



Digital Photogrammetry

Eramca Workshop 2022 – Geomatics

Environmental Risk Assessment and Mitigation on Cultural Heritage Assets in Central Asia



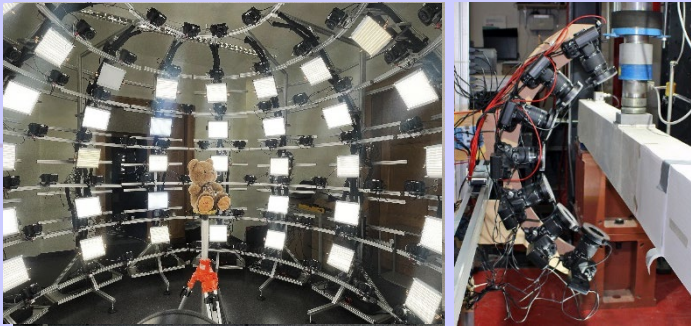
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volker.rodehorst@uni-weimar.de

Co-funded by the
Erasmus+ Programme
of the European Union

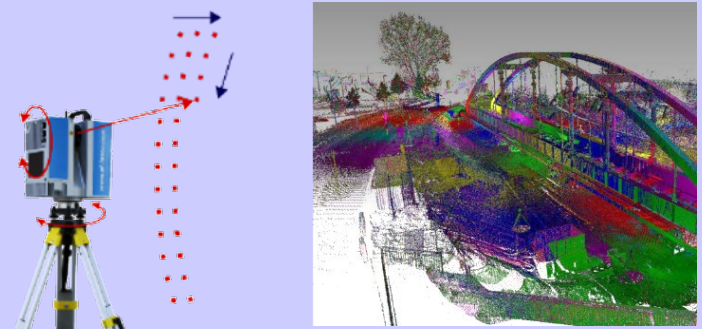


Computer vision in engineering

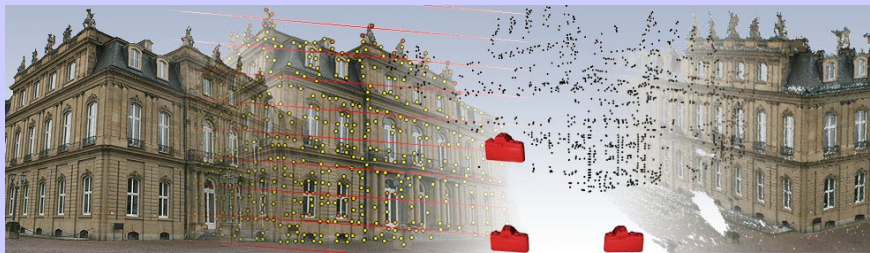
- Sensor platforms (UAS, 3D scanner, ...)



- Geodesy & building stock survey



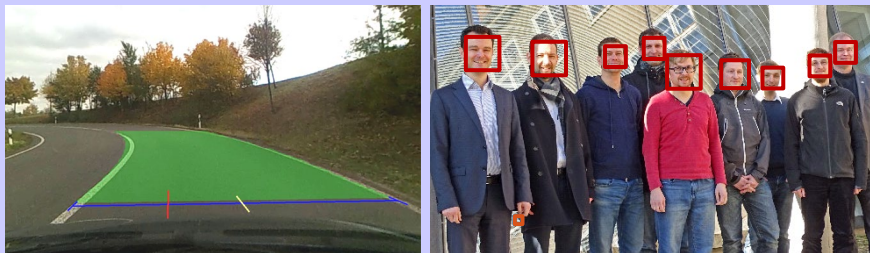
- Sensor orientation and 3D reconstruction



- Spatial information systems (GIS)



- Image analysis and object recognition



- Parallel and distributed systems



Why photogrammetry?

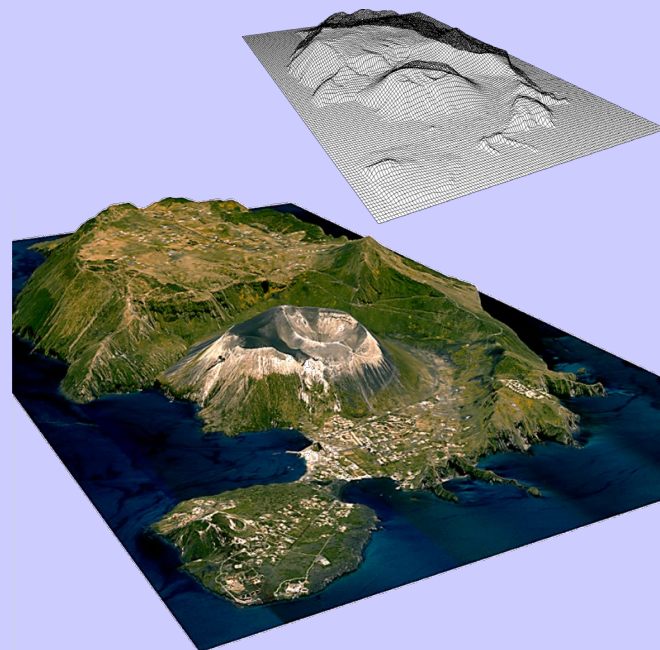
Manual measurements could be ...



... dangerous,

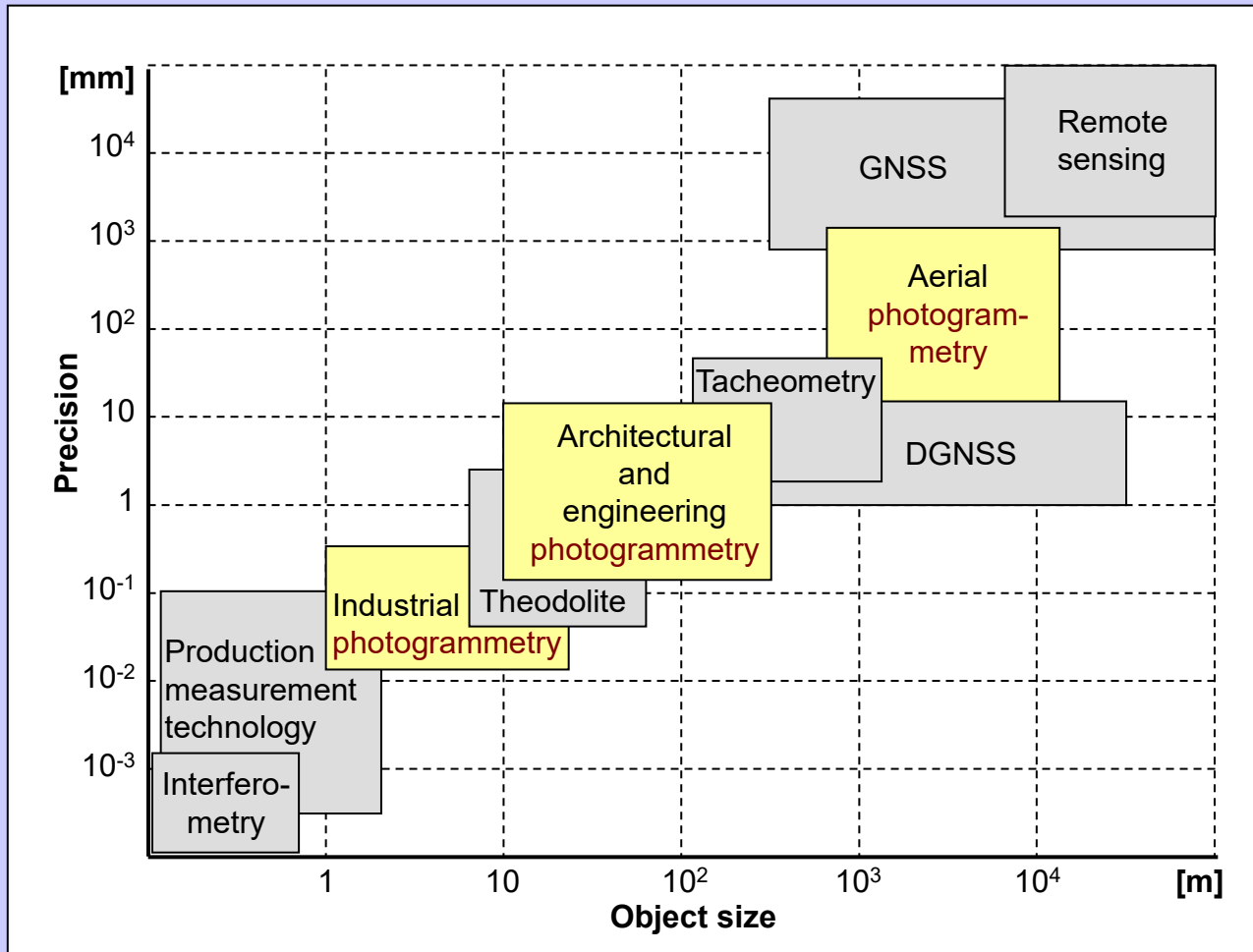


... unaccessible or



... too time consuming!

