FOV: 320°

MENSI

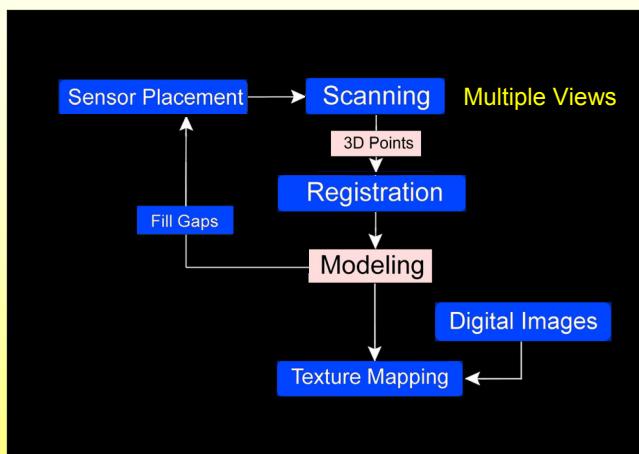
hardware



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Range-Based Modeling



Interactive

Automatic

Registration/ Alignment

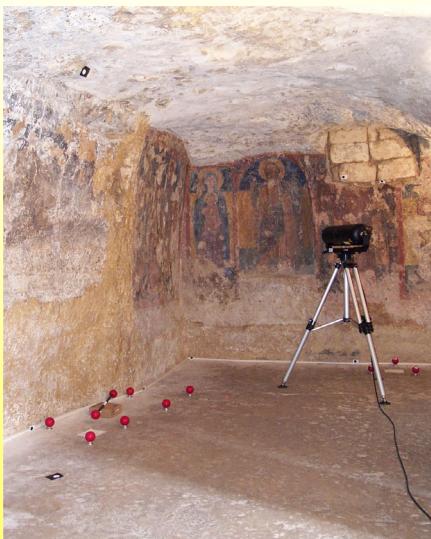
- Spheres
- Actual shape



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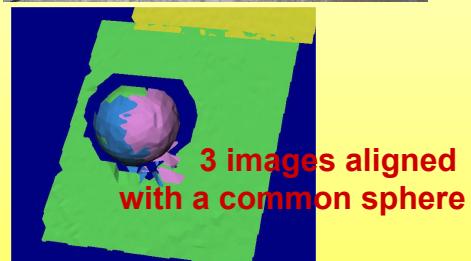


Alignment method with spheres



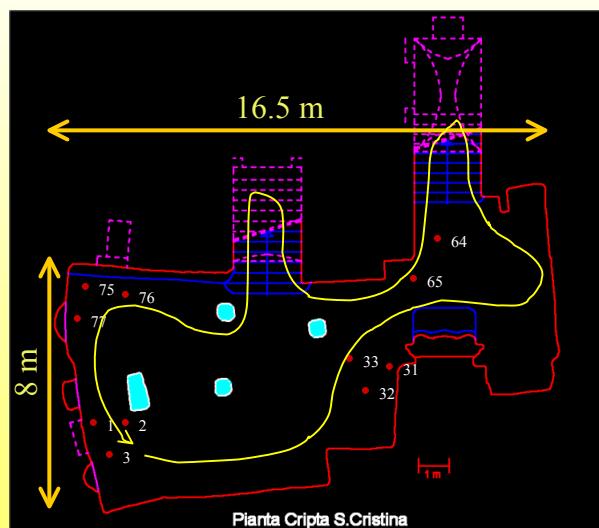
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Scan path



• Some of the spheres

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Registration of 3D images

- Spheres
 - SPHERE 1 (start to finish) : 16.9 mm
 - SPHERE 2 (start to finish) : 16.4 mm
 - SPHERE 3 (start to finish) : 18.2 mm
- Shape data-based (e.g. ICP algorithm)
 - Global integration : 1.2 mm
- Verification of accuracy: on-site

