Prof. Dr. Harald Sternberg

New Technologies in old sciences: Mapping & Archaeology

Nuevas Tecnologías de Adquisición de datos

New Technologies for data acquisition

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Topics

- Introduction: development of laser scanner systems
- measuring methods and und systems
- accuracy / reflectivity
- data handling
- ***BREAK***
- applications: Deformation Measurements
- conclusions
- ***Outlook:***
- Tuesday: scanning with the IMAGER 5006
- Wednesday & Thursday: registration / modeling

Tacheometer

New Tacheometer are:

motorized

Automatic target recognition (ATR)

Automatic target (LOCK)

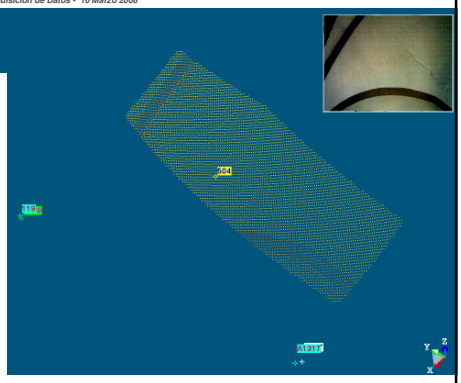
PowerSearch and remote control (robotic mode)

Direct reflex measurement (up to 300 m)

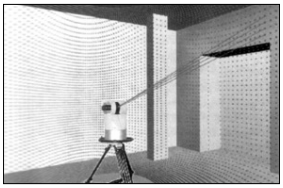
(like Leica TCRP1201-R300,

or Trimble S6 or Trimble VX station)

➔ Scanning of objects



Scanning



three-dimensional capturing of objects with laser distance measurements distributed as grid

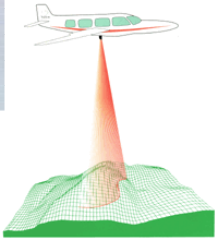
With tacheometer only discret points

With scanner: grid points

Line-scanner

Line-Scanner (Sick LMS 200)

Scan angle : 180°
Angle increment : 1°
frequency : 75 Hz

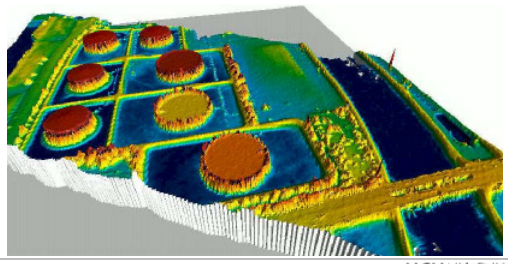


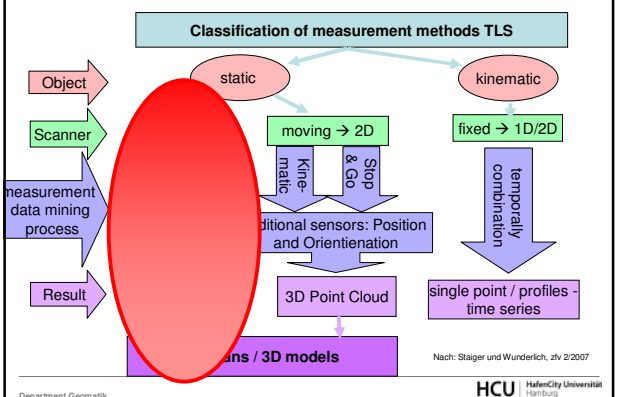
Airborne laserscanning

Distance measurement with pulse
+ Reflectivity
σ < 5mm
Quality control of pieces

development

- *Airborne Laserscanning*
  (third dimension from movement of the airplane)





Nach: Staiger und Wunderlich, zfv 2/2007

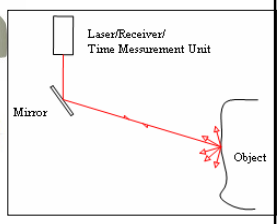
Pulse measurement (time-of-flight)

- Distance calculated from time of light pulse
- measurement of long distances
- Standard deviation of few mm