Selection of measurement techniques



Measurement techniques in relation to **object size** and **precision**

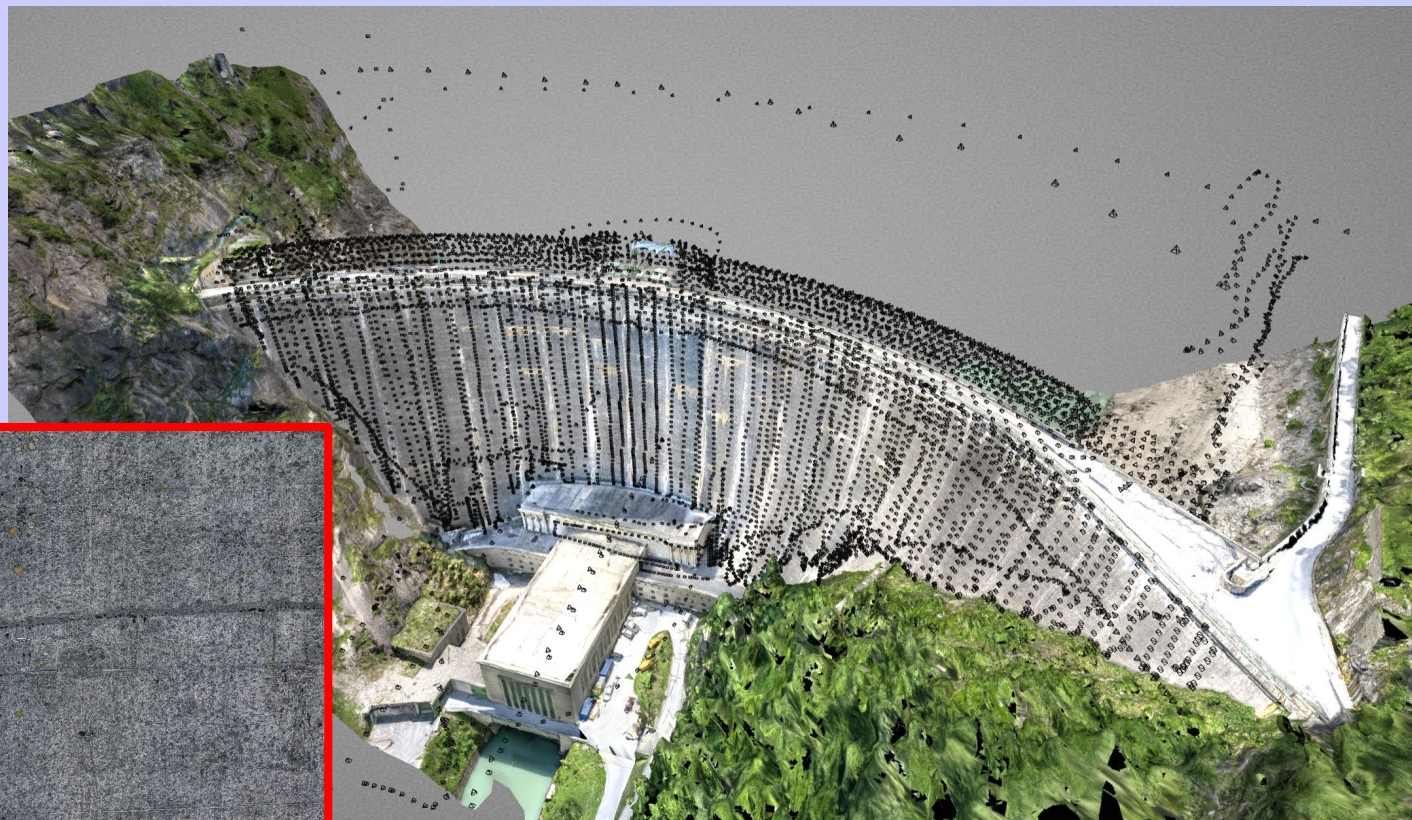
Video: Hirschberg



Video: Caterpillar in SEM



Image-based data acquisition



**Damage detection?
Documentation?**

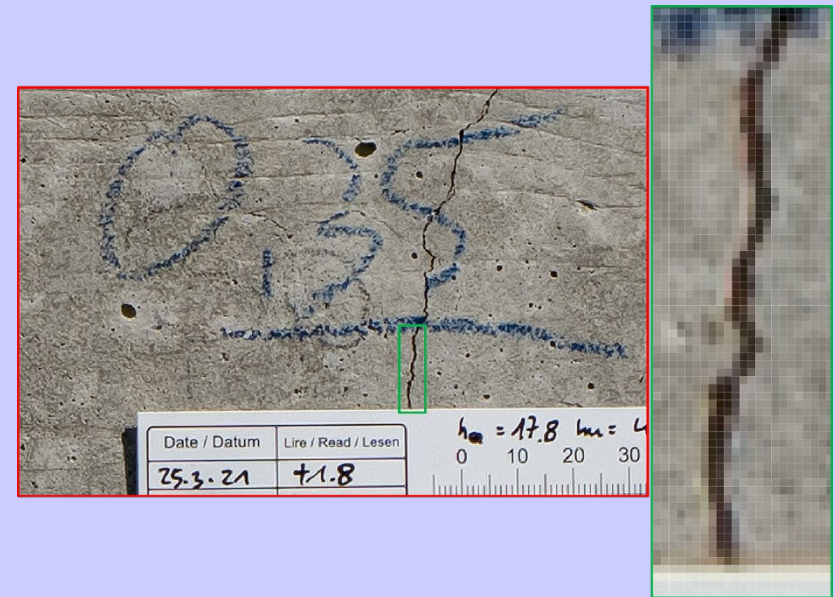
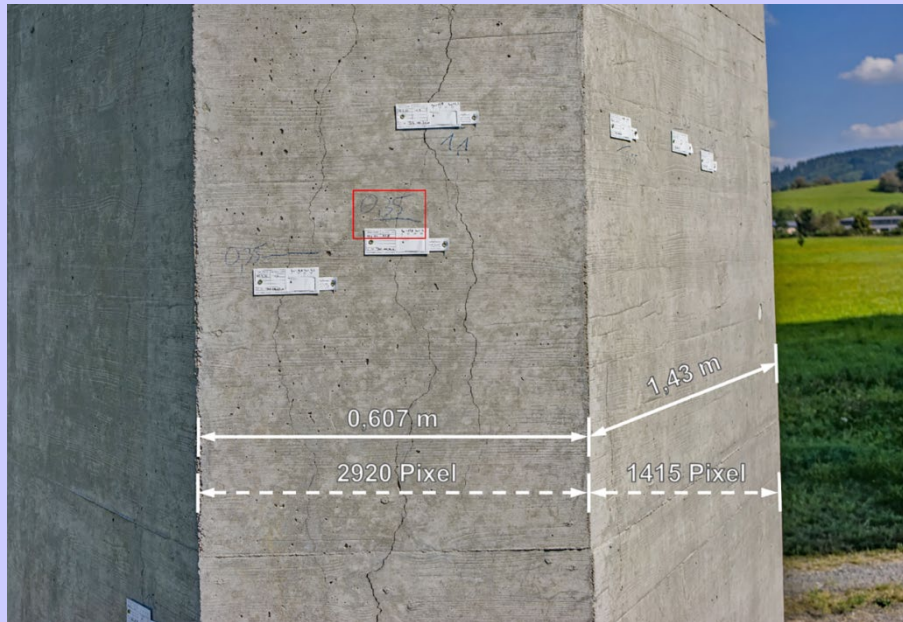
**Complete?
Image quality?**

Image localization

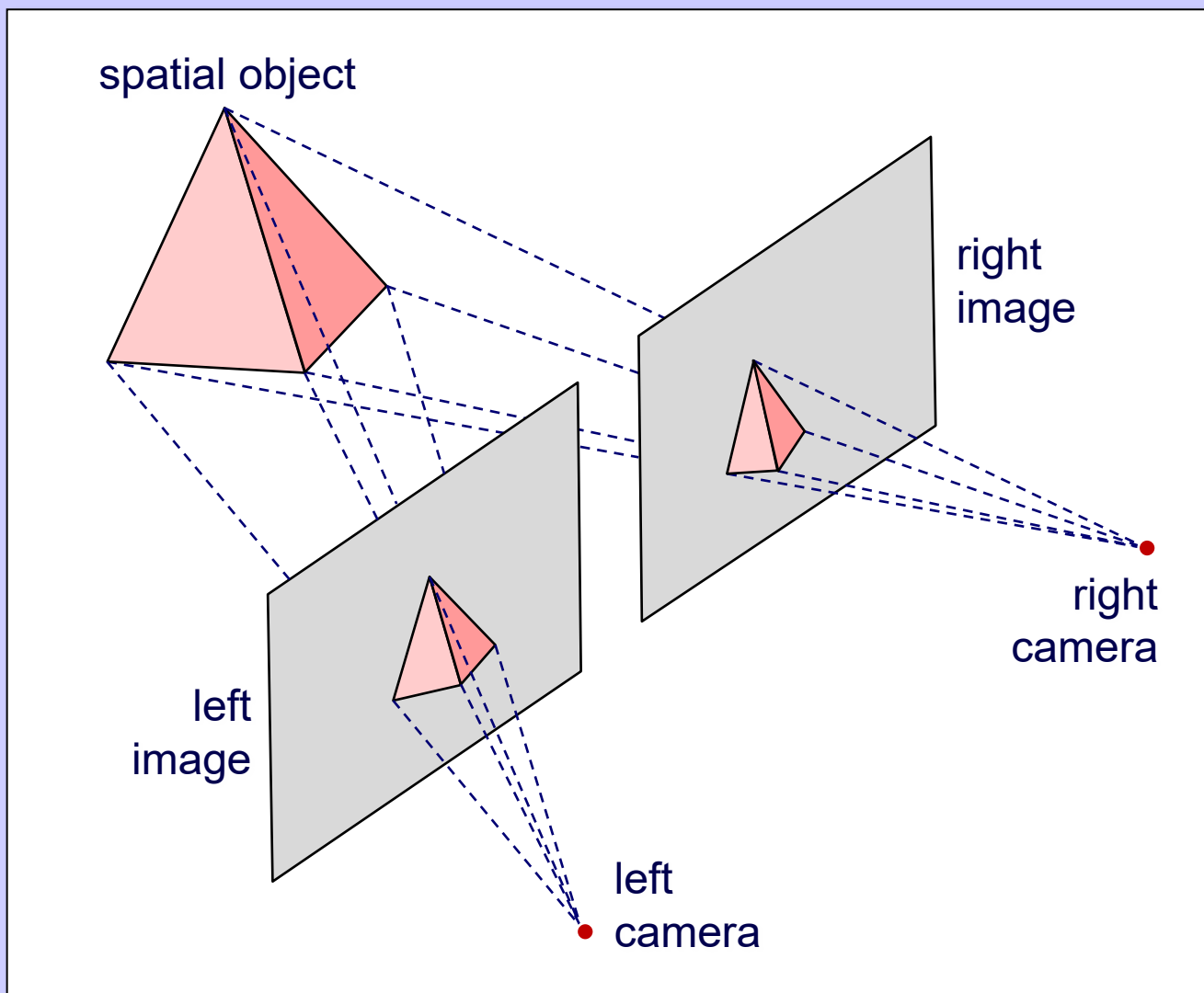


Where?

Image measurements



Stereoscopic measurement principle



Structure-from-Motion (SfM)

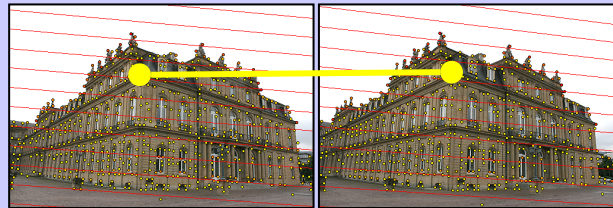
sensor-orientation

relative orientation

(auto-)calibration



1. image sequences



2. features & epipolar geometry



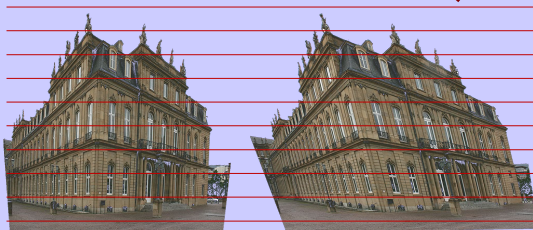
3. cameras & object points

3D reconstruction

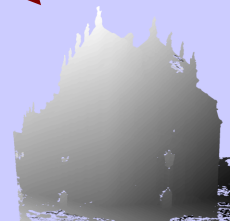
image transformation

stereo image matching

triangulation



4. normal images



5. dense disparity map



6. 3D point cloud

Requirements

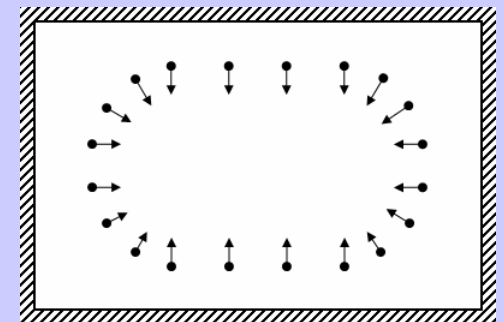
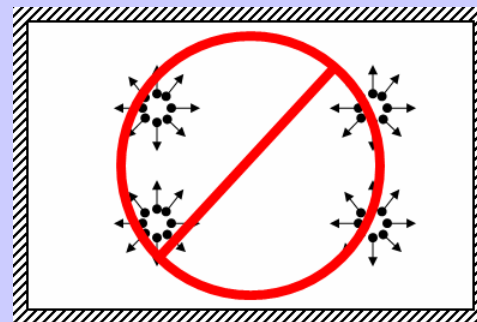
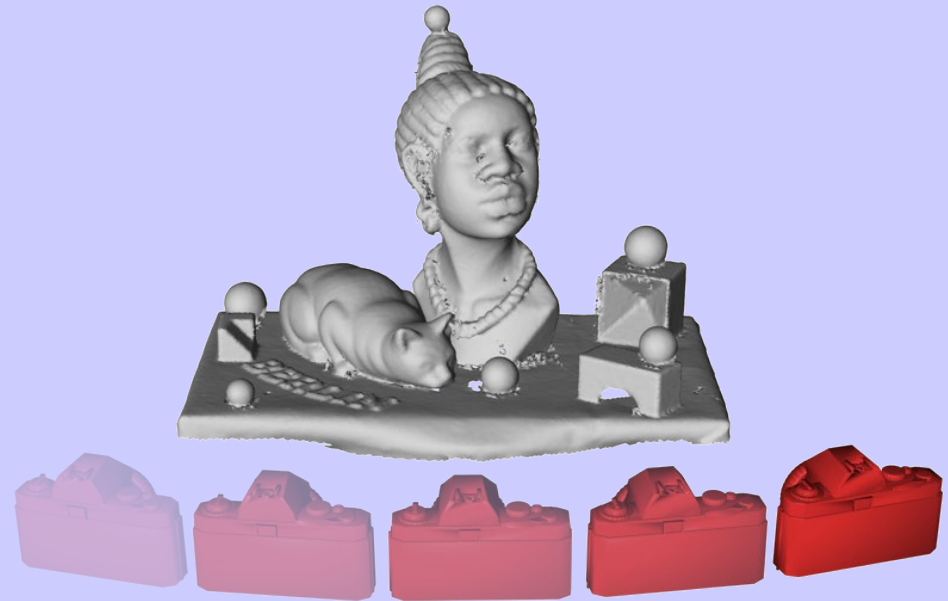
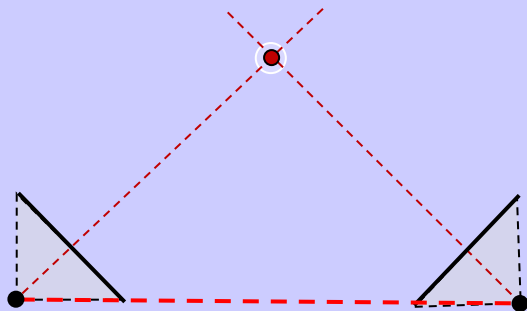
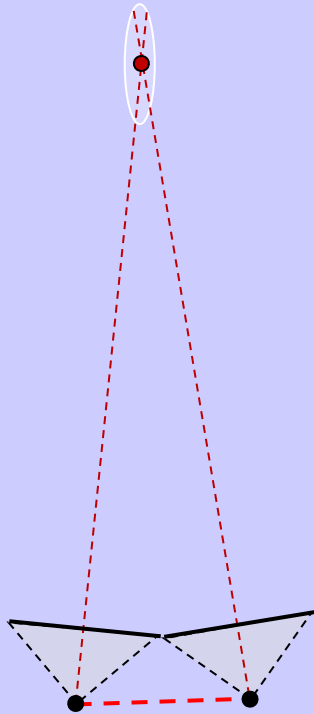
Important:

- constant camera settings (e.g. **no zoom**)
- original images (e.g. **not cropped** or scaled)
- **sharp** images from different points of view
- sufficient image **overlap** (67-80 %)
- surface with good **texture**
- consistent **diffuse lighting**
- sufficient CPU/**GPU** power (and **memory**)

Difficult:

- shiny, reflective or transparent objects
- moving or deformable objects

Baseline problem



Multicopter

AscTec Falcon 8



Yuneec Typhoon H



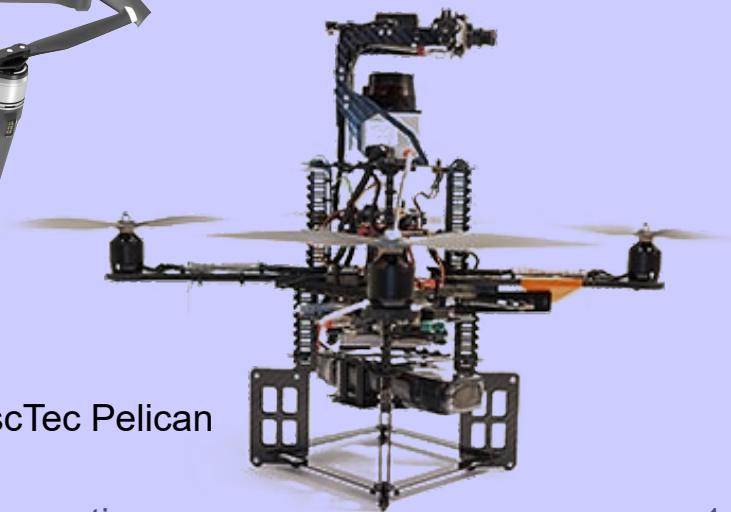
DJI Mavic 2 Pro



Parrot AR.Drone



AscTec Pelican



Vision-based sensors



Sony Alpha 7R
(36 MP, full format)

