

International Workshop on
'Scanning for Cultural Heritage Recording –
Complementing or Replacing Photogrammetry'

Corfu, Greece
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Exploring a Byzantine Crypt through a High-Resolution Texture Mapped 3D Model: Combining Range Data and Photogrammetry

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Outline

- Introduction
- Motivation and requirements
- 3D Model building steps
 - Shape acquisition & Accuracy issues
 - Proposed approach for texture mapping
- Conclusions
- Movie: Carpiniana



<http://siba2.unile.it>

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 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

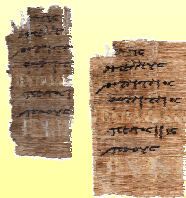
- **Server Laboratory**
- **Laboratory for the acquisition and processing of bibliographical and documentary information**
- **Laboratory for the digital acquisition and processing of images**
- **GIS Lab (Geographic Information Systems)**
- **3D Lab (acquisition and processing of three-dimensional images)**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



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

PUL

papyrologica Universitatis Lupiensis

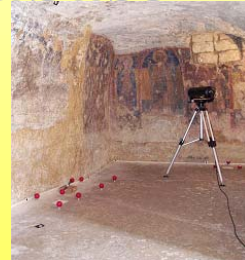


TOD

Terra d'Otranto Database



3D Database





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

Coordinated project of Catania and Lecce Universities

Initiatives 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.

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.

3D Database Project

3D ARCHAEO



3D BYZANTINE



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.

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

3D BYZANTINE

Crypts in the Salento Peninsula



Nardò (LE)



Supersano (LE)



Veglie (LE)

3D BIZANTINO: 3D Crypts

Santa Cristina Crypt, Carpignano (LE): Outside view



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

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 be editable easily without re-doing the texture mapping, e.g. virtual restoration

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

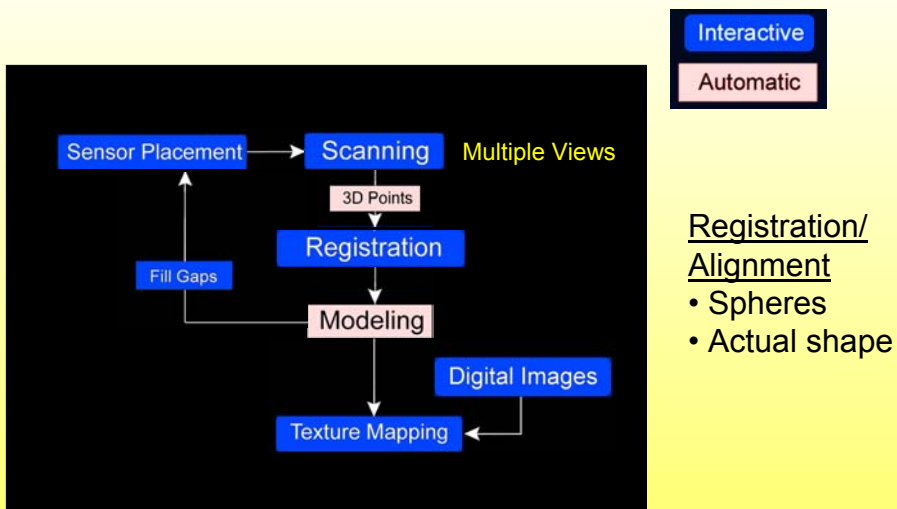
Some photographs



Some photographs



Range-Based Modeling



Scanner 3D laser Mensi SOISIC 2000

- ✓ distance range: 0.8-10 m
- ✓ scanning speed: 100 pt/sec
- ✓ minimal mesh: 0.2 mm per meter
- ✓ Field of view (FOV): 46°
- ✓ Panoramic FOV: 320°

•Scanners for a range between 2 m and 6 m are not readily available!

–This range represents the transition between triangulation and time of flight technologies

MENSI
hardware

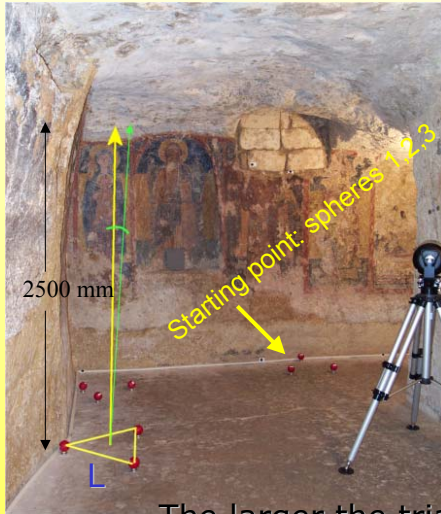


Alignment method with spheres



3 images aligned
with a common sphere

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!