- CYRAX 2500 / Leica HDS ScanStation2

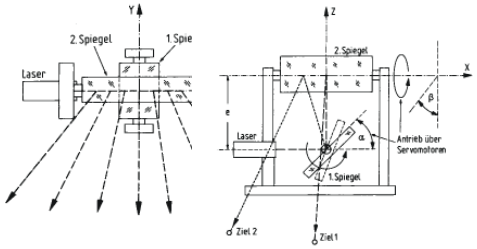
- Mensi GS100/200/GX

- Riegl LMS-Zxxx



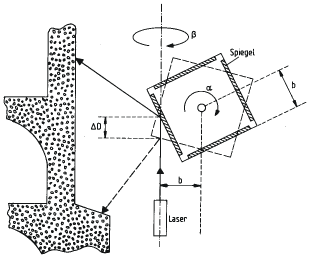
Pulse measurement (time-of-flight)

- laser beam in the CYRAX 2500 (2 rotating mirrors)



Pulse measurement (time-of-flight)

- laser beam in RIEGL system (1 rotating mirror)



Phase difference

- *More accurate as pulse*
- *Reduced distance*
- *Measure with higher frequency*
- *Standard deviation about 1 mm*

- IMAGER 5003 / 5006 (Zoller & Fröhlich)
- iQsun880 / FARO
- Callidus CPW 8000
- Trimble FX



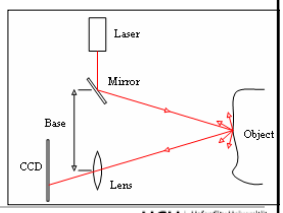



With Triangulation methods

- *known (fixed) base and measurement of the outgoing and incoming angle*
- *Only for short distances and small objects*
- *Standard deviation below 0.5 mm in a distance of less than 2 m*
- *single or double cameras*

- MENSI S10 and S25
- Minolta VI - 910

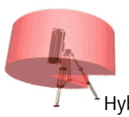




Scan angle

Camera-View

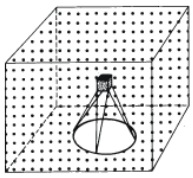
Panorama - View



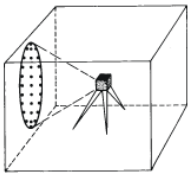

Hybrid : 40°x 320°

Scan Angle

Panorama - View



Camera-View



Systems

System	method	accuracy	frequency	distance	Scan angle
MENSi S10	Trian-gulation	0.4 mm	100 Pkte / sec	10 m	40 x 320 gon
Minolta VI -910	Trian-gulation	**0.1 mm**	120000 Pkte / sec	2,5 m	12,5 x 12,5 gon
Z&F IMAGER 5003	Phase difference	3 mm	**625000 Pkte /sec**	53,6 m	400 x 344.4 gon
MENSI GS100	pulse	6 mm	5000 Pkte / sec	100 m (200 m)	400 x 60.7 gon
CYRAX 2500	pulse	4 mm	1000 Pkte /sec	100 m	44.4 x 44.4 gon
Riegl LMS-Z420	pulse	10 - 15 mm	6000 Pkte / sec	**Max. 800 m**	88.9 x 377.8 gon

Accuracy depends on:

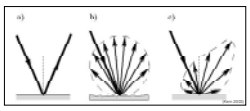
distance

reflectivity of the object

Spot size (0.6 mm / 10 m – 6 mm / 10 m)

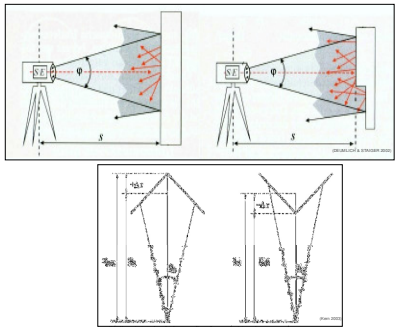
grid space (0.03mm / 10 m – 7 mm / 10 m)