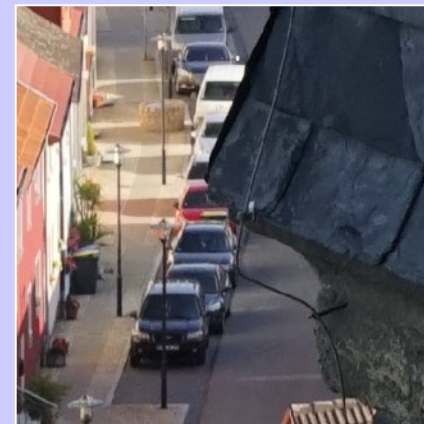
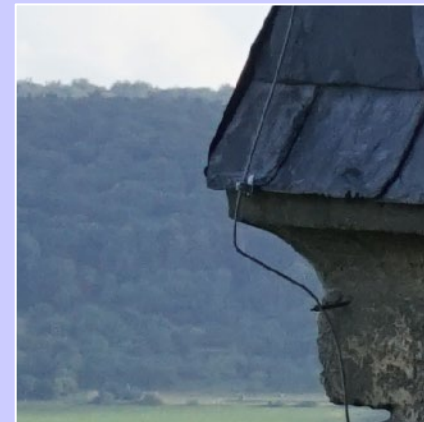
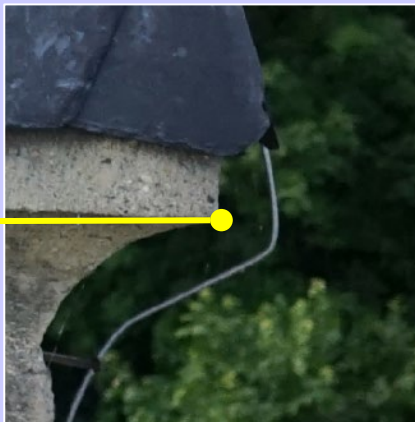
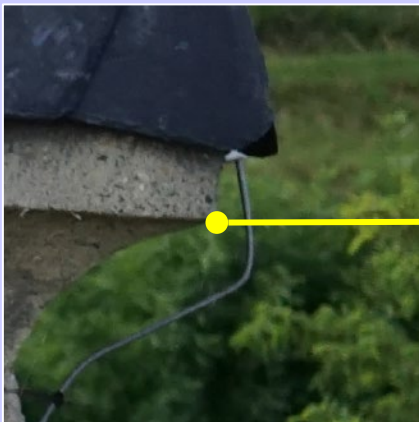


Sony Camcorder PJ810E
(Full HD video)

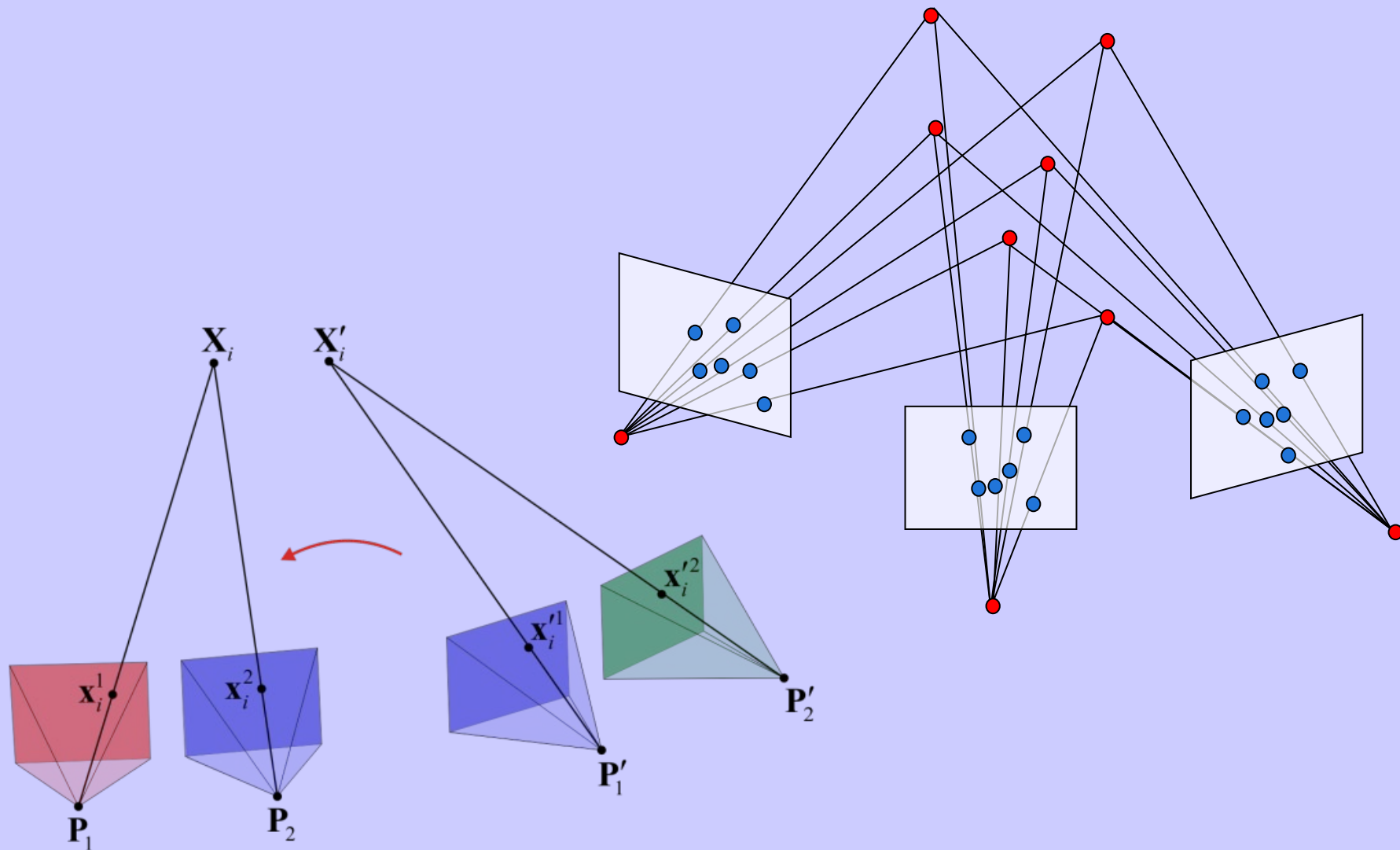


**FLIR TAU 2 640 with
Panasonic Lumix TZ61**

Correspondence problem



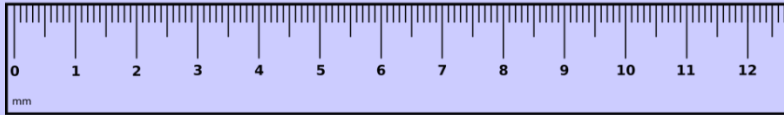
Relative orientation & bundle adjustment



