

Virtualizing a Byzantine Crypt: challenge and impact

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Outline

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

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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.

<http://siba2.unile.it>

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Digital scan back
(max res. 7520x6000 px)



Instantaneous digital back
(max res. 3000x2000 px)



3D Scanner Minolta Vivid 900



3D Soisic Mensi Scanner

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



3D Database



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<http://siba3.unile.it/ctle/>

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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 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 Database Project

3D ARCHAEO



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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)

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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 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
- Image editing without re-doing the texture mapping, e.g. virtual restoration

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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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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 (CDROM, DVD, Web)

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Some photographs



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Some photographs



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From Preparation to Actual Models

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

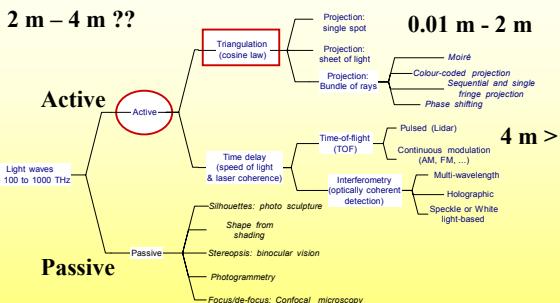
$$Z \sim 2.5 \text{ m}, \sigma_z \sim 0.4 \text{ mm}, \Delta x, \Delta y \sim 5 \text{ mm}$$

- Time to acquire 2D images, range images and build the 3D models
- Scan strategy to make sure of uniform resolution and uncertainty

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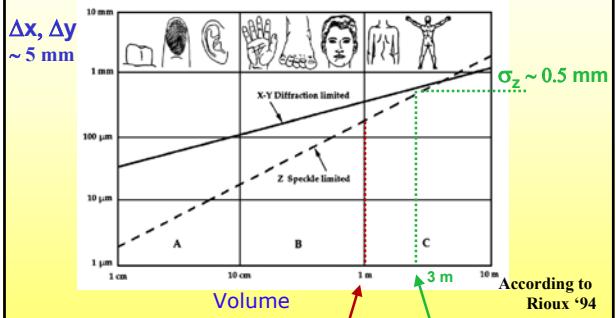
Measuring 3D shape: Light waves



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Physical limitations: laser triangulation



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Scanner 3D laser Mensi SOISIC 2000

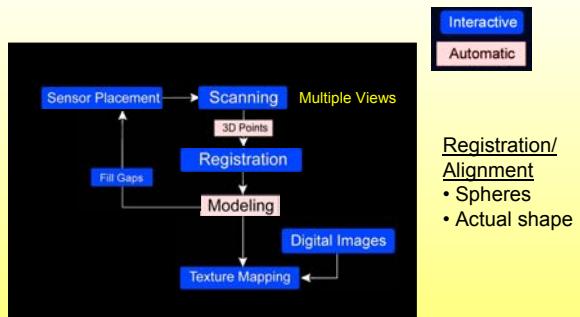
- ✓ distance range: 0.8 - 10 m
- ✓ uncertainty 0.6 mm at 4 m
- ✓ scanning speed: 100 pt/sec
- ✓ minimal mesh: 0.2 mm per meter
- ✓ field of view (FOV): 46°
- ✓ panoramic FOV: 320°



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Range-Based Modeling

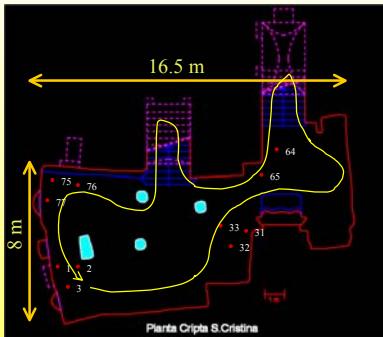


- Registration/ Alignment
- Spheres
 - Actual shape

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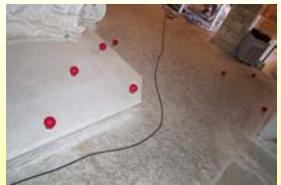
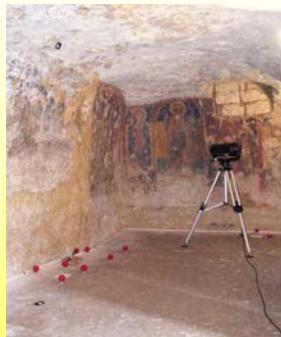
Scan path



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Alignment method based on spheres



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Alignment with spheres: prediction of uncertainty and results



- A simulation gave an average distance between spheres of
 - 750 mm, error < 3 mm
- Results of global alignment: final deviation 1st image to last image
- The larger the triangle base (L), the better!

