3D MODELING OF CLOSE-RANGE OBJECTS: PHOTOGRAMMETRY OR LASER SCANNING?

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Introduction

- **Photogrammetry** is a well proved and reliable technique for 3D object reconstruction
- Advantages: easy to use, very portable surveying system, analog or digital imagery, wide availability of commercial processing/modeling software
- Disadvantages: camera calibration, time consuming (semi-automated) measurements, image resolution

- **Laser scanning** technology as promising alternative for many kind of surveying/modeling applications
- Advantages: fast acquisition of a huge amount of 3D data, recording of intensity (gray values) and color data (digital images), high LOD of the data combined with quite good metric accuracy (depending on the used instrument)
- Disadvantages: data handling, registration, modeling, edges, noise

Motivations & Goals

- 3D models are used/required for Cultural Heritage documentation & visualization, restoration projects, generation of VR environments, etc.
- Some works presented the integration of range and image data, but few good/reliable methods/approaches are available
- Only few works addressed the metric and geometric accuracy of 3D models. More interest towards texturing and viewing quality of generated models

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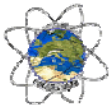
Compare *range data* and *image-based* approach for the assessment of the geometric accuracy



Compare *range data* and *image-based* approach concerning the correct modeling of object's details

Case Studies

Case Studies - 1

1. Ancient church of Pozzoveggiani, located in the sourrounding of Padua (Italy)

- Little church with simple geometry
- Only the outside was surveyed
- Dimensions: 7m x 16m (planar), 8m - 17m (height)

LEICA HDS 2500 laser scanner (former Cyrax 2500)
- Accuracy: 4mm @ 50m
- Range: 1m to 150m
- FOV= 40° H x 40° V
- no rotating head

Nikon COOLPIX 5700
- 5 Megapixels, 2/3" CCD sensor size
- Images resolution: 1024 x 768
- 8.6 μm pixel size

Goal: assesment of geometric accuracy

Image-based approach

- 22 images used, 1024 x 768 image size, 8.6 μm pixel size, ca 0.9 cm foot print

- Automated tie points extraction (ca 200), using interest operator, LSM, epipolar geometry between two/three images

Image-based approach

- 22 images used, 1024 x 768 image size, 8.6 μm pixel size, ca 0.9 cm foot print

- EOP approximations with space resection and GCPs (Leica TCR 705 Total Station, accuracy of about 5 mm)
- Self-calibrating bundle-adjustment with 29 GCPs

  (not all the APs recovered, due to unfair network geometry)

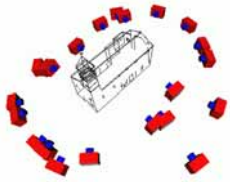
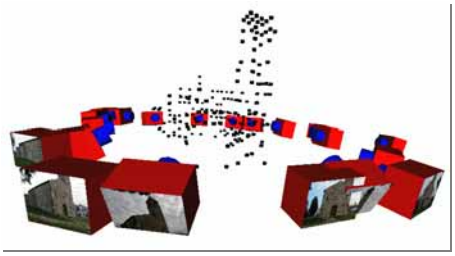
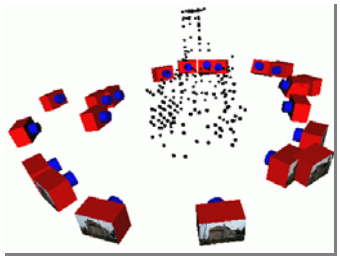


Image-based approach



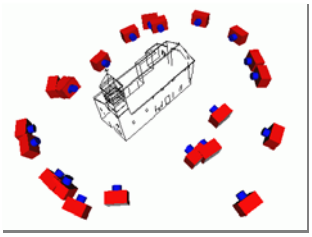
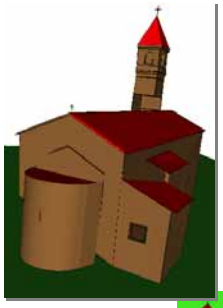