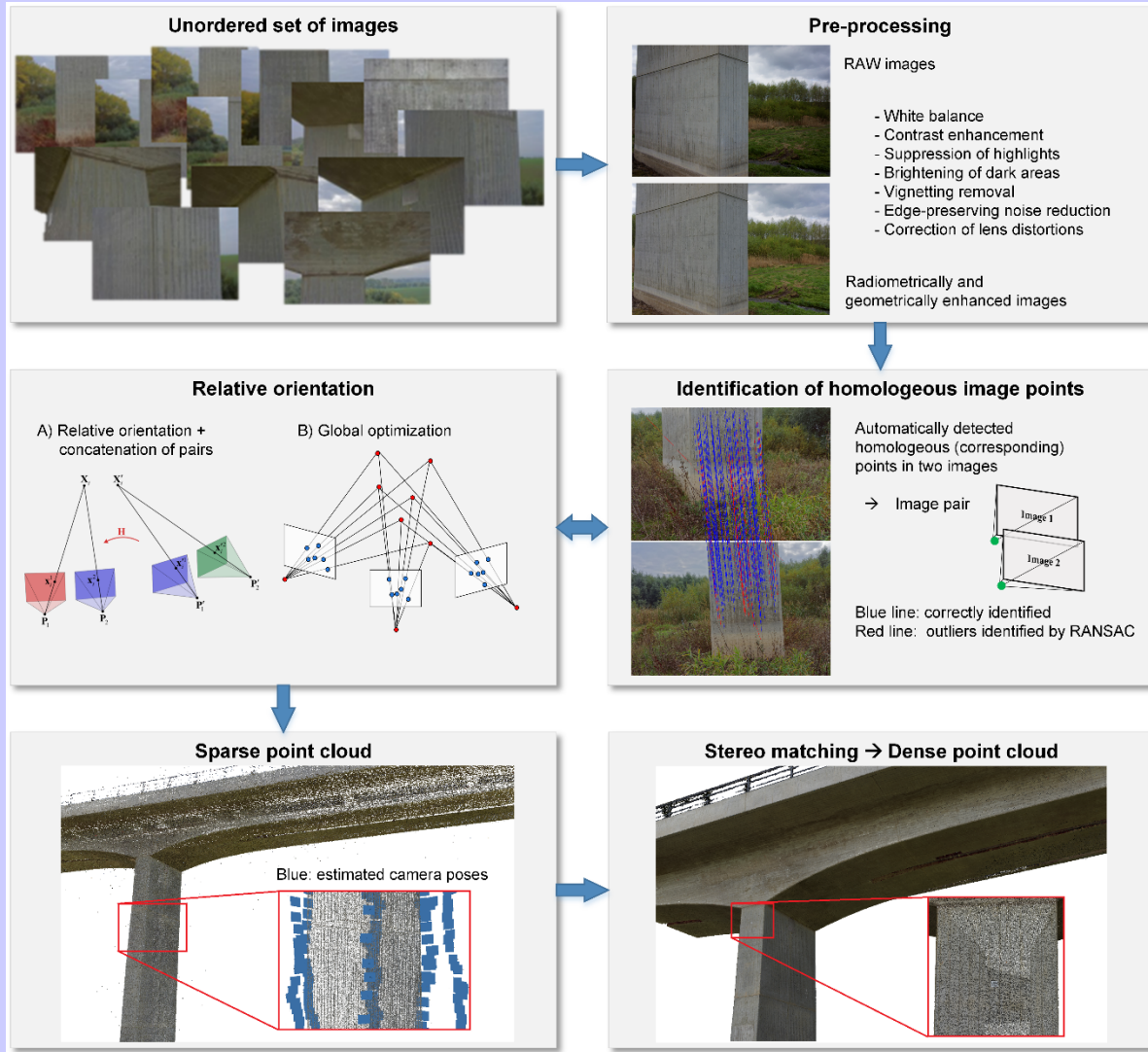
Radial lens distortion



Georeferencing

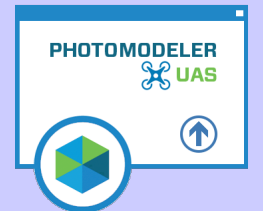


Summary: image-based 3D reconstruction

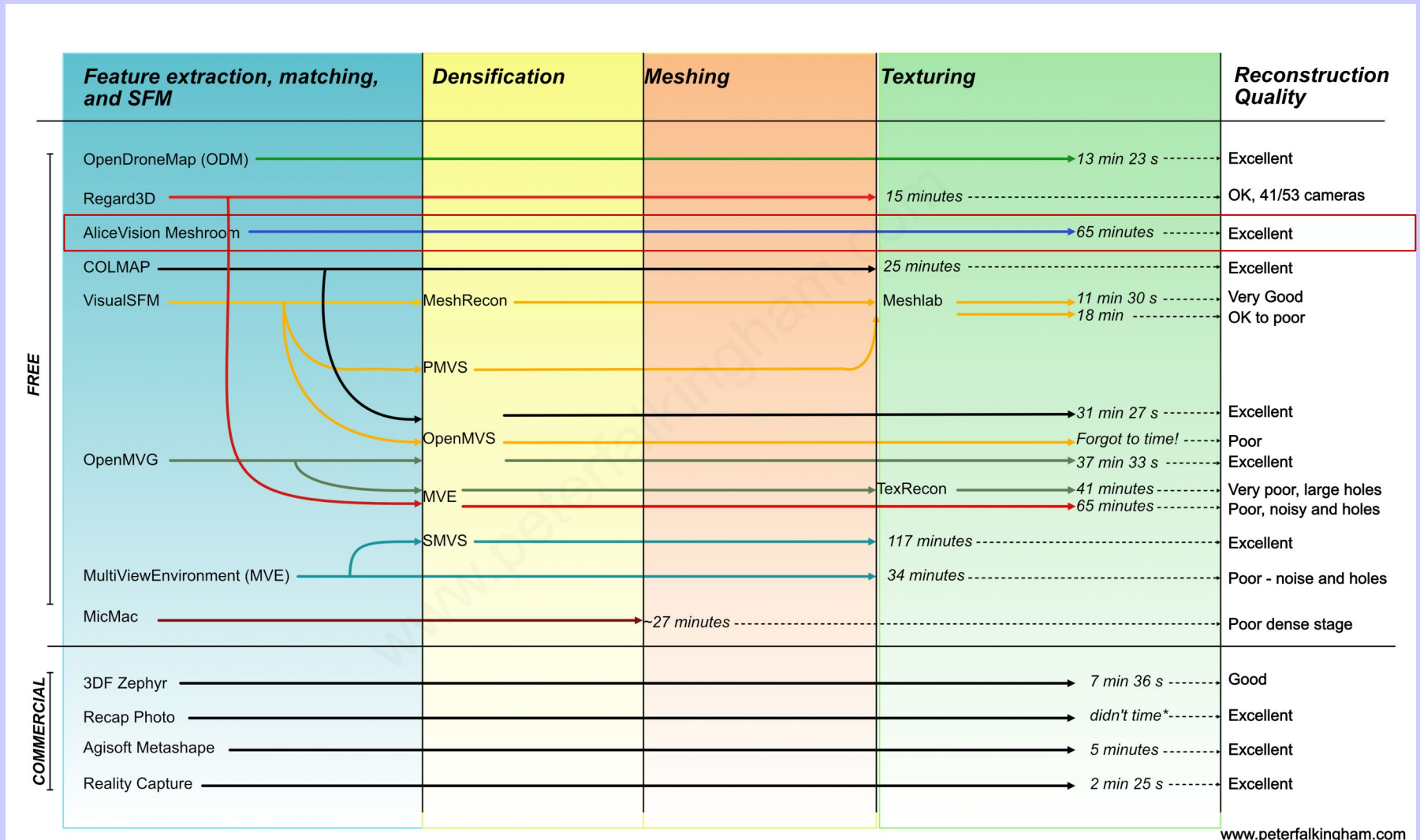


Commercially available and free tools

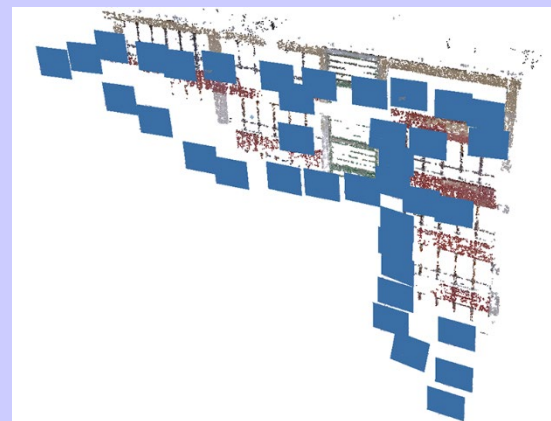
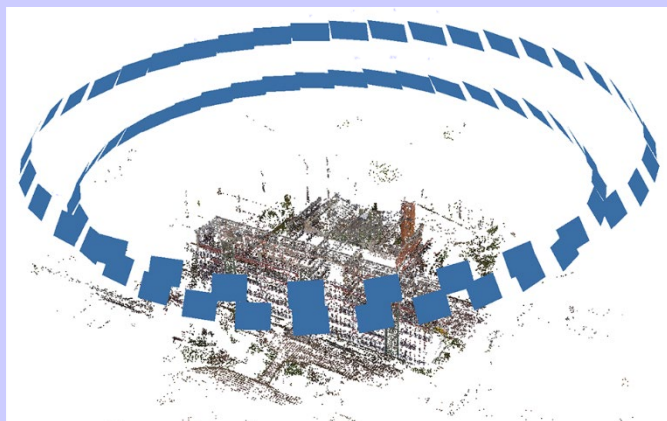
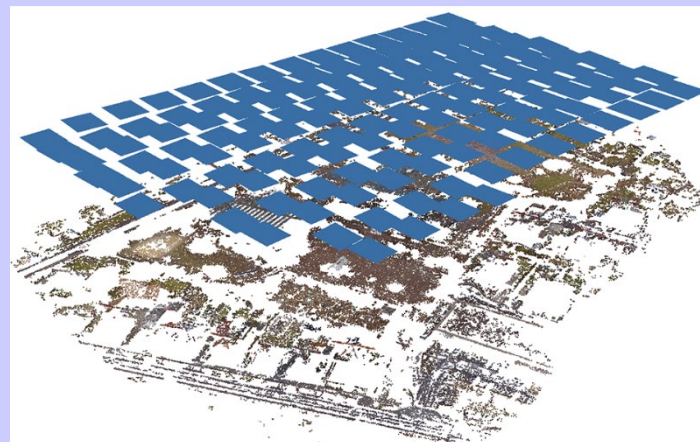
- **AgiSoft** ~~PhotoScan 1.4~~ / **MetaShape** 1.8
- Capturing Reality **RealityCapture** 1.2
- Pix4D Pix4Dmapper 4.8
- 3DFlow Zephyr 6.503
- Bentley ~~Acute3D~~ ContextCapture 4.4.9
- Autodesk ~~Remake~~ ReCap Pro 2022
- PhotoModeler UAS 2022
- Trimble Inpho UASMaster 12
- ...
- VisualSFM + openMVS + MeshLab
- COLMAP (colmap.github.io)
- AliceVision **Meshroom** (alicevision.org)
- ...



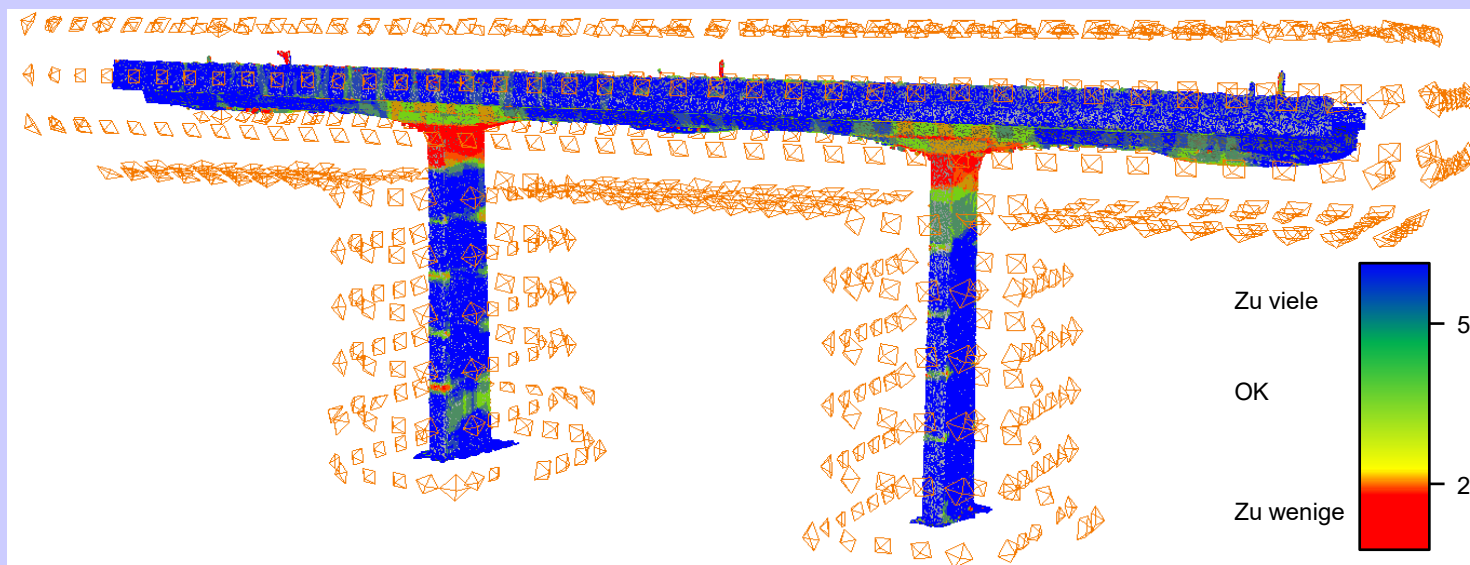
Benchmarking 2021



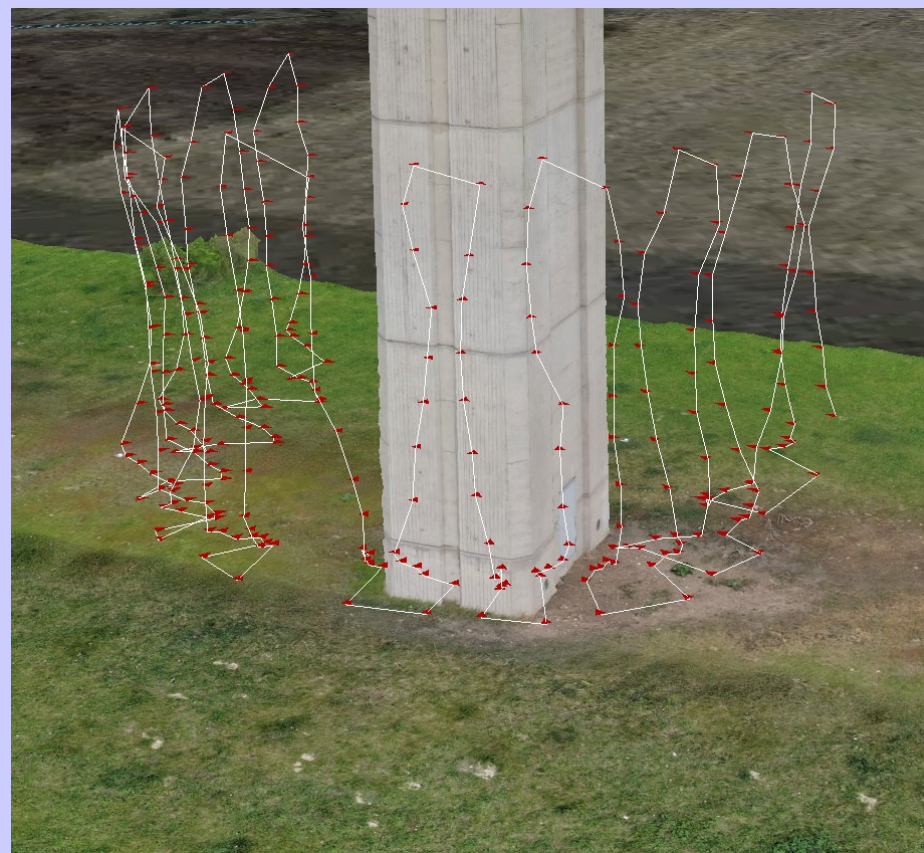
Flight planning



Object aligned 3D flight path



Automatic flight using GNSS waypoints



Import of GNSS & compass data



Import CSV

Coordinate System
WGS 84 (EPSG::4326)

Rotation angles: Yaw, Pitch, Roll

Ignore labels

Threshold (m): 0.1

Delimiter
 Tab
 Semicolon
 Comma
 Space
 Other:
 Combine consecutive delimiters

Columns

Label: 2 Accuracy

Longitude: 3 8 Yaw: 6 9 Rotation Accuracy

Latitude: 4 8 Pitch: 7 9

Altitude: 5 8 Roll: 8 9

Enabled flag: 10

Start import at row: 2 Items: All

First 20 lines preview:

Date Time	Label	Longitude	Latitude	Altitude	Yaw	Pitch
	Filename	longitude [degr...	latitude [degree	height [m]	yaw [degree]	pitch [
24.02.2018 0...	P1000145.JPG	11.35246849060...	50.96288681030...	28.038	325.07	-43.84
24.02.2018 0...	P1000146.JPG	11.35249996185...	50.96289825439...	27.993	323.61	-43.84
24.02.2018 0...	P1000147.JPG	11.3525390625	50.96291351318...	27.889	315.41	-43.82
24.02.2018 0...	P1000148.JPG	11.35256767272...	50.96293258666...	27.973	305.09	-43.84
24.02.2018 0...	P1000149.JPG	11.35258674621...	50.96295547485...	27.897	295.32	-43.84

OK Cancel

Heritage conservation

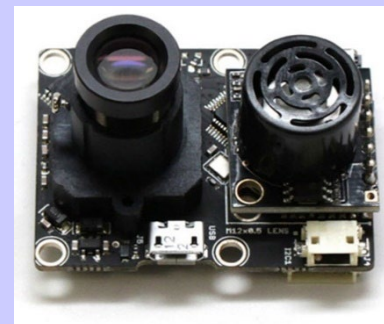
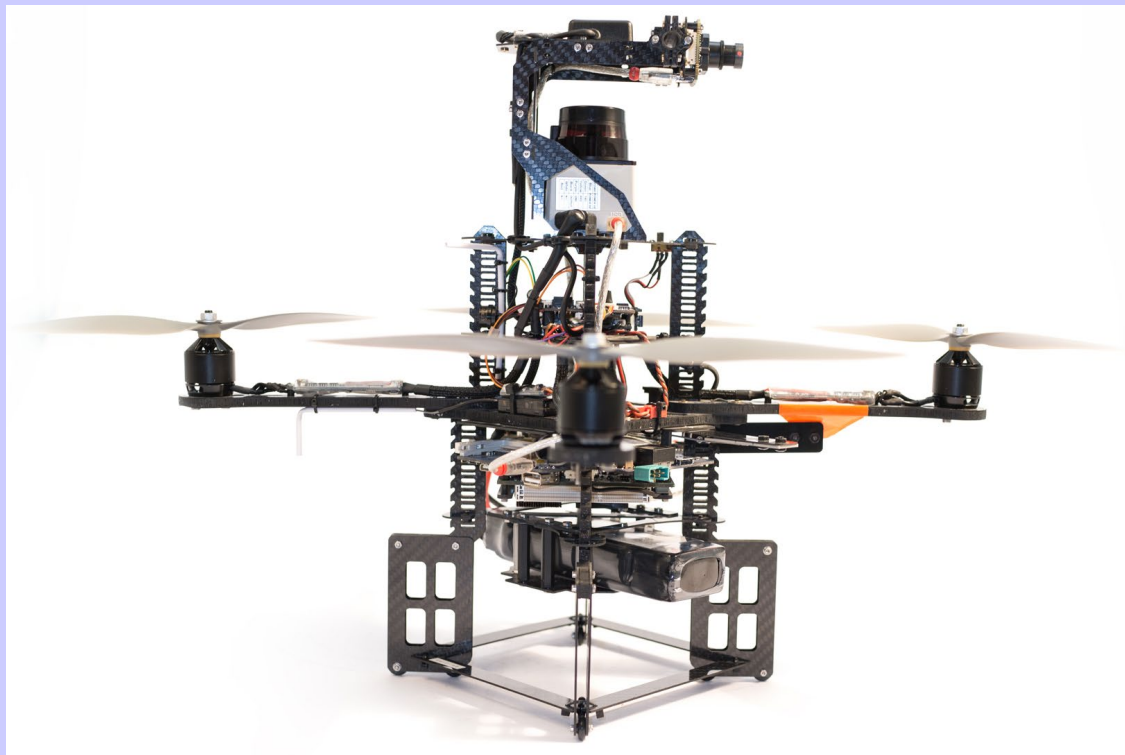
Figure in the cathedral of Halberstadt