Reflections

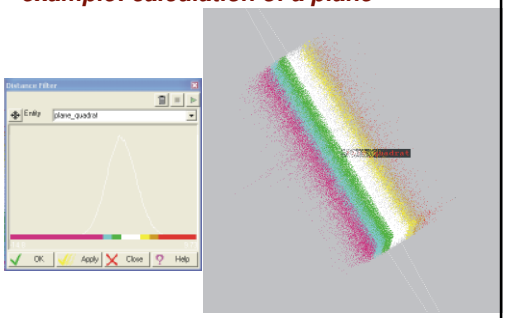


a) Reflection as mirror
b) diffuse Reflexion
c) combined reflection

- **Divergence of laser beam**



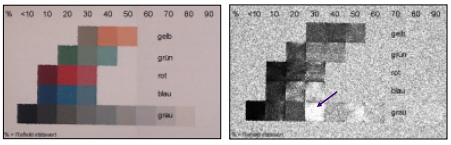
example: calculation of a plane



example: calculation of a plane

	Punkte	s0[mm]	Pkte/sec
GS100	460.000 / 3.000 / 120	5,8	5000
Imager 5003	~100.000	1,0	650000
TCRA1105+	143	0,4	0,4

Defined colors



True-color

Intensity

intensity

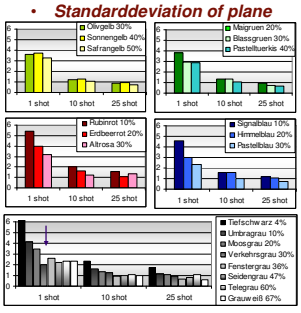
Tiefschwarz 4%	11
Rubinrot 10%	30
Signalblau 10%	51
Umbragrau 10%	66
Erdbeerrot 20%	68

Telegrau 60%	203
Grauweiß 67%	206
Pastellblau 30%	213
Seidengrau 50%	226
Verkehrsgrau 30%	250

black, red, blue, grey, red

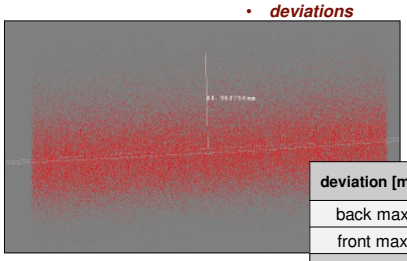
colors

- **Standarddeviation of plane**



Colored paper

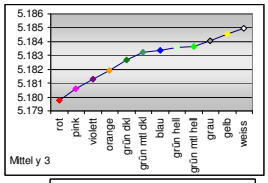
- *deviations*

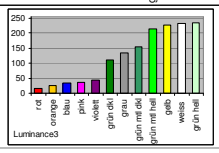


deviation [mm]	Red	Blue	Green
back max.	48	30	19
front max.	46	23	14	
back ca.	-	13	12
front ca.	-	10	8

Colored paper

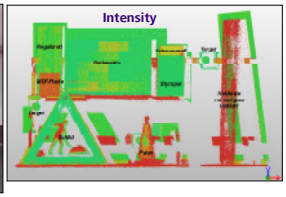
- Differences between the planes





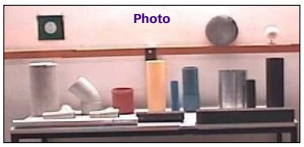
Diff to white [mm]	(10mm/1shot)
Yellow	-0
grey	-1
green_middle_bright	-1
green_bright	-1
blue	-2
green_middle_dark	-2
green_dark	-2
orange	-3
magenta_dark	-4
magenta_bright	-4
red	-5

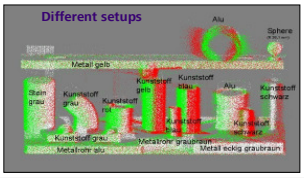
materials



- *high distribution and standard deviation*
- *white area not captured (whole in point cloud)*

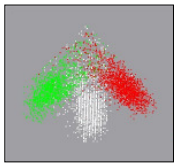
Geometries

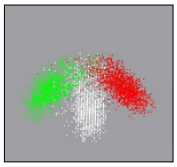




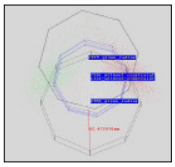
Geometries : cylinder

- *Differences from best-fit-Radii to true value : ± 1mm bis ± 3mm*
- *black plastic cylinder: - 13 mm*