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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

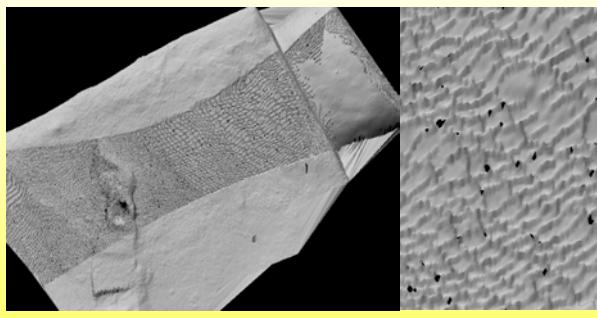
Theodolite-based

TBD

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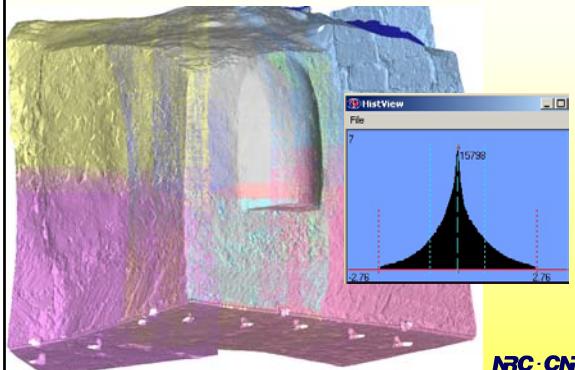
Meshting of 2 range maps when spheres have moved



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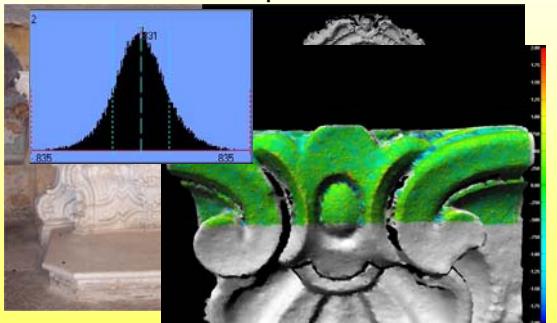
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Alignment error statistics



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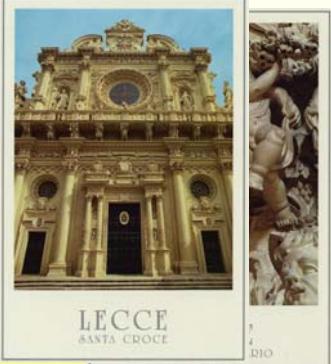
Modeling the Altar: you say Baroque???



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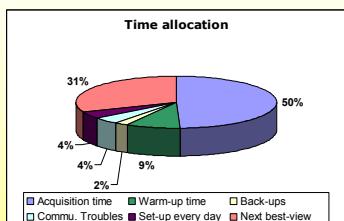
How about this one!



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Time allocation during scan session



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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Texture

- Mensi scanner
 - exports unorganized clouds of 3D points (no intensity channel)
 - Low-resolution on-board video camera
- Nikon D1x
 - Image Resolution: 3008 x 1960
- Lights: Xe



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Texture mapping methods

XYZ to XYZRGB

- Assigns an RGB value for each XYZ value - vertex
- Suitable for Polyworks texture maps
 - Overlap between images soften difference in intensities
 - Transition between 2D images less noticeable
 - But difficult to work with
 - Intensity sampling 1 mm
 - 3D at about 5 mm

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Texture mapping methods

XYZ to XYZRGB



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Texture mapping methods

- **XYZ to XYZIJ**
Assigns an IJ value for each XYZ value
 - Possibility to combine high res Color with low res Geo. Allowing us to use highest acquired res.
 - Textures can be applied to finished 3D model
 - Textures can be reduced in size without any impact
 - Possibility to switch between different textures
 - Virtual restoration
 - Mapping of IR, UV, or other 2D photographs

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Texture mapping methods

XYZ to XYZIJ



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Partitioning of 3D model



Mapping of B&W, Colour, IR, UV

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Partitioning of 3D model



Mapping of B&W, Colour, IR, UV

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3D modeling & Texture mapping

- Use Polyworks™ (3D modeling):
 - Import point clouds, triangulate, align, merge
 - Verify features in 3D
- ShapeCapture™: photogrammetry
- TexCapture™:
 - Camera calibration: 6 distortion parameters
 - Robust pose estimation: 2D image to a 3D section on the model
 - Texture map

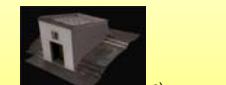
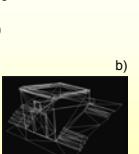
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Entrances to the Crypt: Built with photogrammetry



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



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

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3D models: beyond visualization