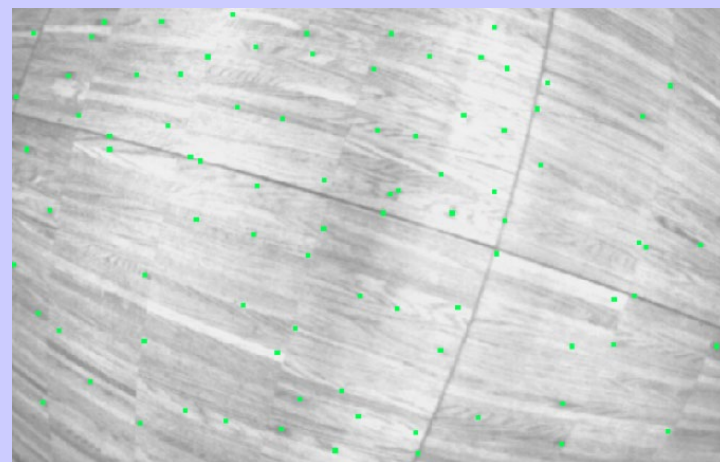
Autonomous indoor navigation



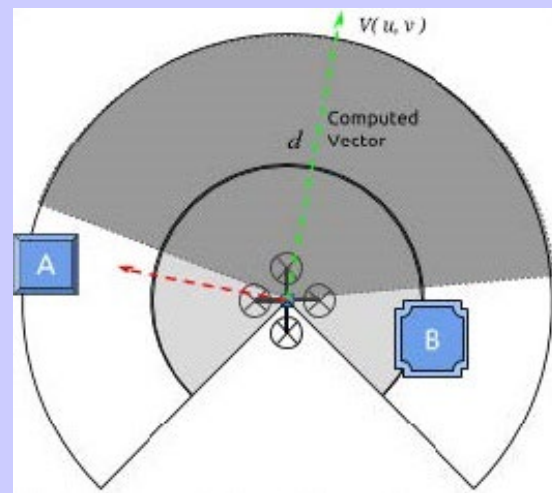
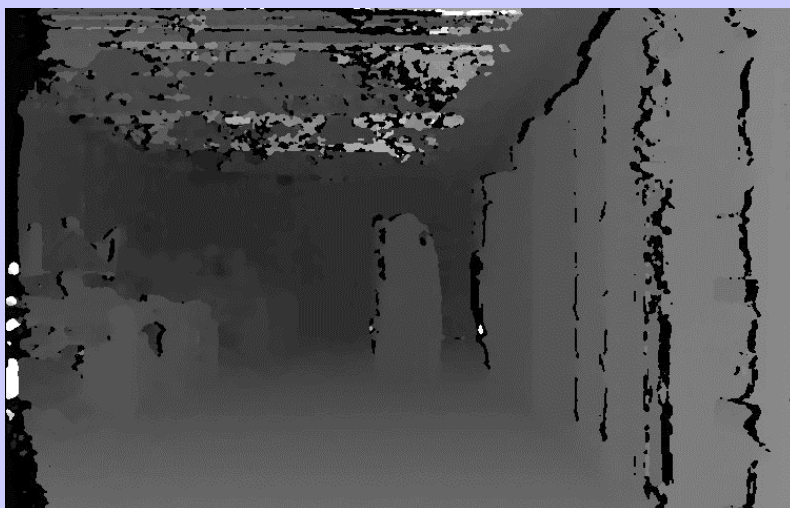
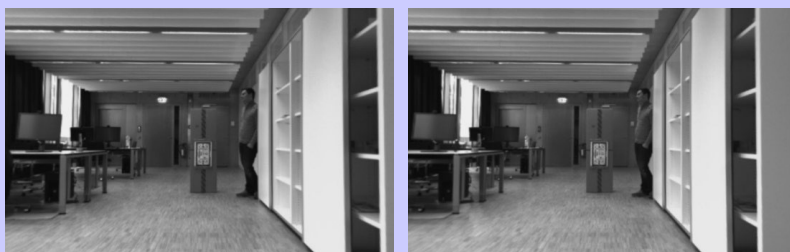
Sensor integration: optical flow



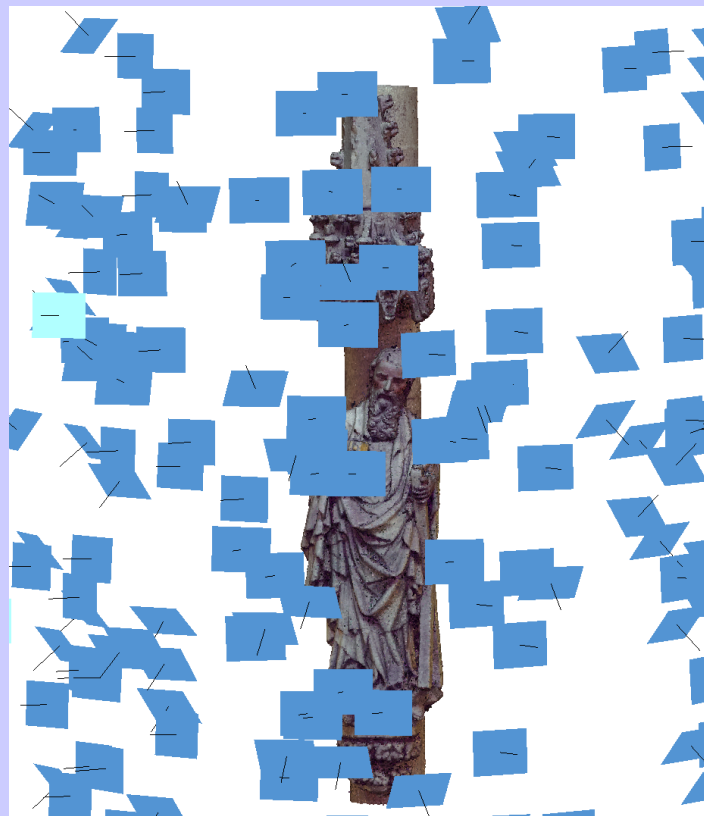
Optical flow sensor and sonar



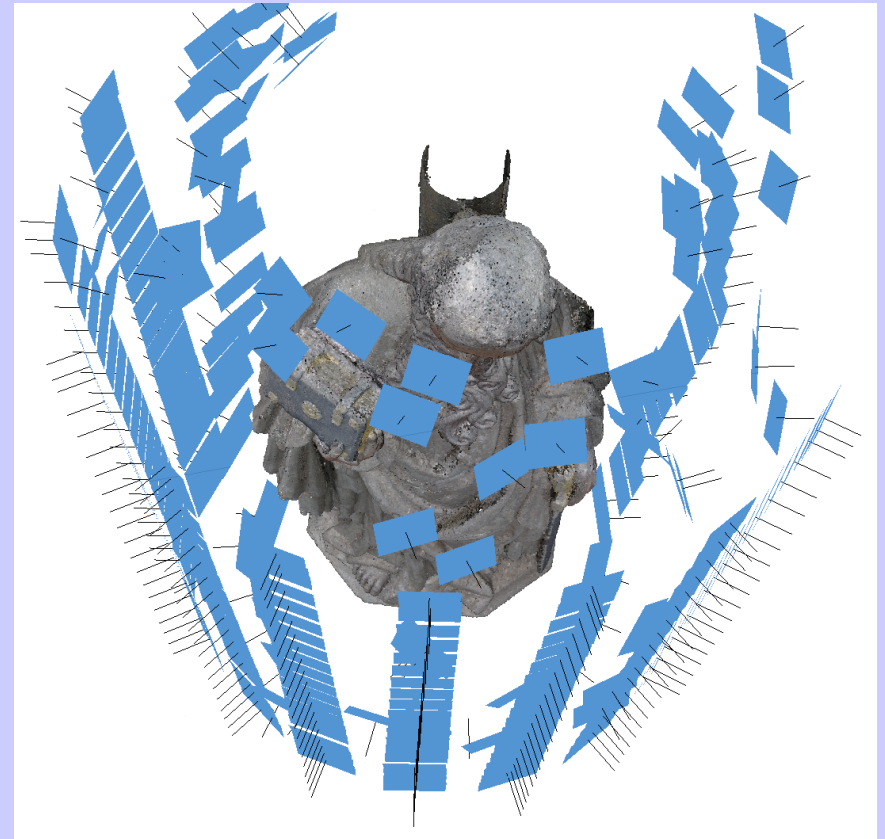
Obstacle detection



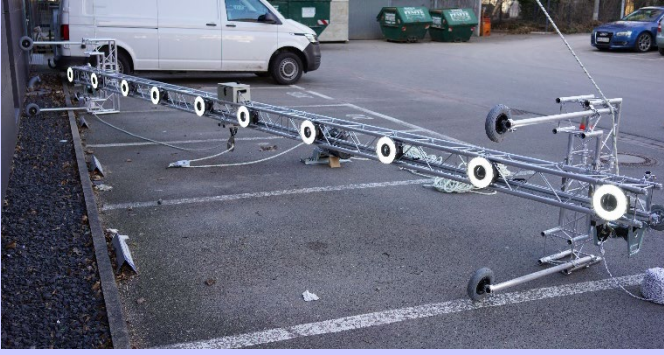
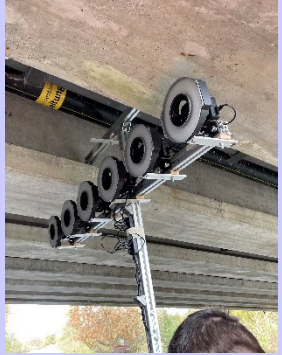
Manual image acquisition



Systematic image acquisition



Recording strategies



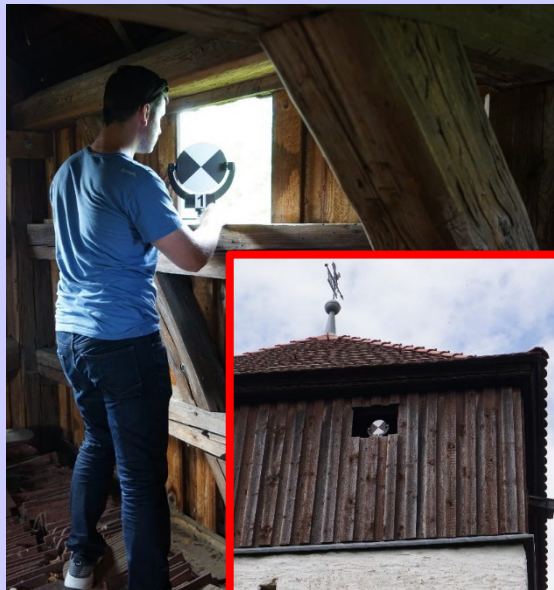
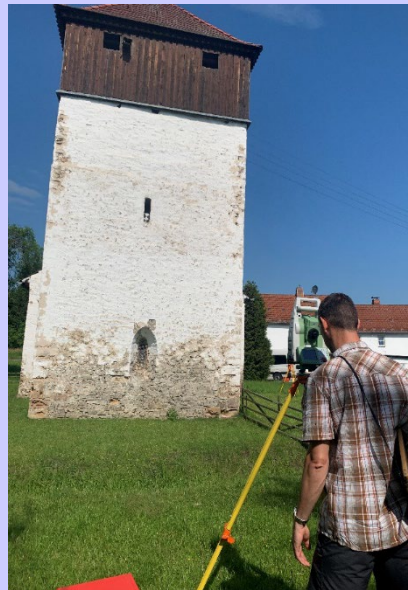
3D data acquisition weir church Döblitz



Video: Döblitz



Georeferencing of the structure



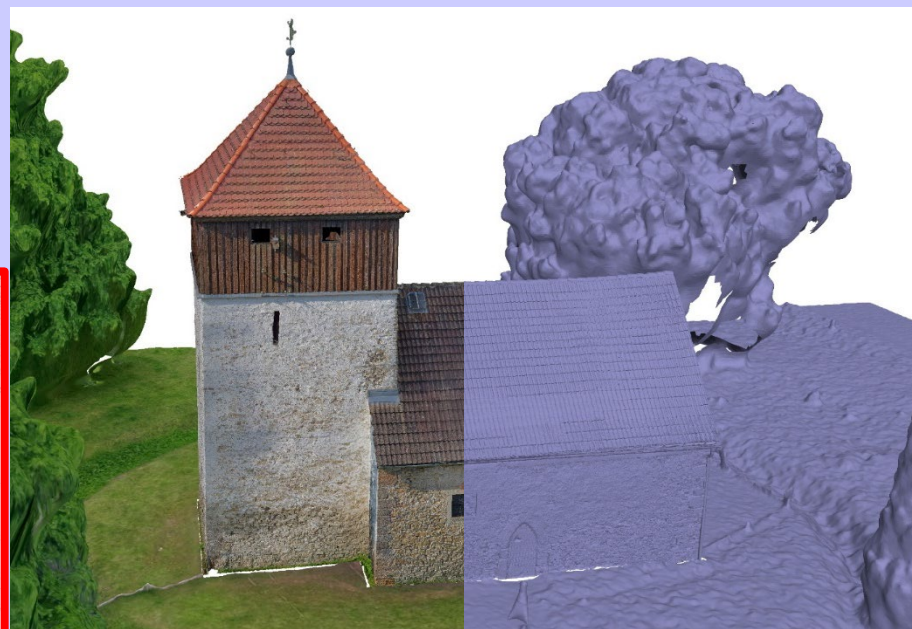
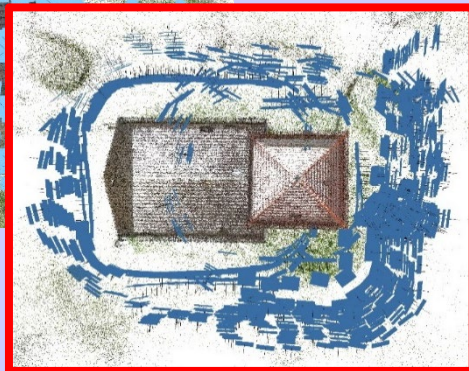
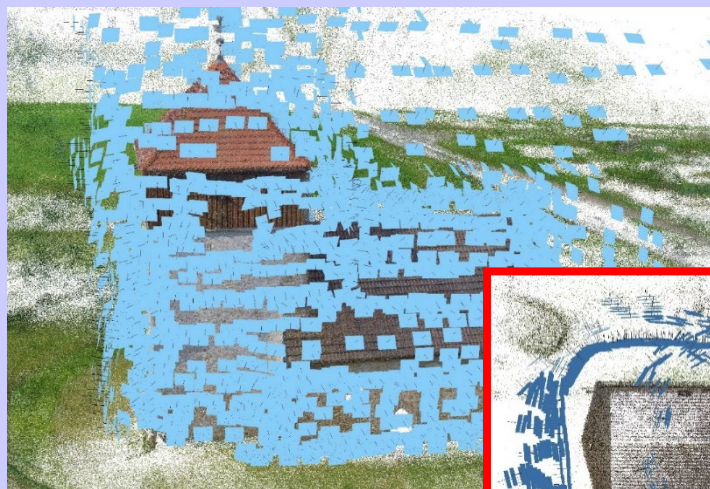
First flight with UAS