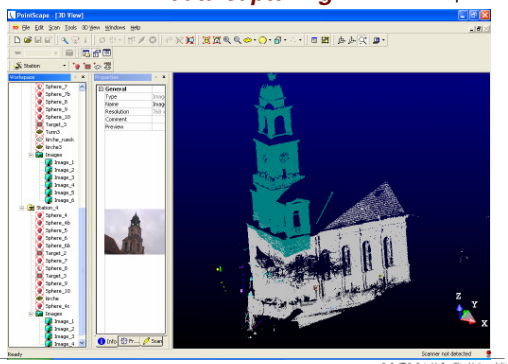


Point clouds from different scanner positions



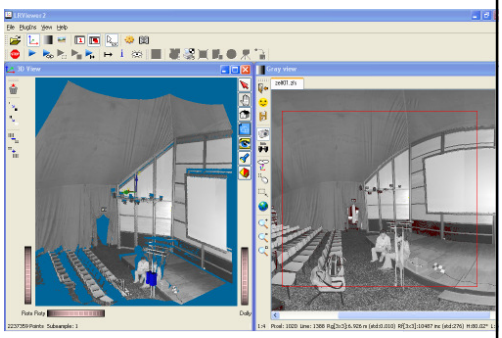
Best fit cylinder

data capturing PointScape

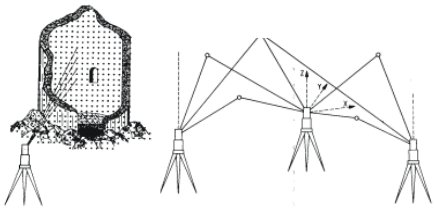


data capturing

Z&F



Registration



- ***Combinations of the scans with identical points (signaled)***

Trimble - sphere

Leica - target

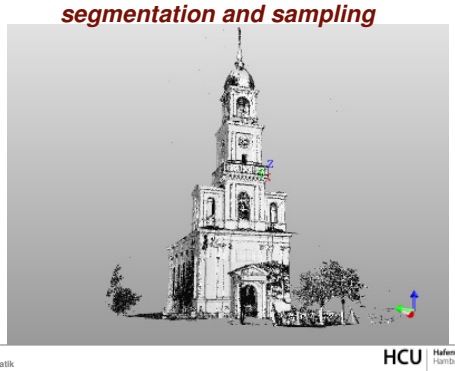
Z&F

FARO

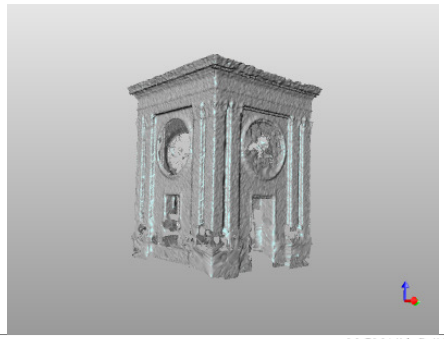
paper-target

Registration (RealWorks)

Simple processing / segmentation and sampling



simple processing / mesh

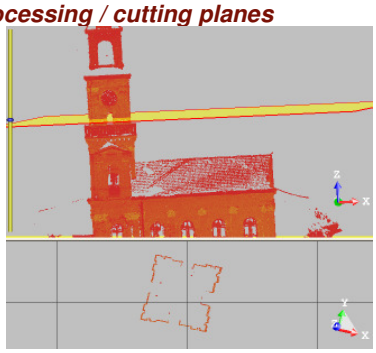


Simple processing / cutting planes

Single or multiple slices

Thickness
and interval,

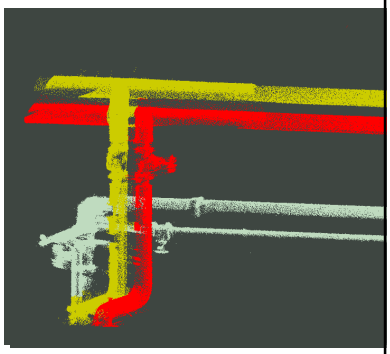
polyline generation



modelling

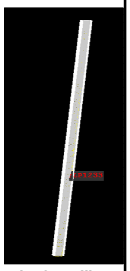
- *3D IPSOS*

Pipes and tubes
(semi-automatical)

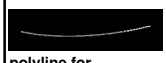


modelling

- Visualisation of objects in the model
- discription of the objects
  - position
  - attitude
  - form
- Use of elements:
  - geometrical primitives