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

$\sigma = 0.8 \text{ mm}$

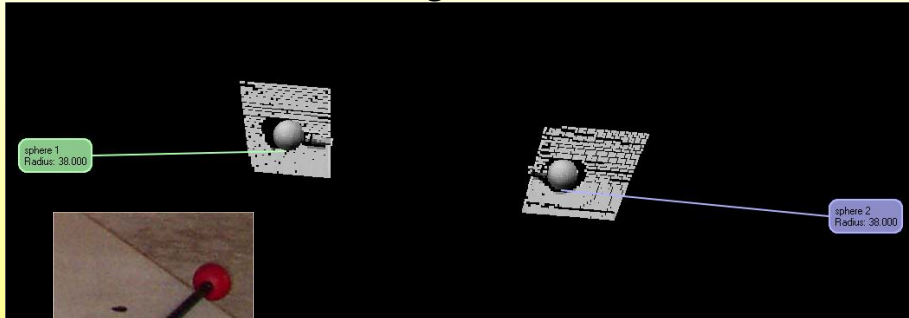
$\Delta = + 0.2\%$

Whole model

Theodolite-based

TBD

Verification of accuracy on-site: Stadia's length 699.3 mm



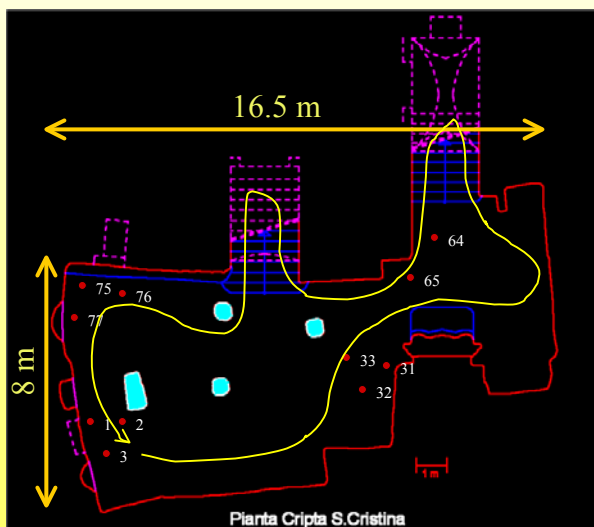
After measurements in 3D images of 12 positions

Average = 700.8 mm (699.3 mm $\pm$?)

s= 0.85 mm

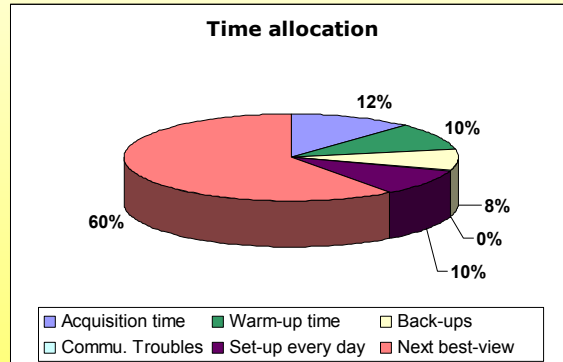
D= + 1.5 mm (+ 0.2%)

Scan path

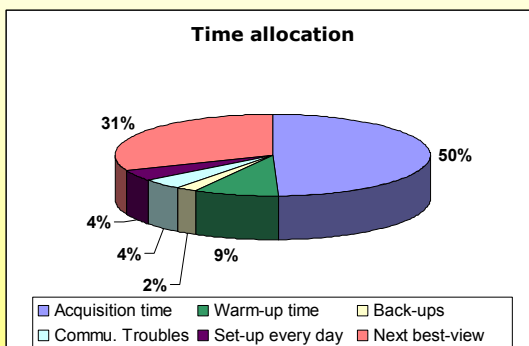


• Some of the spheres

Time allocation using a fast scanner (20X)