Flight route planning and automated flight



Creation of a high-resolution 3D model

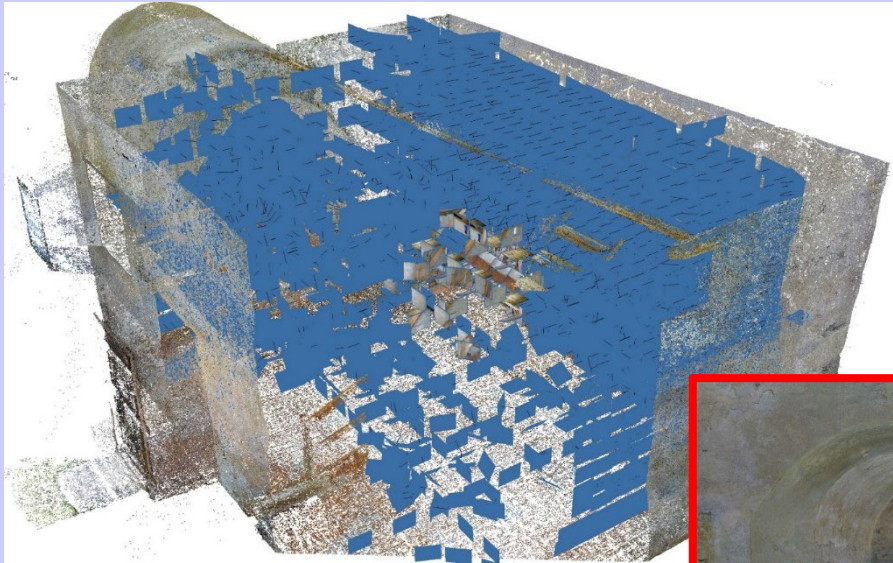


Number of images: 2326
Image resolution: 0,7mm/Pixel

Interior shots - capture first floor

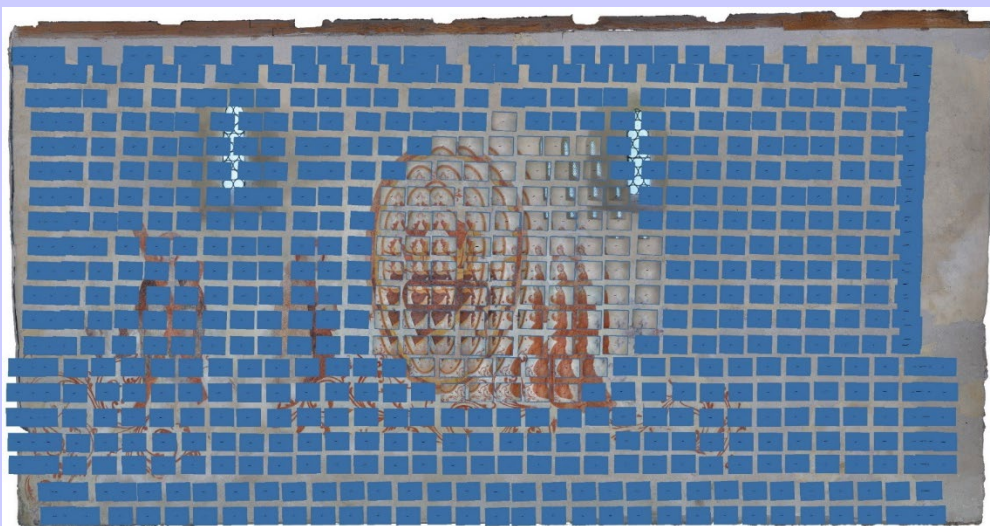


Interior



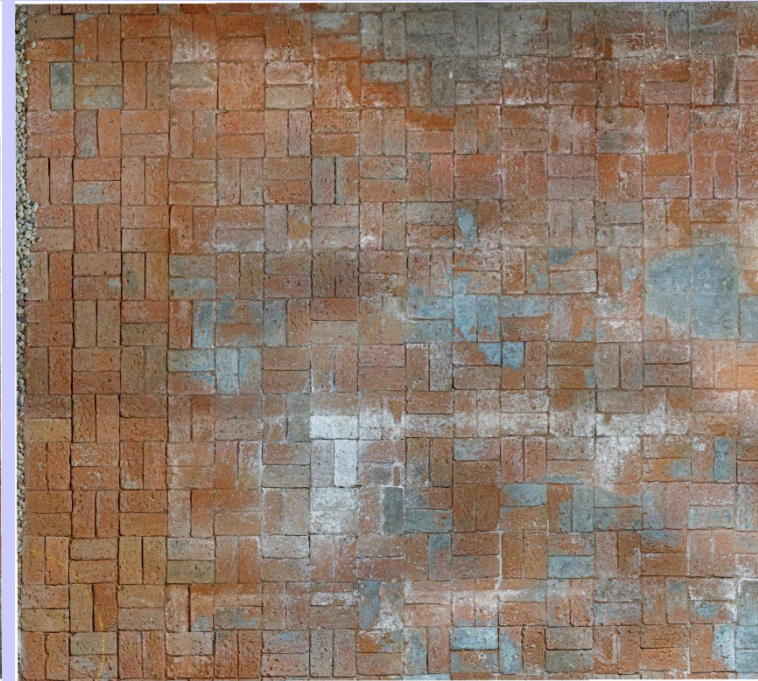
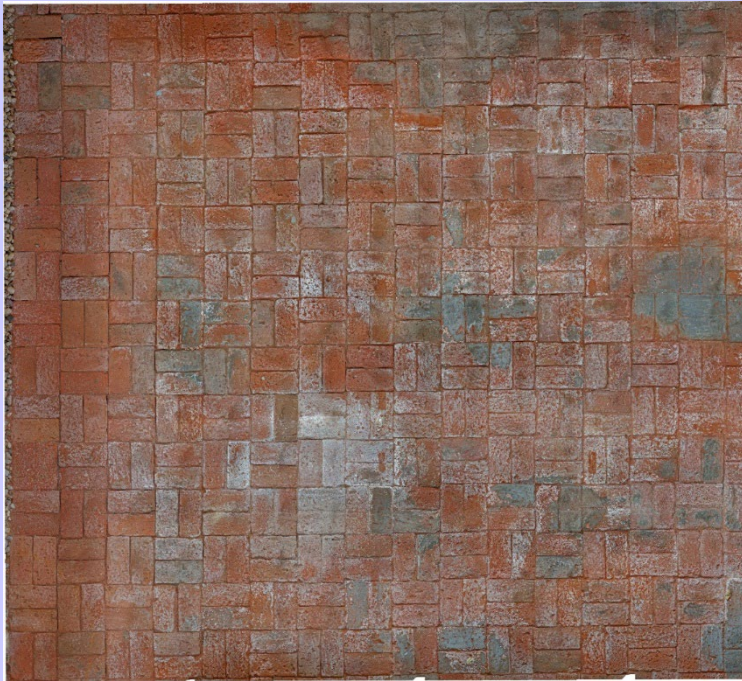
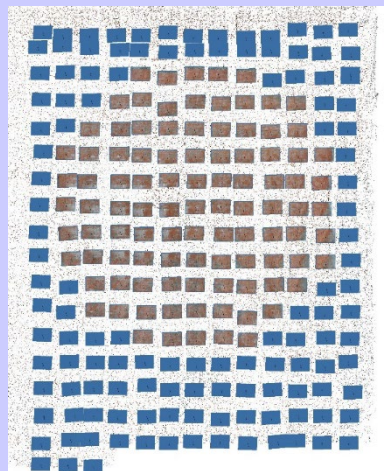
Number of images: 2503
Image resolution: < 0,3 mm/pixel

Wall painting



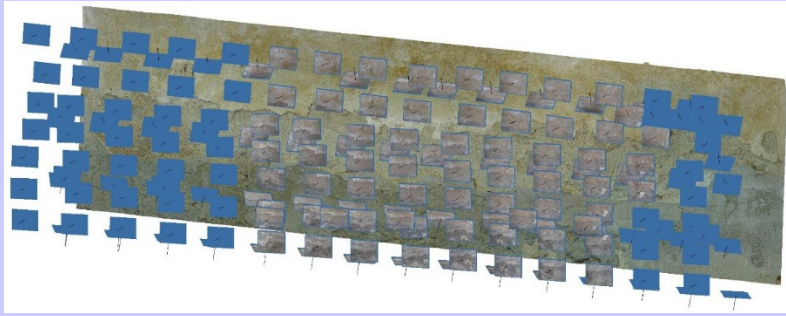
Number of images: 707
Image resolution: < 0,1 mm/pixel

Seasonal floor change



Number of images: 234
Image resolution: < 0,2 mm/pixel

Spalling in altar room



Number of images: 185
Image resolution: < 0,08 mm/pixel

Resulting 3D model



Resulting 3D model



Interactive visualization in VR



Interactive visualization in VR



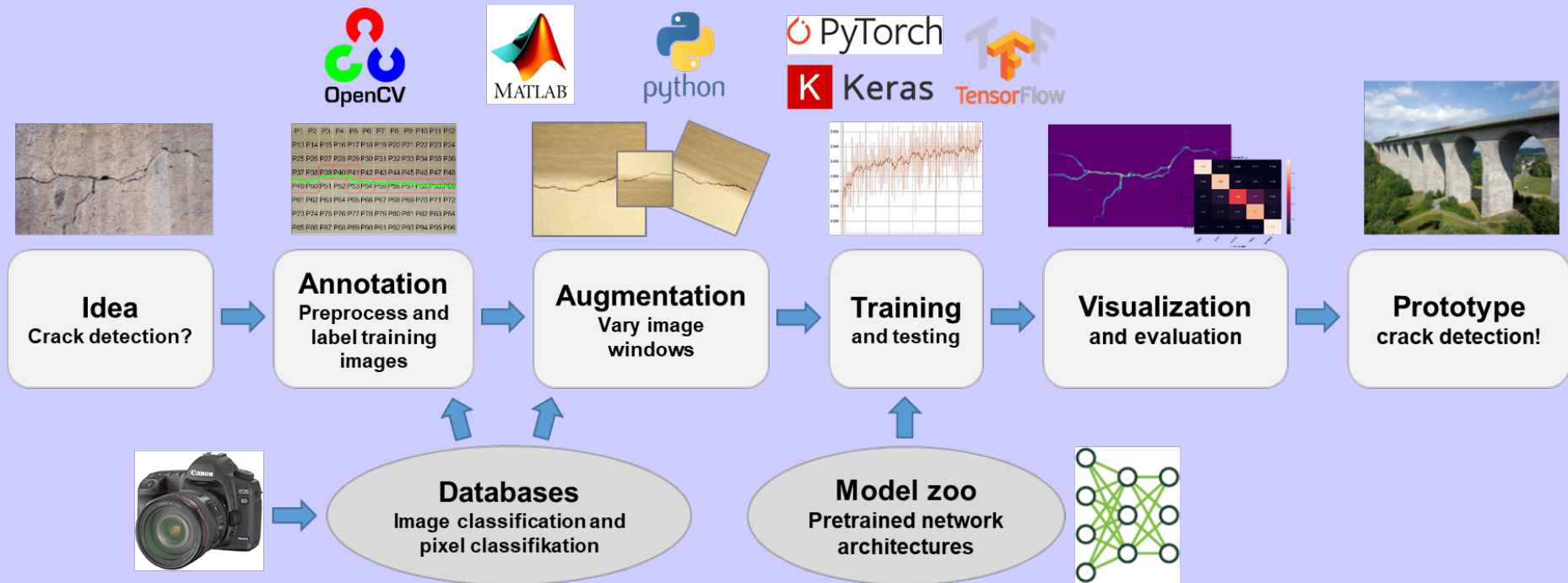
Interactive visualization in VR



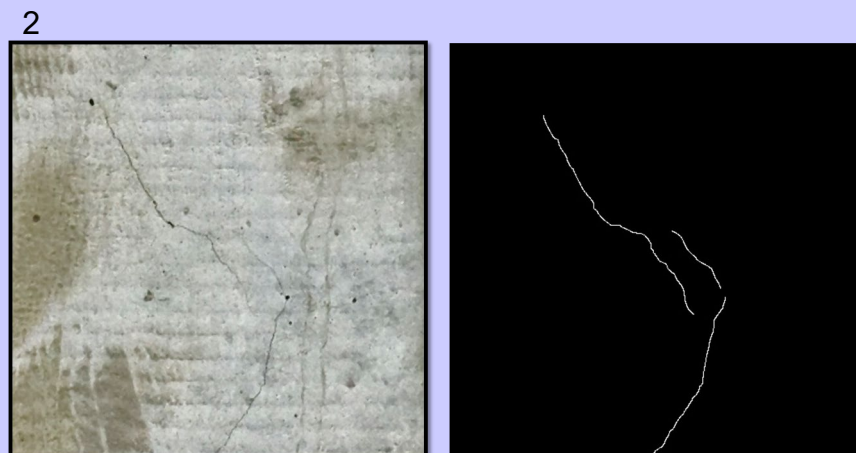
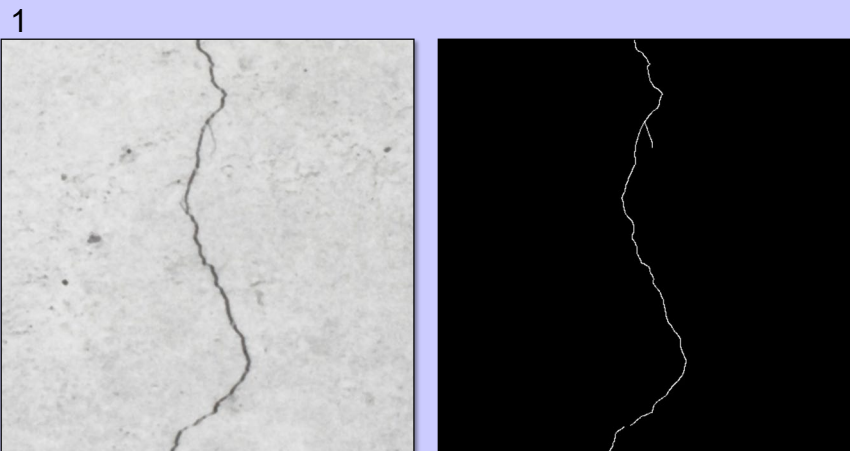
Discussion in collaborative VR