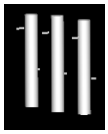


H-carrier from library



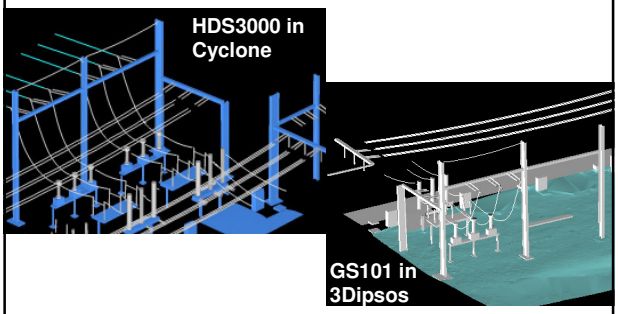
polyline for
electric power line

box for baseplate

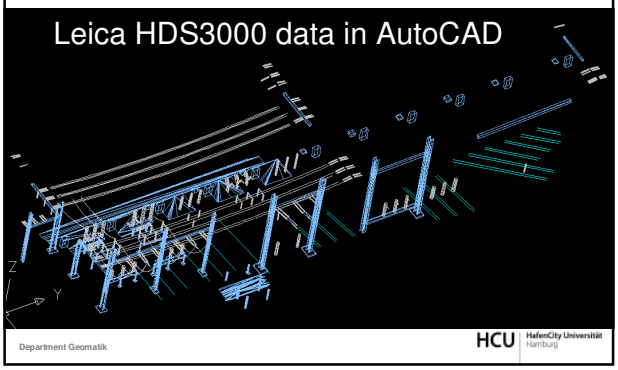


cylinder for isolators

Generated 3D model

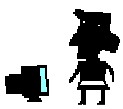


Result of modelling (22-26 hours)



- Break

- Applications



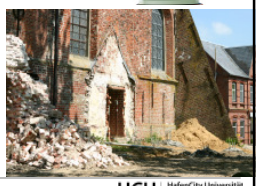
Deformation measurements at historical buildings with the help of three-dimensional recording methods and two-dimensional surface evaluations

- Classical Deformation Measurements
- The terrestrial 3D laser scanning systems
  - Hard- and Software
- Old Church Pellworm – As built documentation
- St. Johannis Cathedral Meldorf –
  - Recording of the present state
  - Deformation measurements

Classical Deformation Measurements

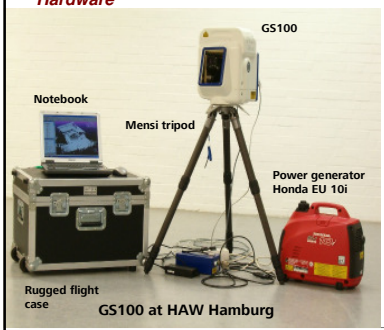
- Only discrete signaled points
- Distributed uniformly as grid
- or attached at selected locations
- Standard deviation of 3 D position at 1...2 mm

- Only movement of selected points - not entire building
- Measuring the movements of the cover around the church



The terrestrial 3D laser scanning systems

Hardware



The terrestrial 3D laser scanning systems

Technical specifications

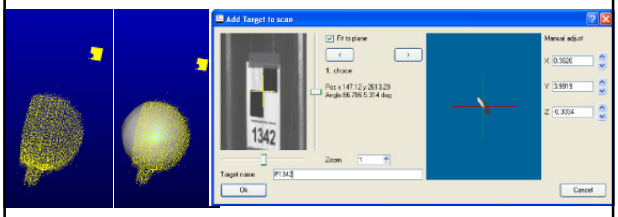

	Mensi GS100	IMAGER 5003
Metrology method	pulsed time of flight	phase differences
Field of view	360° horizon., 60° vertical	360° horizon., 310° vertical
Optimal scan distance	2 – 100 m	2 – 53.5 m
Scanning speed	up to 5000 points/sec.	up to 500000 points/sec.
Accuracy in distance (25m)	6mm (single distance)	~ 6 mm
Angular resolution	0.002 gon	0.020 gon
Divergence / Spot size in 25 m	0.06 mrad / 3 mm	0.22 mrad; approx. 11mm
Calibrated video camera	768 x 576 Pixel color res.	-