Single-image

$\sigma = 0.8 \text{ mm}$

$\Delta = + 0.2\%$

Whole model

Theodolite-based

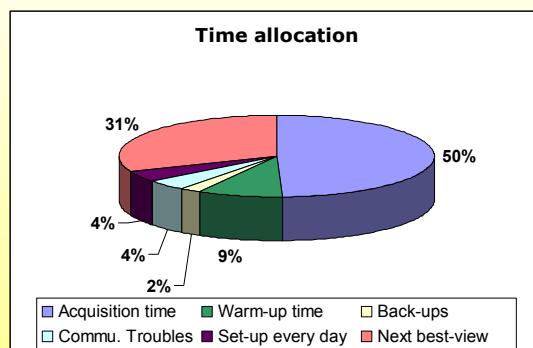
TBD



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Time allocation during scan sessions



Total of 92 hours in the Crypt (20-80 min/image)

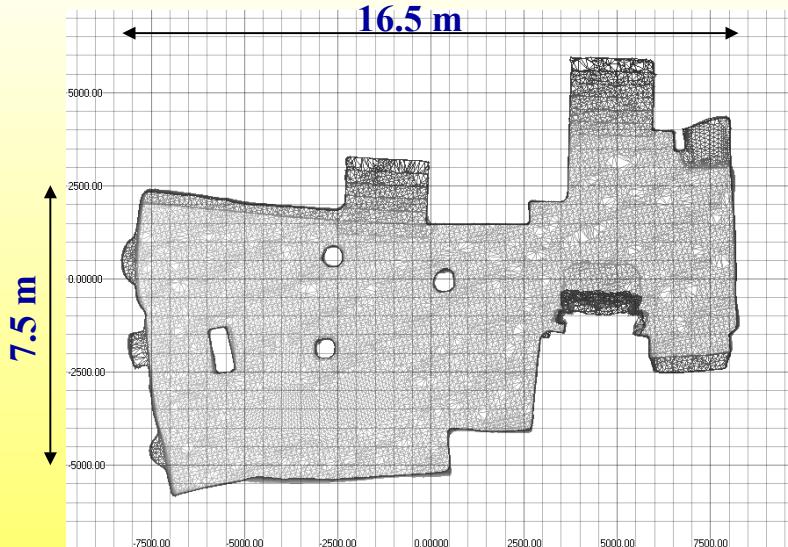
- 50-3D images for the Crypt
- 30-3D images for the altar
- Spatial resolution
 - Walls 5 mm
 - Ceiling & Floor 15 mm
- Uncertainty
 - Evaluated
 - 0.8 mm @ 2.5 m
 - Predicted
 - 0.4 mm @ 2.5 m



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Section of Crypt

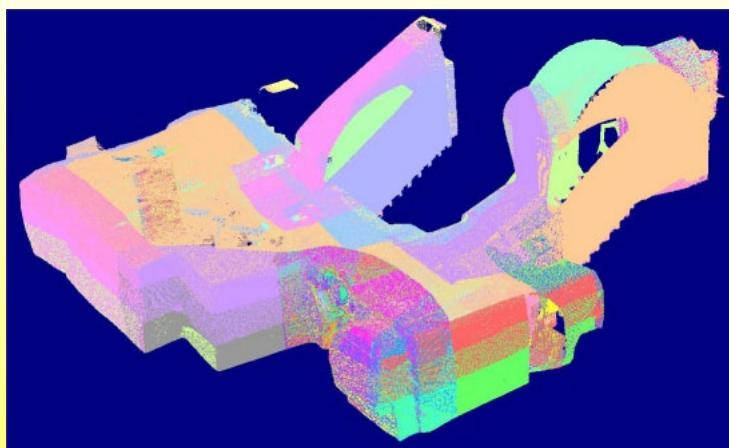


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3D model of Crypt:
1 colour per 3D image

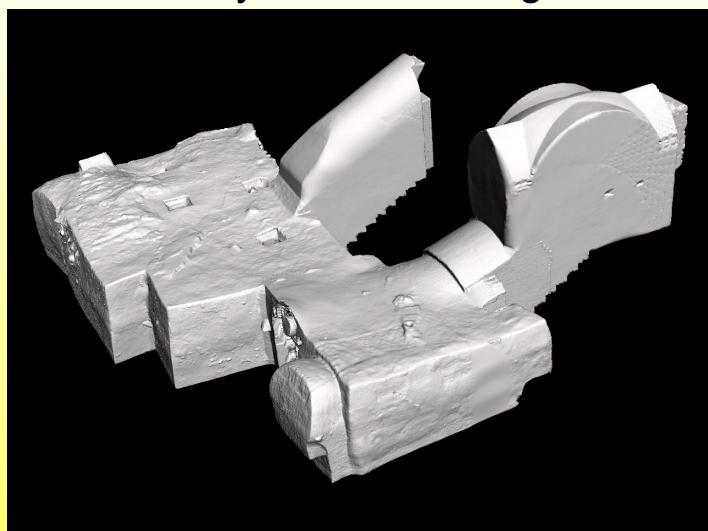


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3D model of Crypt: Synthetic shading