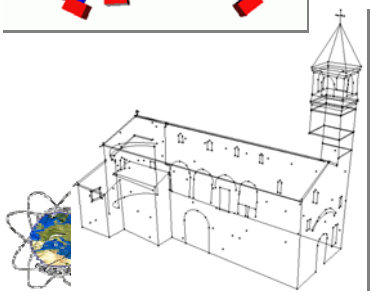
- Theoretical precision of object coordinates: 0.017 m, 0.027 m, 0.022 m
- Accuracy analysis performed using with some check points

Analysis with respect to	Numb.	RMSE X [m]	RMSE Y [m]	RMSE Z [m]
Control points	29	0.006	0.009	0.006
Check points	21	0.030	0.048	0.024

Image-based approach

- The extracted tie points were then manually linked each other, defining edges, curves and surfaces in order to recover the 3D geometry of the object.
- Texture was then projected knowing the camera parameters



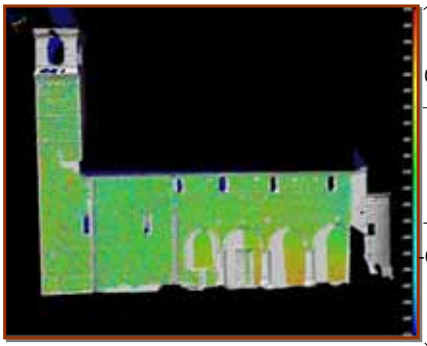
Laser scanner approach

- The church was surveyed with 23 scans (no rotating head)
- Scan resolution was set to 0.7 cm at about 5m distance
- Global data set: about 11 000 000 points.
- Range data registration/alignment performed within Polyworks (ICP)

All the scans were globally registered with a residual error of 4.3 mm (i.e. the measurement sensor's error)

- Point cloud decimated (8 900 000 pts)

- Georeferencing with 3D similarity transformation (8 GCPs)



Laser scanner approach

- Most of measured points were located on corners or edges, critical features for laser scanning (laser beam ripple)

LASER SCANNER	Numb.	RMSE X [m]	RMSE Y [m]	RMSE Z [m]
Check points	50	0.043	0.047	0.033

PHOTOGRAMMETRY	Numb.	RMSE X [m]	RMSE Y [m]	RMSE Z [m]
Check points	21	0.030	0.048	0.024

Case Studies - 2

2. Small buddha statue

- Material: wooden
- Dimensions: 30x40x20 cm
- Many small details, approximately 2 cm width

NRC/BIRIS laser scanner
- Triangulation principle
- System suited for C.R. applications
- Accuracy: 50μm @ 20-40 cm

Leica DIGILUX 1
- 4 Megapixels, 1/1.76" CCD sensor size
- Images resolution: 2240 x 1680 (3.4 μm pixel size)

Goal: compare 3D modeling results

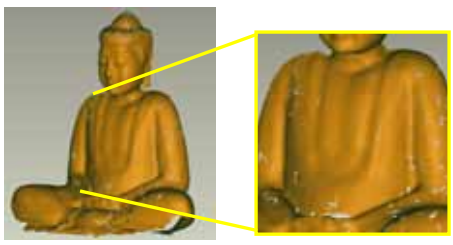
Image-based approach

- 5 images (in front of the object) are used
- Testfield in the background is used to facilitate the image orientation
- Pre-calibrated camera
- Block adjustment for EOP

- Surface measurement with automated LSM program (Viewtripletgtk, N.D'Apuzzo, ETHZ)
- 2 image triplets => dense set of correspondences (ca 95 000 and 94 000 points)

Image-based approach

- 3D point cloud obtained with forward intersection (smoothed results)