The terrestrial 3D laser scanning systems

Software modules for data acquisition and post processing


	Mensi GS100	IMAGER 5003
Field service programme	**PointScape** Scanner Initialisation Scanning of objects	**Z+F Laser Control** Scanner Initialisation Scanning of objects Resampling/Reduction
Post Processing	**Real Works Survey** Registr. & Geo-referencing Module OfficeSurvey (tools)	**LFM Modeller** Registr. & Geo-referencing Fitting of primitives
Post Processing	**3Dipsos** Registr. & Geo-referencing Engineering module (fitting of primitives, e.g. pipelines)	**LFM Server + Generator** Handling of huge point clouds

Registration

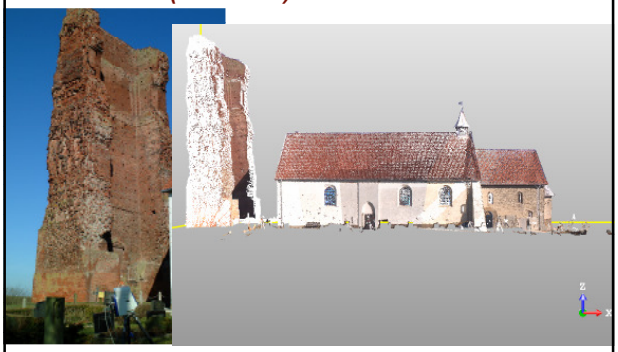


- Scan and automatic recognition of a sphere (Point Scape)
- Target recognition (Z+F Laser Control)

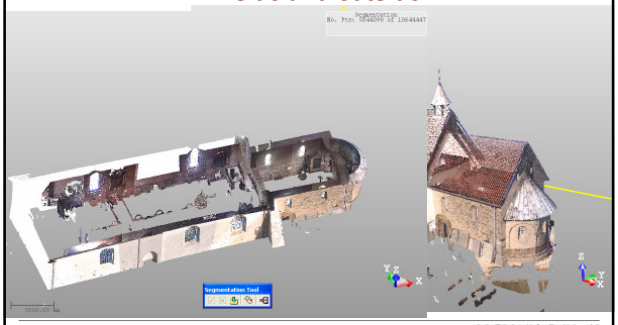
Old Church Pellworm – As built documentation

- Built in 1095 on a dwelling mound on the relics of a wooden church
- Tower collapsed in 1611

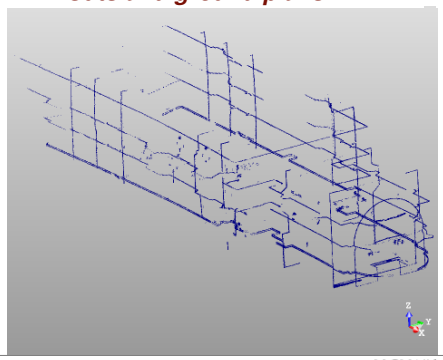
St. Salvator (Pellworm) / outside measurements



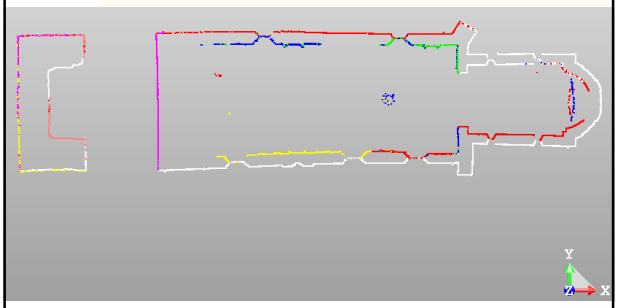
Registered and georeferenced point clouds: inside and outside