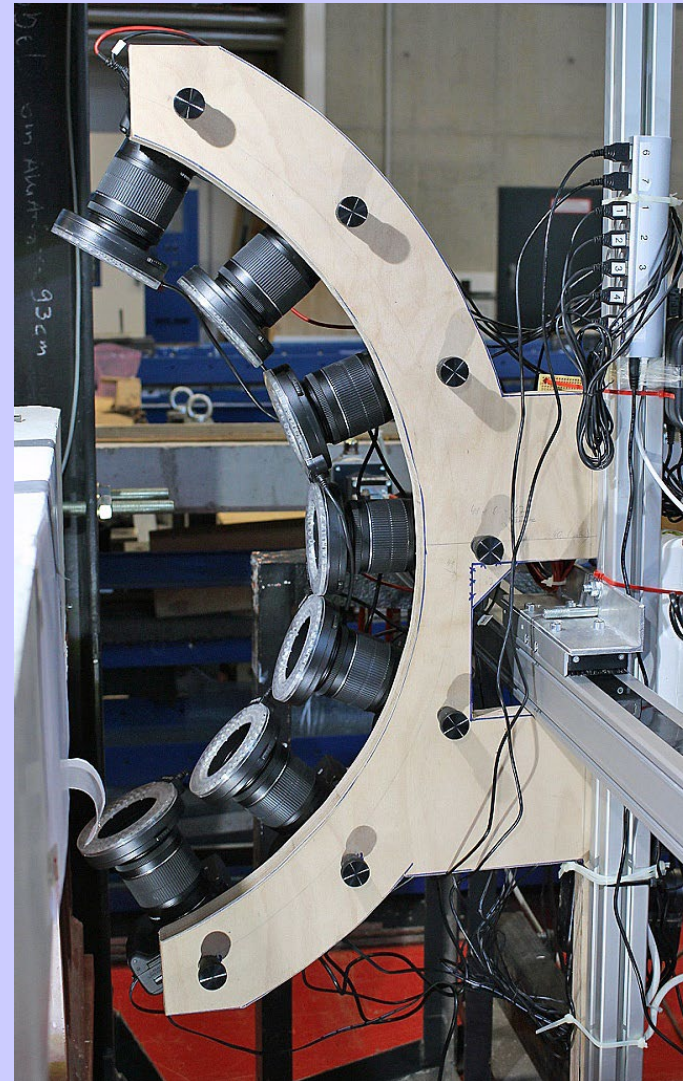
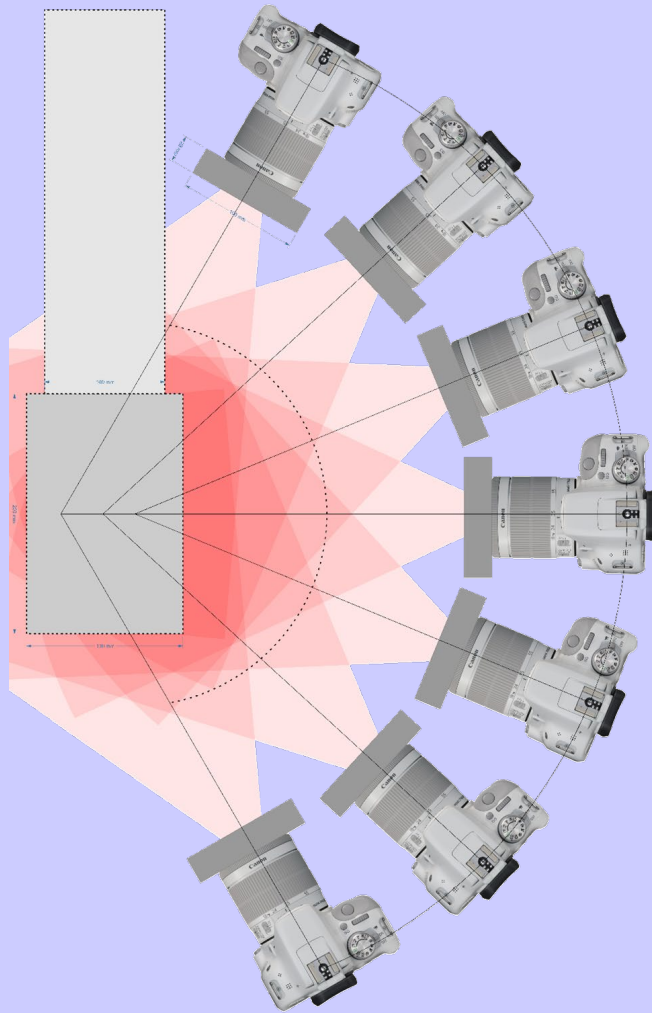
Workflow: Image-based crack detection



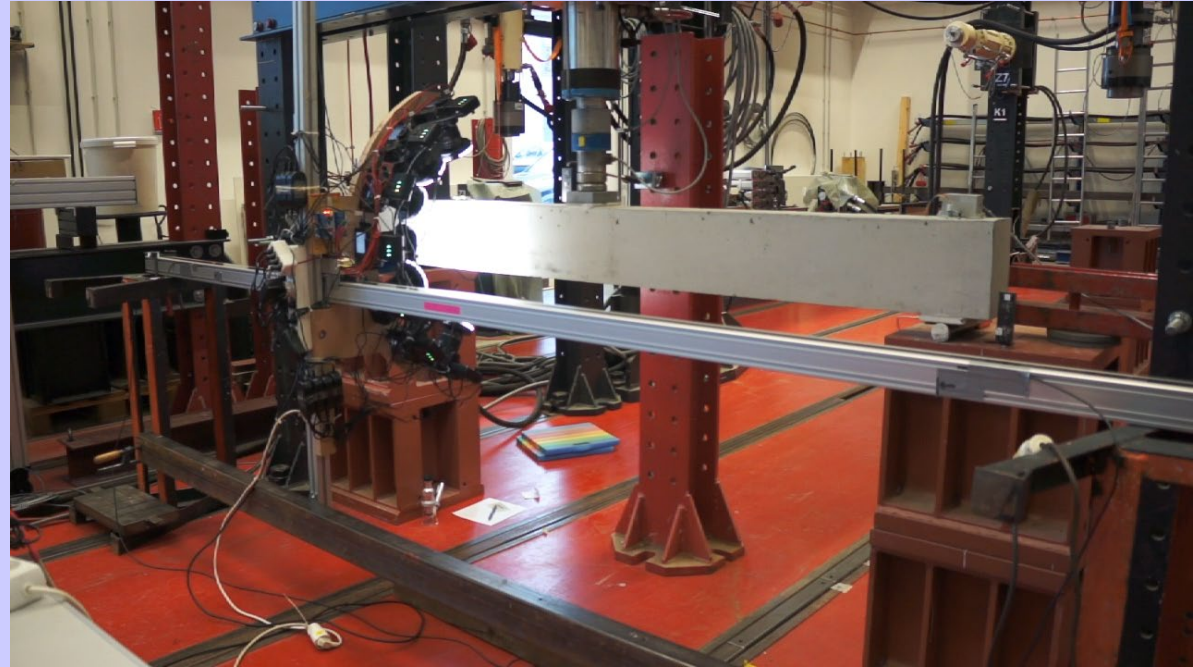
Pixel-precise annotation of training data



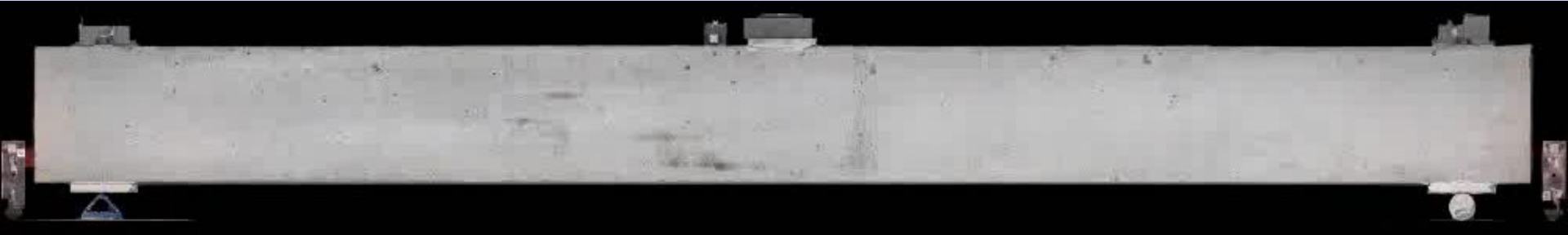
Sensor platform on linear track



Automated data acquisition

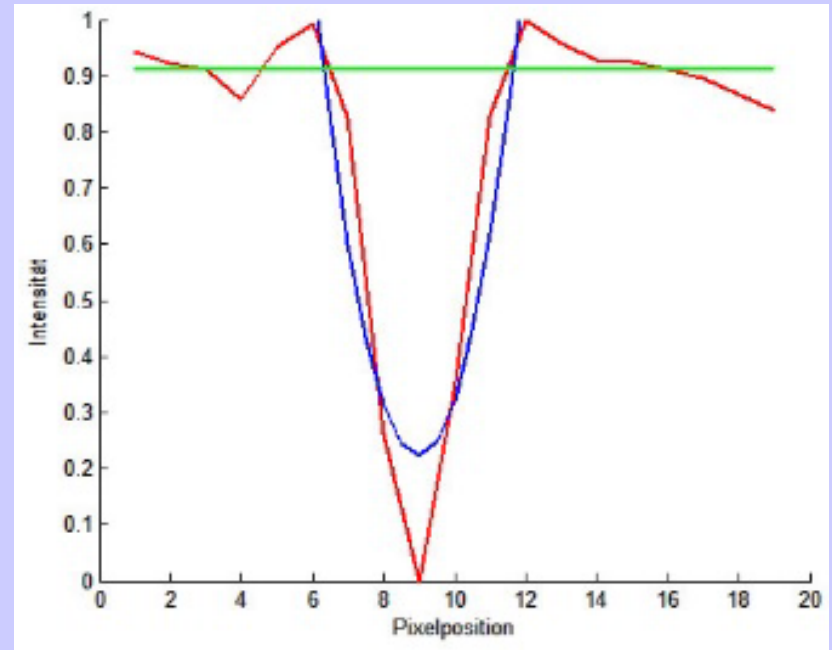
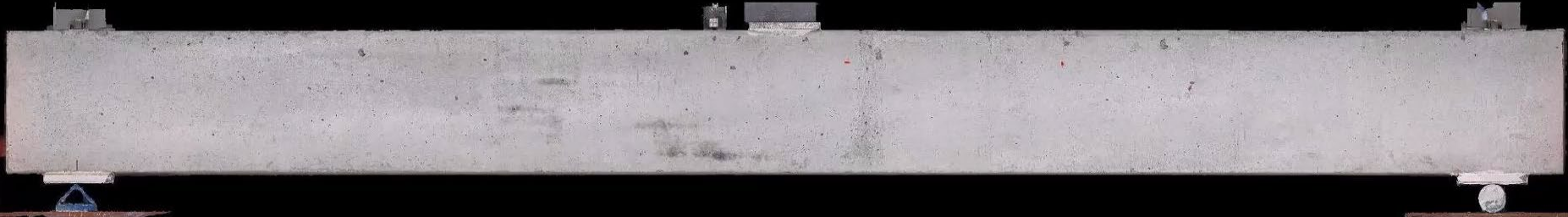