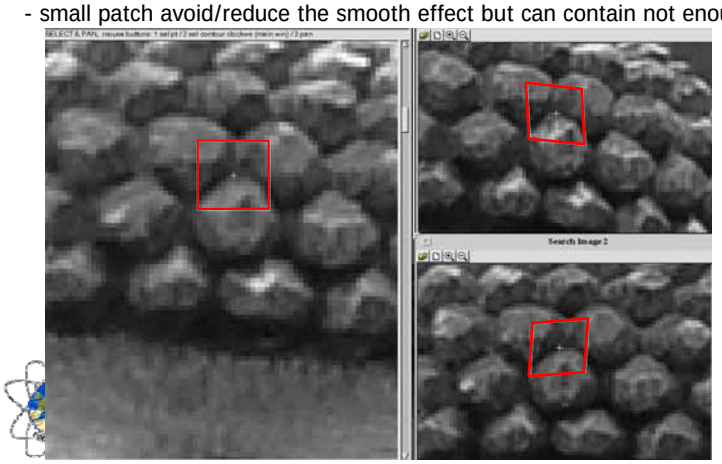


Small details are not modeled

Image-based approach

Surface measurement with Least Squares Matching:

- holes due to lack of texture
- smoothing effects with automated procedure
- patches are assumed to be planar (often it is not the case)
- smaller patches *vs* bigger patches
- small patch avoid/reduce the smooth effect but can contain not enough signal content



Laser scanner approach

- BIRIS: 700 vertical profiles with 256 pts/profile
- 54 scans performed

- Point clouds registration and surface generation within Geomagic Studio (ICP)

Shaded points

Shaded surface

Conclusions & Comparisons: CASE STUDY 1

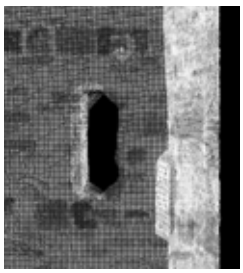
- Image-based approach (photogrammetry) has slightly better accuracy in the reconstruction of the architectural object

LASER SCANNER	RMSE X [m]	RMSE Y [m]	RMSE Z [m]
Check points	0.043	0.047	0.033

PHOTOGRAMMETRY	RMSE X [m]	RMSE Y [m]	RMSE Z [m]
Check points	0.030	0.048	0.024

- Precise model comparison should be performed using the same check points. How to select the same check points?

Conclusions



Some noise (ripple) on edges along the 3D range data

Despite the not-high resolution of the images, the edges and corner are quite well visible/identificable

Conclusions: CASE STUDY 1

- Image-based approach (photogrammetry) has slightly better accuracy in the reconstruction of an architectural object

LASER SCANNER	RMSE X [m]	RMSE Y [m]	RMSE Z [m]
Check points	0.043	0.047	0.033

PHOTOGRAMMETRY	RMSE X [m]	RMSE Y [m]	RMSE Z [m]
Check points	0.030	0.048	0.024

- Precise model comparison should be performed using the same check points. How to select the same check points?
- Possible solutions: higher scan resolution and use of artificial targets, in order to help for the point recognition
- Common problem (concerning the full object modeling): missing of data (roof, lower corners, etc.)

Conclusions: CASE STUDY 1

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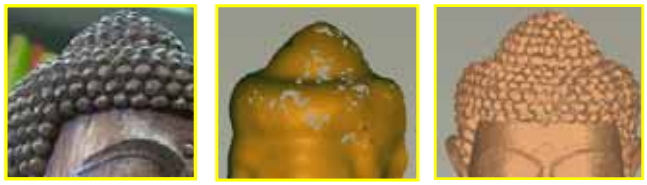
Modeling time (image/data acquisition, processing, modeling, texturing):

Photogrammetry: 10 hours (22 images)

Laser Scanner: 7-8 hours (23 scans)

Conclusions: CASE STUDY 2

- Laser scanner could model more precisely the small details smoothed out in the image-based approach



- Photogrammetry => problems in the correct and accurate measurement and reconstruction of small features / absence of good texture, but potentialy able
- Possible solutions: higher image resolution / patter projection
  manual measurements (time consuming), advanced matching

Conclusions

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- Image-based approach & laser scanning are not competitive but rather complementary. The former is most suited when higher (geometric) accuracy is required, while laser scanner is useful when higher LOD is required
- Combination of the method allows good results
- Selection of the measurement / reconstruction system depends on many factors (BUDGET, processing time, object availability, object shape, application, ...)
- In both approaches the modeling part (from 3D point cloud to surface) is still the most problematic and time consuming

THANK YOU FOR YOUR ATTENTION !