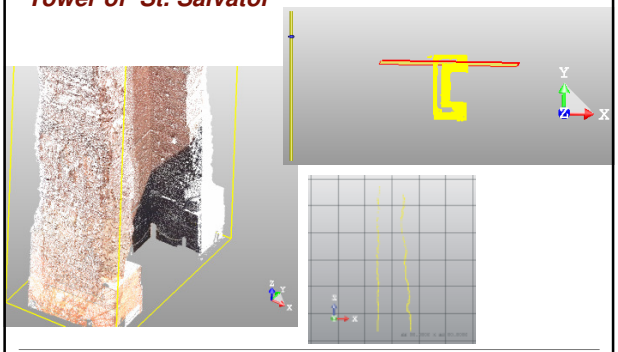
Cuts and ground plans



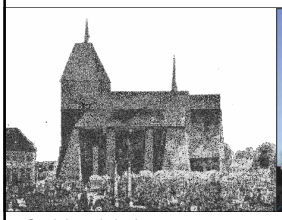
Ground plan cut



Tower of St. Salvator



St. Johannis Cathedral in Meldorf

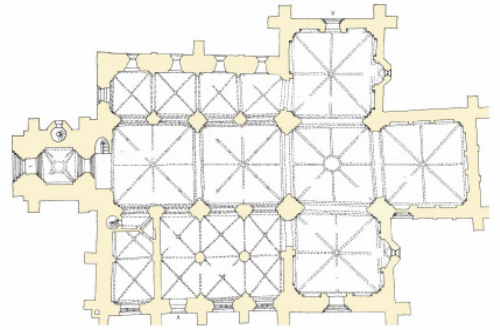


St. Johannis in the year: 1820

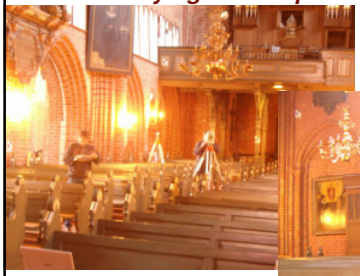
and today

- Built in the 13 th century
- Many reconstruction
- In 1880 coated with machine bricks.