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Texture

- Mensi: exports unorganized clouds of 3D points (no intensity channel)
- Nikon D1x
- Image Resolution: 3008 x 1960
- Lights: Xe



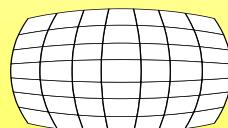
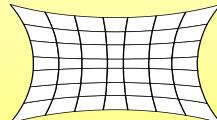
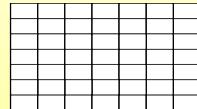
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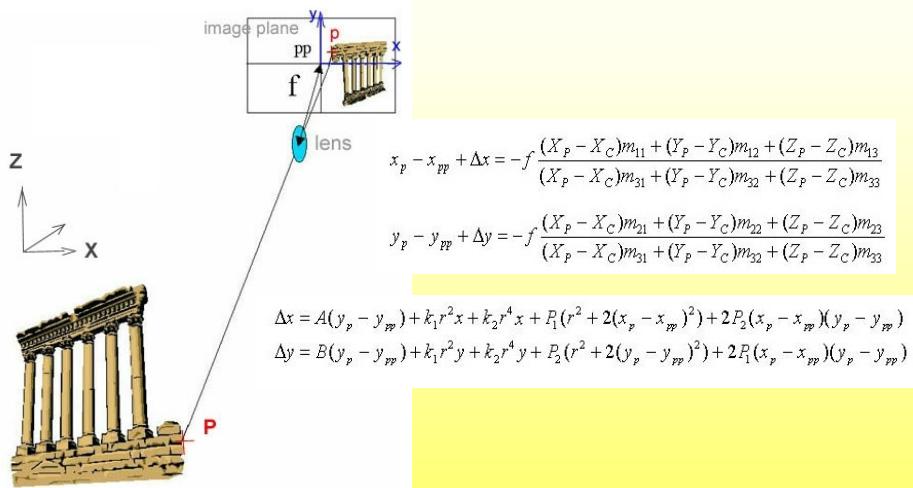
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2D camera calibration: Distortions

- Distortion is a change in magnification as a function of field of view:
- Zero distortion
- Positive or Pincushion distortion
- Negative or Barrel distortion



Complete image formation model



From ShapeCapture

Entrances to the Crypt: Built with photogrammetry



b)

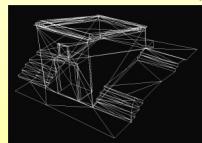


Main entrance:
a) Photograph, b) mesh, c) model with texture.

c)



a)



b)



c)

Second entrance:
a) Photograph, b) mesh, c) model with texture.



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Texture mapping methods

XYZ to XYZ_{ij} XYZ to XYZRGB

• XYZ to XYZ_{ij} XYZ to XYZRGB



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Texture mapping tools

- Use Polyworks (used also for 3D modeling):
 - Import point clouds, triangulate, interpolate
 - Find features in 3D
- ShapeCapture:
 - Camera calibration
 - Pose estimation: 2D image to a 3D section on the model
 - Texture map*
- *New version of ShapeCapture**