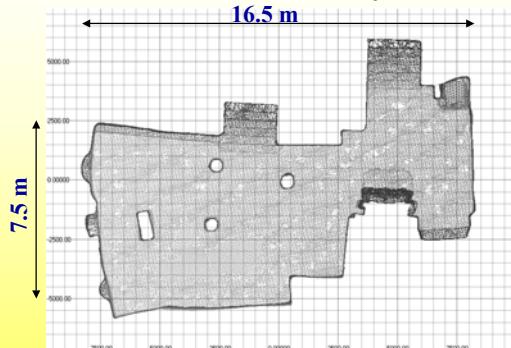
- A 3D model contains a wealth of information that can be analyzed and enhanced.
- The results can be used to enhance the understanding of a site using a multimedia CDROM.



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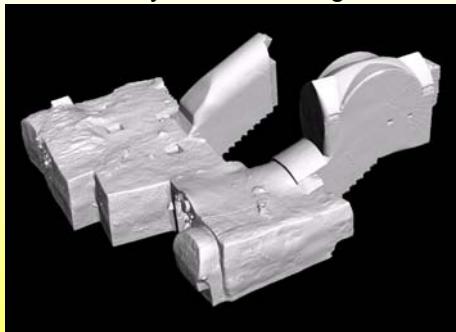
Section of Crypt



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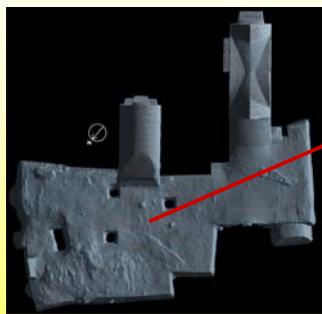
View from the outside rendered using synthetic shading



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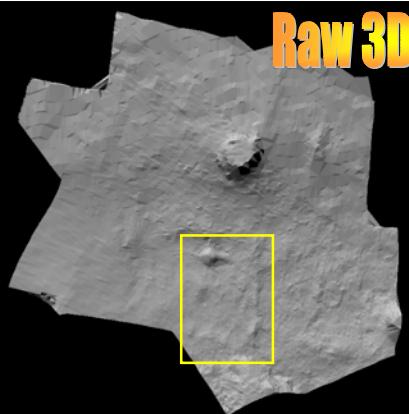
Searching for the lost column



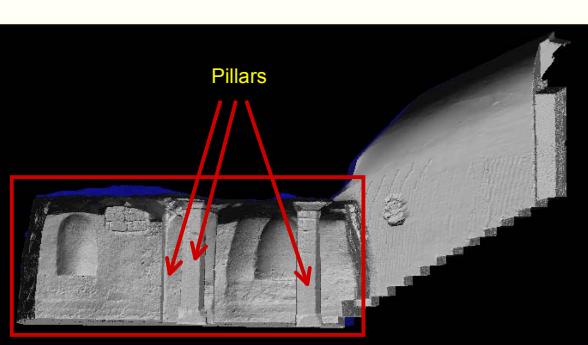
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Raw 3D Data



Cross-section of 3D model



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Orthophoto generated from 3D model



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Virtual restoration



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A screenshot of the Carpiniana website, which is a virtual representation of the Crypt of Santa Cristina in Carpignano Salentino. The page shows a 3D reconstruction of the crypt's interior with frescoes on the walls. Navigation links at the bottom include "the crypt", "location", "history", "site", "frescoes", "virtualization", "movie", "archive", and "exit".

carpiniana
Virtual representation of the Crypt of Santa Cristina in Carpignano Salentino

A VIRTUALIZED BYZANTINE CRYPT

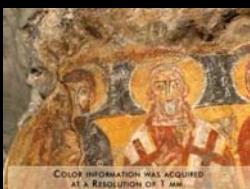
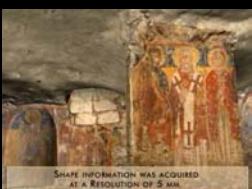


CARPINIANA

COME WITH US
EXPLORE
A BYZANTINE CRYPT
THROUGH
HIGH-RESOLUTION
TEXTURE MAPPED
3D MODELS



ACQUIRED 3D IMAGES WERE ASSEMBLED
INTO A SEAMLESS 3D MODEL



COLOR INFORMATION WAS ACQUIRED
AT A RESOLUTION OF 1 MM

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Conclusion

- Model building
 - Time to acquire a 3D model is predictable
 - Picking a suitable scanner is not easy
 - Global model accuracy must be checked
 - Not all surfaces can be measured
- Texture Mapping with photographs
 - Very valuable to art historians: virtual restoration, fruition
 - Method should allow the mapping of other image types
- Release of the CDROM & Video to the scientific community and to the public followed by a survey will tell us “useful or not!”

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