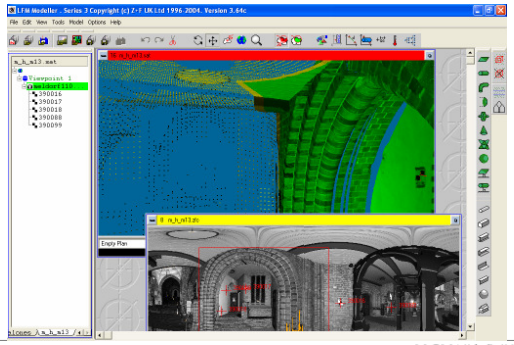
Ground plan St. Johannis, Meldorf

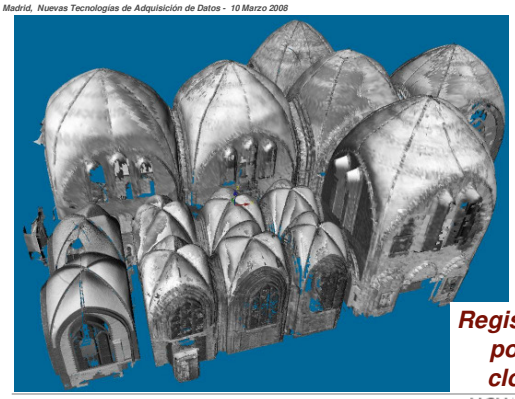


Surveying control points and scanning

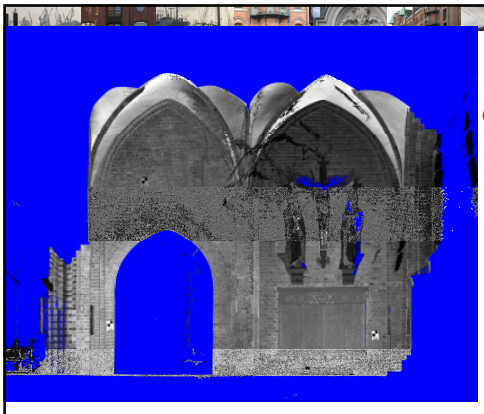


Registration with LFM Modeller

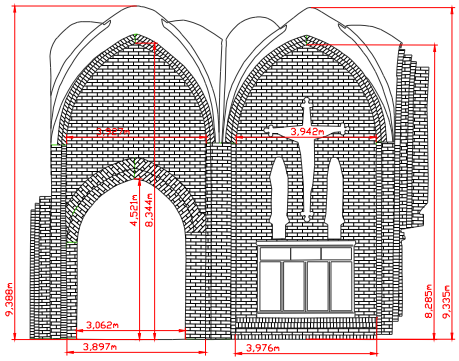




Registered point cloud

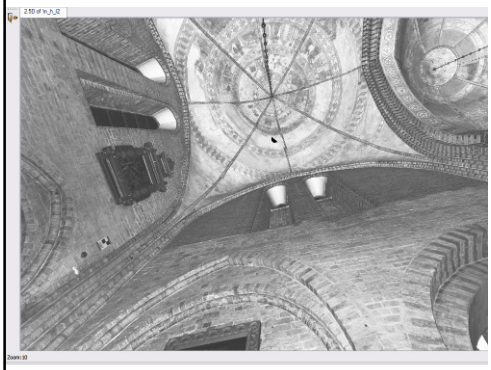


Orthophoto from LFM Modeller

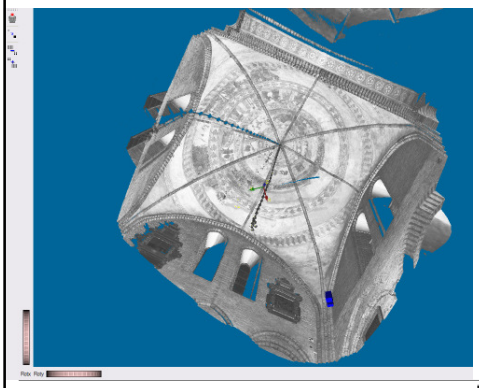


AutoCad Plan from the Orthophoto of the LFM Modeller

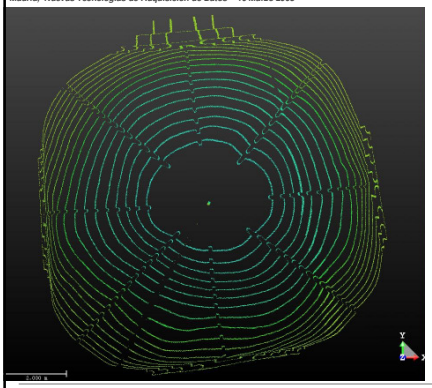
Gray scale picture



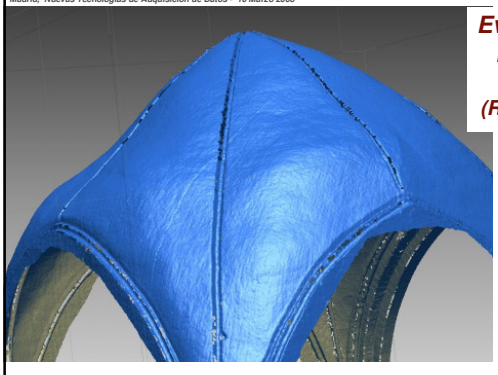
2D orthogonal view



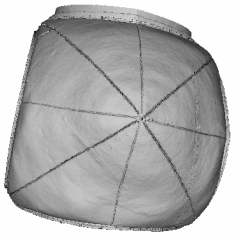
3D point cloud



Evalution: level lines of of a vault (Real Works)



Evaluation: meshed surface (RapidForm)

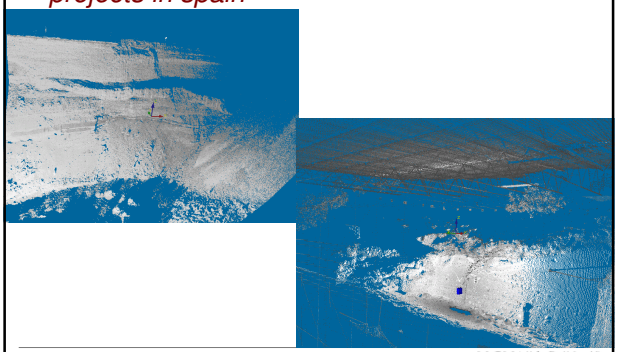


Conclusions

- Good results from 3D laser scanning under non-ideal conditions in the churches for documentation of indoor objects (cultural heritage)
- Data acquisition relatively simple and quick
- Data post processing very complex and time consuming, but the 3D-model is not needed every time
- No scanner for all applications, but for each application one specific scanner
- 3D laser scanning system = scanner + software for post processing, but often third party software has to be used
- New possibilities for deformation analysis - surfaces instead of single points
- Next deformation measurement in 4 years, further improvement of scanner evaluation software

Thank you for your attention

- *projects in spain*



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