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Partitioning of 3D model



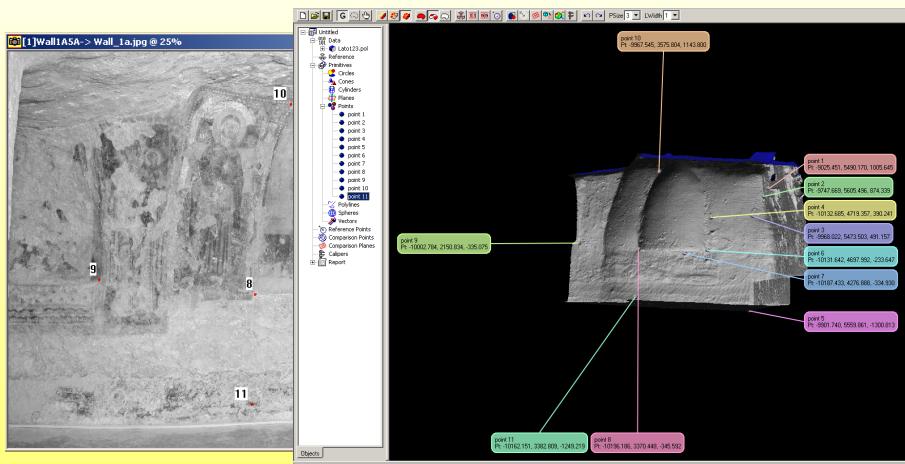
Mapping of B&W, Colour, IR, UV



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Pose estimation

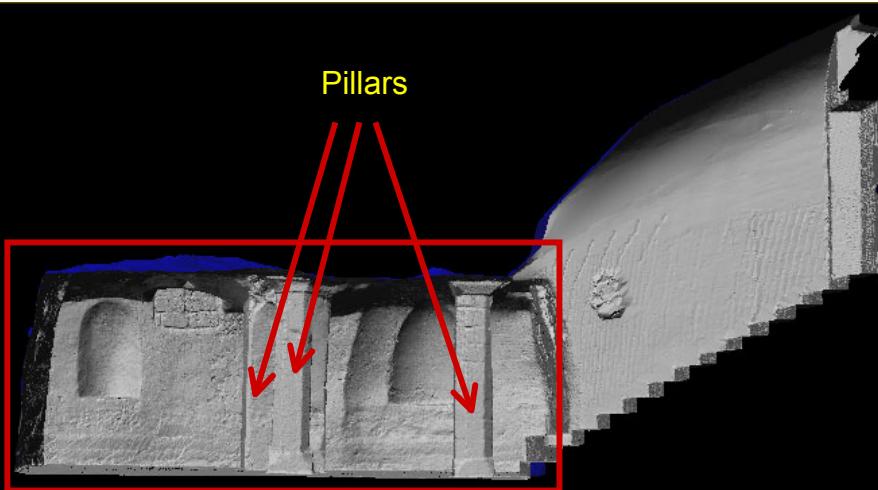


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Cross-section of 3D model



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Orthophoto generated from 3D model



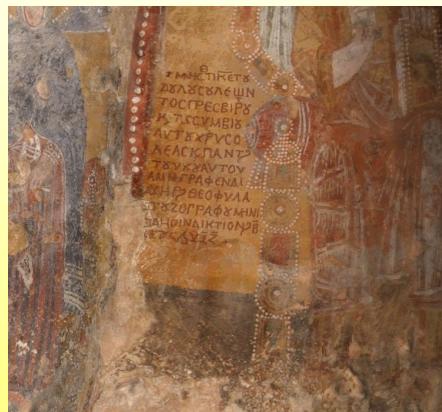
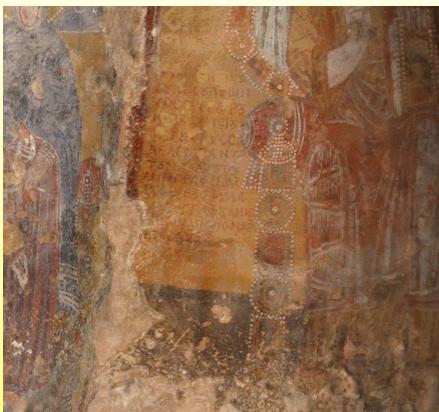
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Example of application: Virtual restoration



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Carpiniana: The Movie



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Conclusion

- Time to acquire a 3D model
 - Predictable with good certainty
- Model building using spheres vs actual 3D data
 - Closure of the model with spheres: 10 mm - 20 mm error
 - Has been improved by using the 3D data (ICP)
 - Global model accuracy will be checked with a theodolite survey
- Texture Mapping with photographs:
 - Very valuable to art historians: virtual restoration, fruition
 - Procedure should allow non-expert to build a 3D model
 - *Method should allow the mapping of other image types*



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