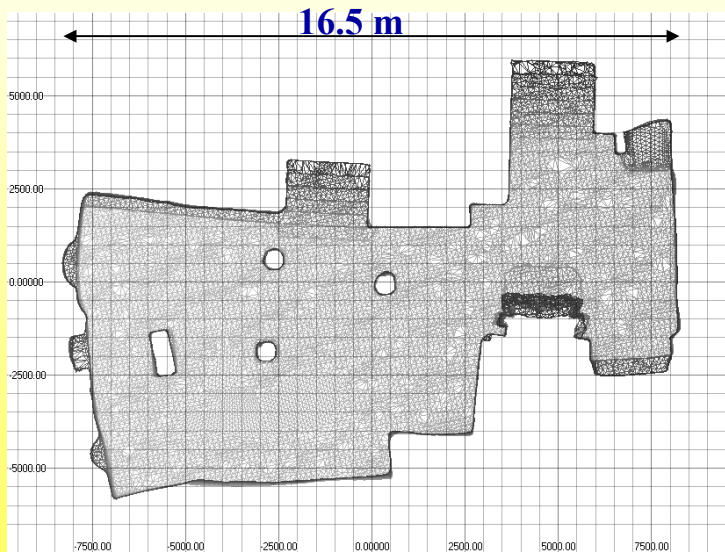
Actual time with current scanner



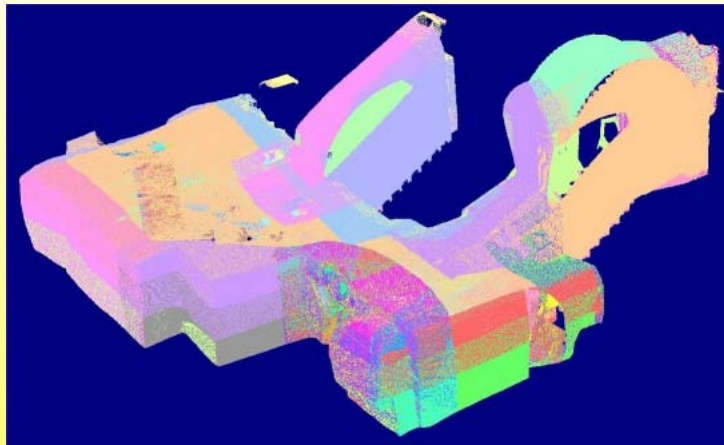
Total of 92 hours in the Crypt

- 50-3D images for the Crypt
- 30-3D images for the altar

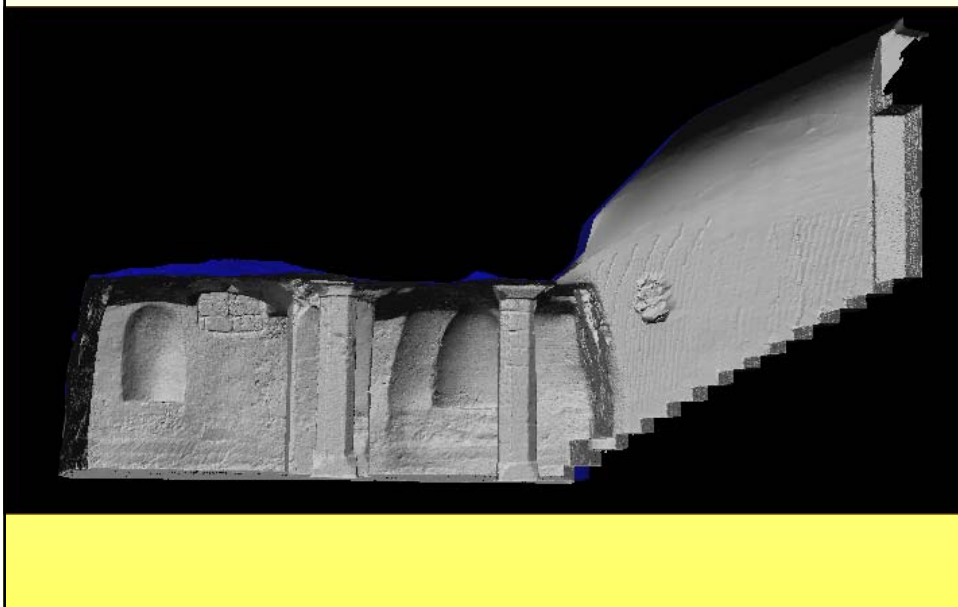
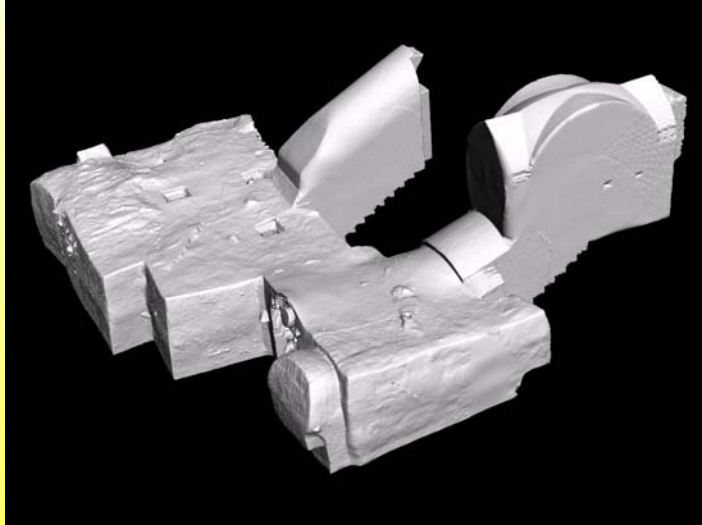
Section of Crypt



3D model of Crypt:
resolution of 10 mm, 1 colour per 3D image



3D model of Crypt: resolution of 10 mm, Shaded



Texture

- Mensi: provides only unorganized clouds of 3D points (no intensity channel)
- Nikon D1x
- Image Resolution: 3008x1960
- Lights: Xe



Texture mapping methods

- We have tested 2 methods
 - Both methods uses the same calibration and pose estimation to project the 3D data onto the 2D image
- First method: XYZ to XYZRGB
 - In this method we assign an RGB value for each XYZ value - vertex (The RGB value assigned is the closest to the projected XYZ value)
- Second method: XYZ to XYZIJ
 - In this method we assign an IJ value for each XYZ value (IJ values being normalized coordinates in our 2D image)

Advantages of each method

- XYZ to XYZRGB
 - Suitable for Polyworks texture maps
 - Overlap between images soften difference in intensities
 - Transition between 2D images less noticeable
- XYZ to XYZIJ
 - 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
 - Compatible with current compression practices including hardware, software, format (JPG)
 - Textures can be reduced in size without any impact
 - Possibility to switch between different textures
 - ex: As is Virtual restoration

Texture mapping tools

- Use Polyworks:
 - Import point clouds, triangulate, interpolate
 - Find features in 3D
- ShapeCapture:
 - Calibration
 - Pose estimation
 - Texture map*

* In new version

Partitioning of 3D model



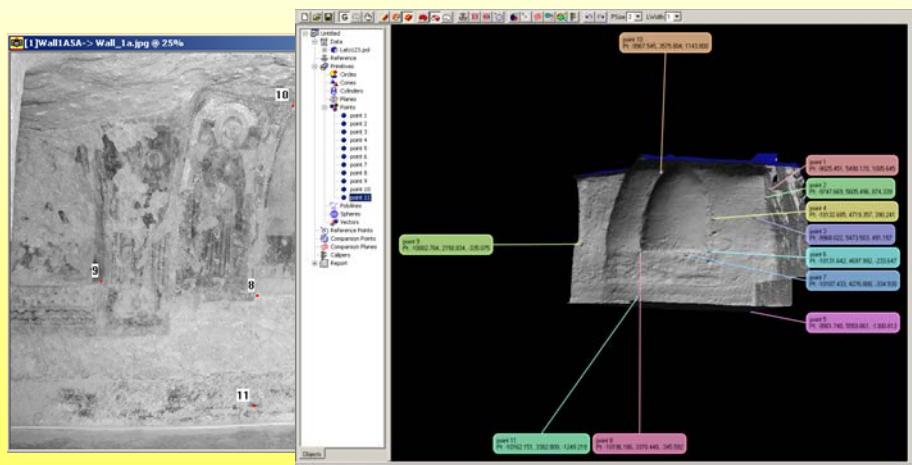
Partitioning of 3D model



Partitioning of 3D model



Pose estimation



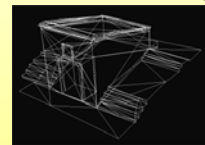
Virtual restoration



Outside of Crypt: Built with photogrammetry



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



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

see El-Hakim
same workshop

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*

Movie

A Virtualized Byzantine Crypt Carpiniana

Produced by
SIBA Coordination
University of Lecce
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