Concrete beam bending test



Progress through crack width measures

0.0kN



Challenges of damage detection



Pollution



Discoloration



Graffiti

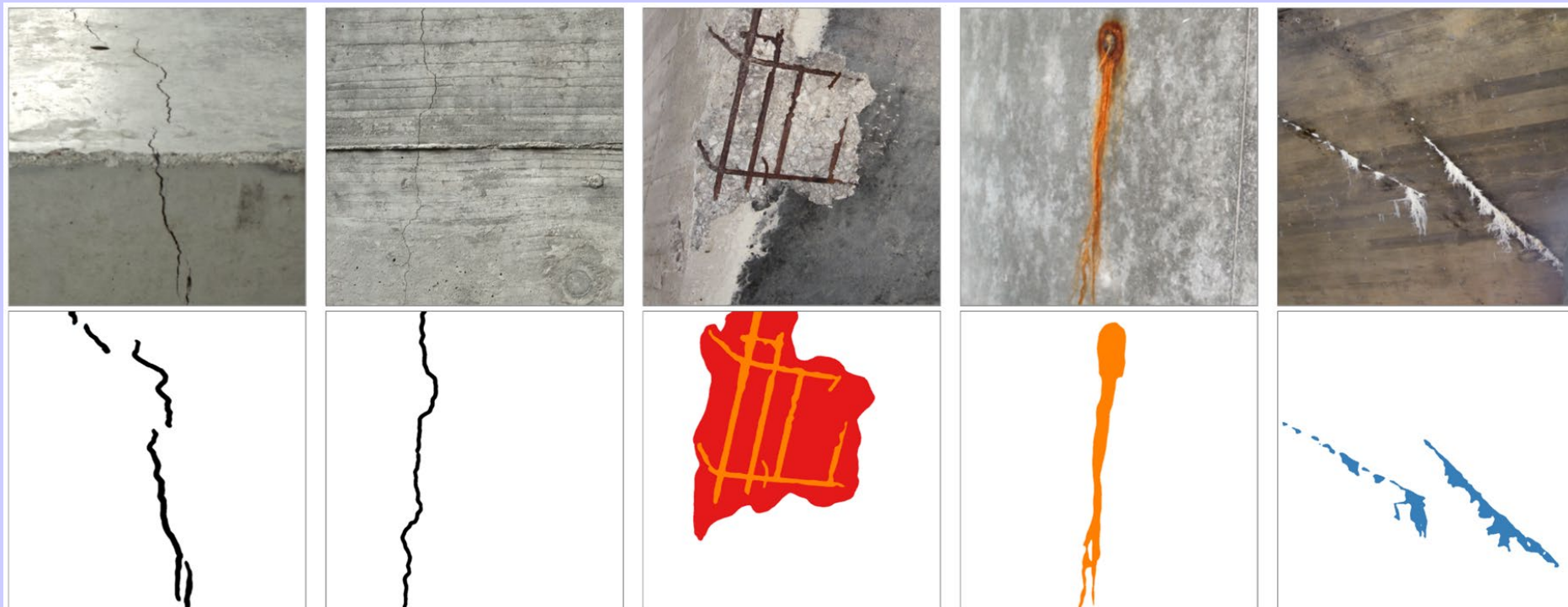


Scarf edges



Wood grain

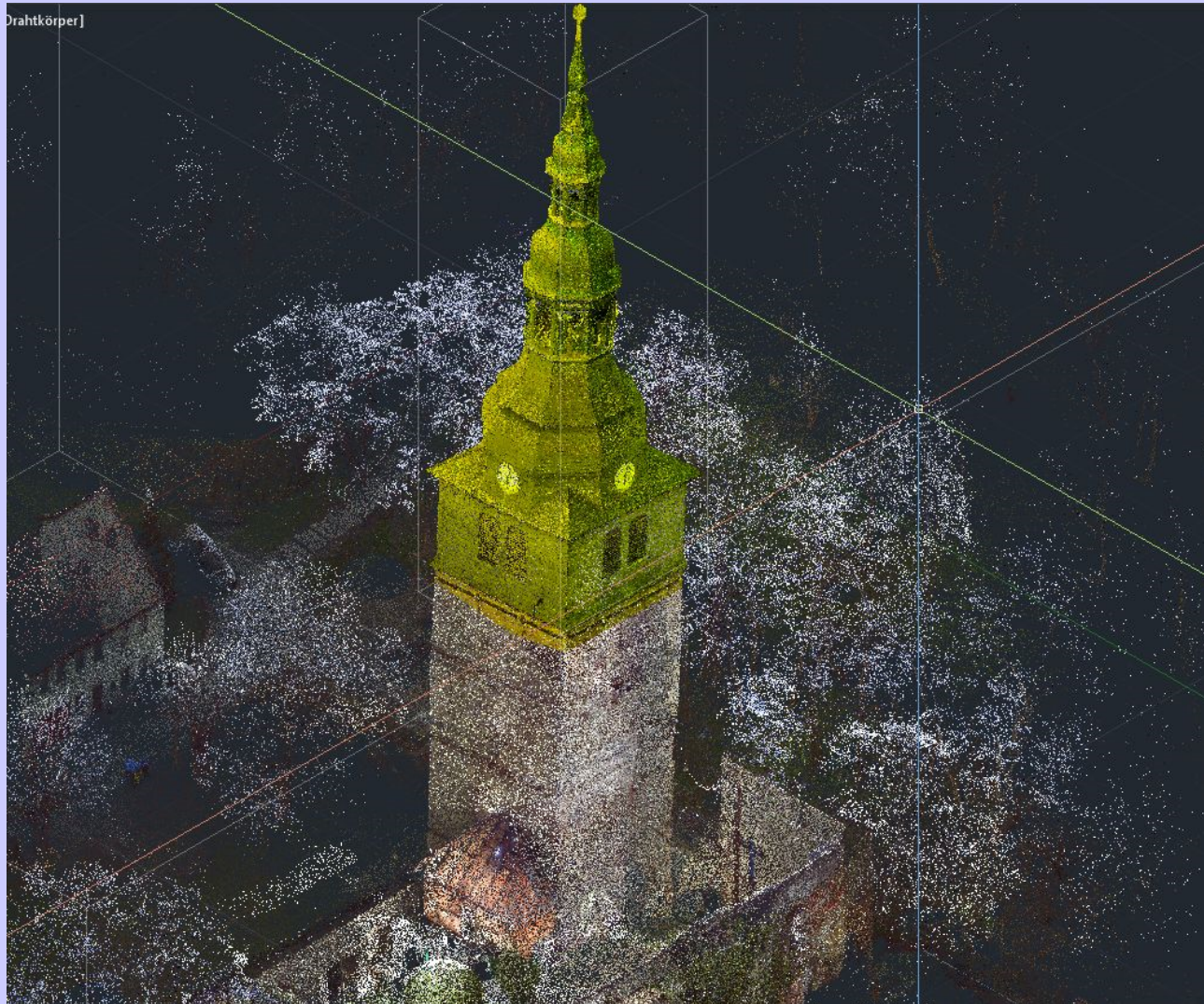
Other types of damage



Tower in Bad Frankenhausen



Laserscanning vs. photogrammetry



UAS as sensor platform



Monitoring of monuments



Data representation



Sparse point cloud (7 Mio.)



Dense point cloud (310 Mio.)



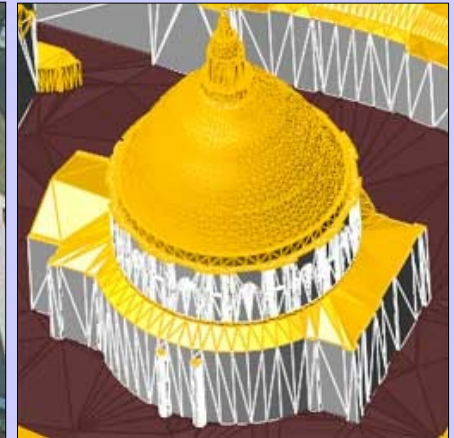
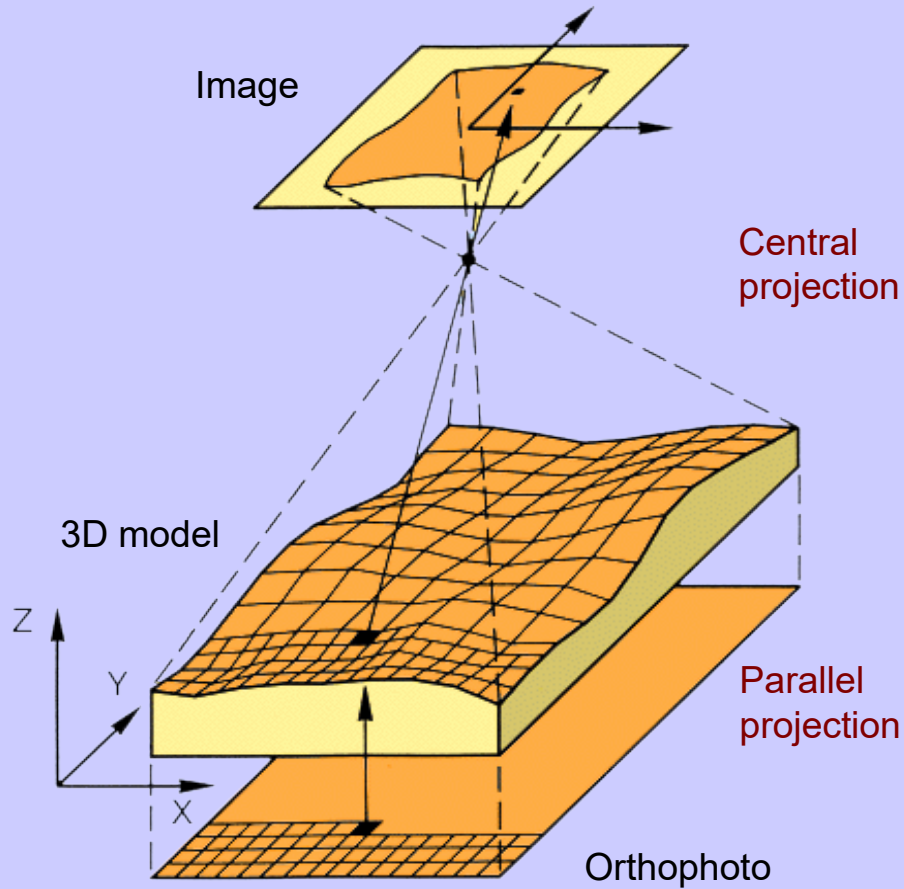
Polygon mesh of triangles
with texture map (62 Mio.)

Shaded relief



Detail view of the dense point cloud

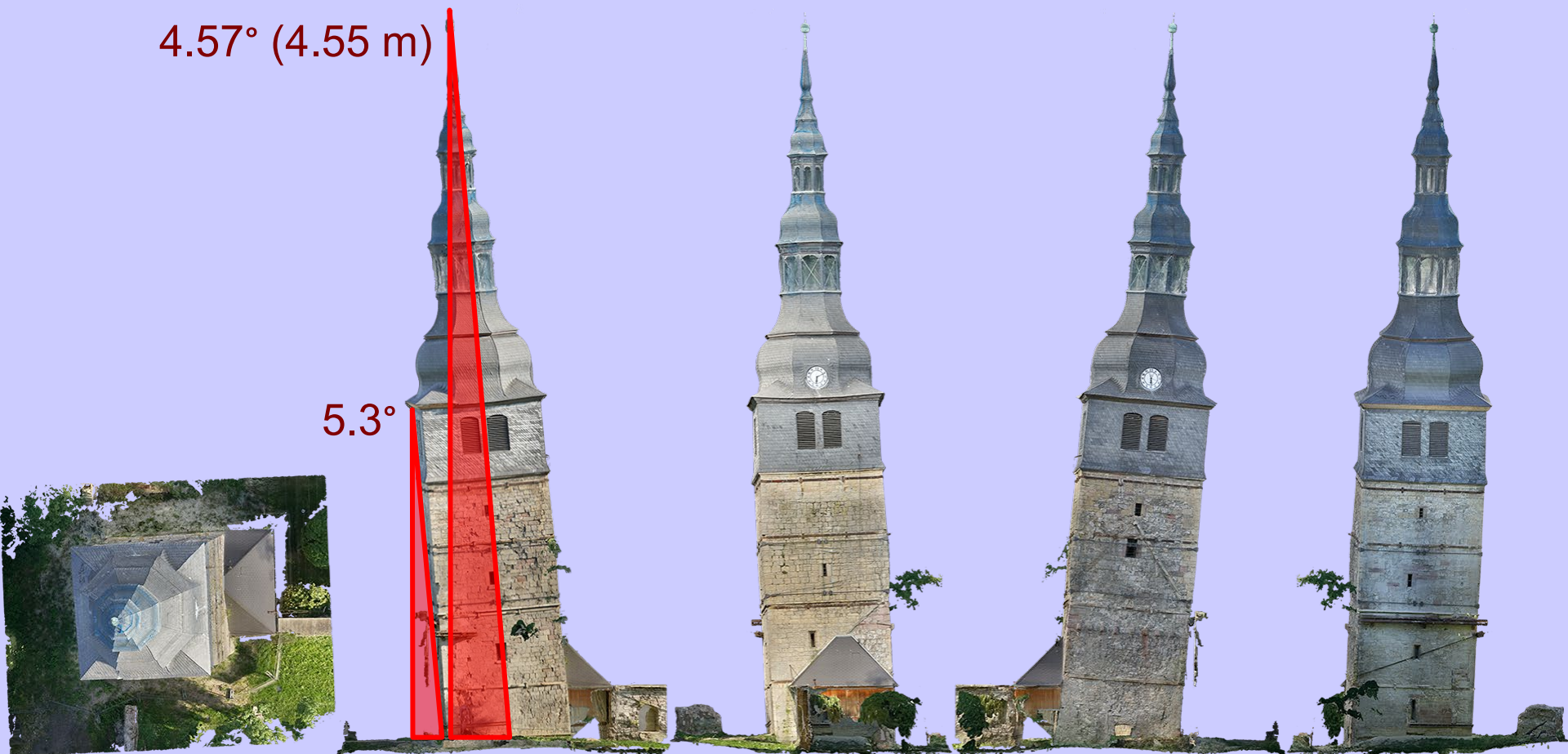
Orthophotos by differential rectification



Orthophoto mosaics

4.57° (4.55 m)

5.3°



top

north

west

south

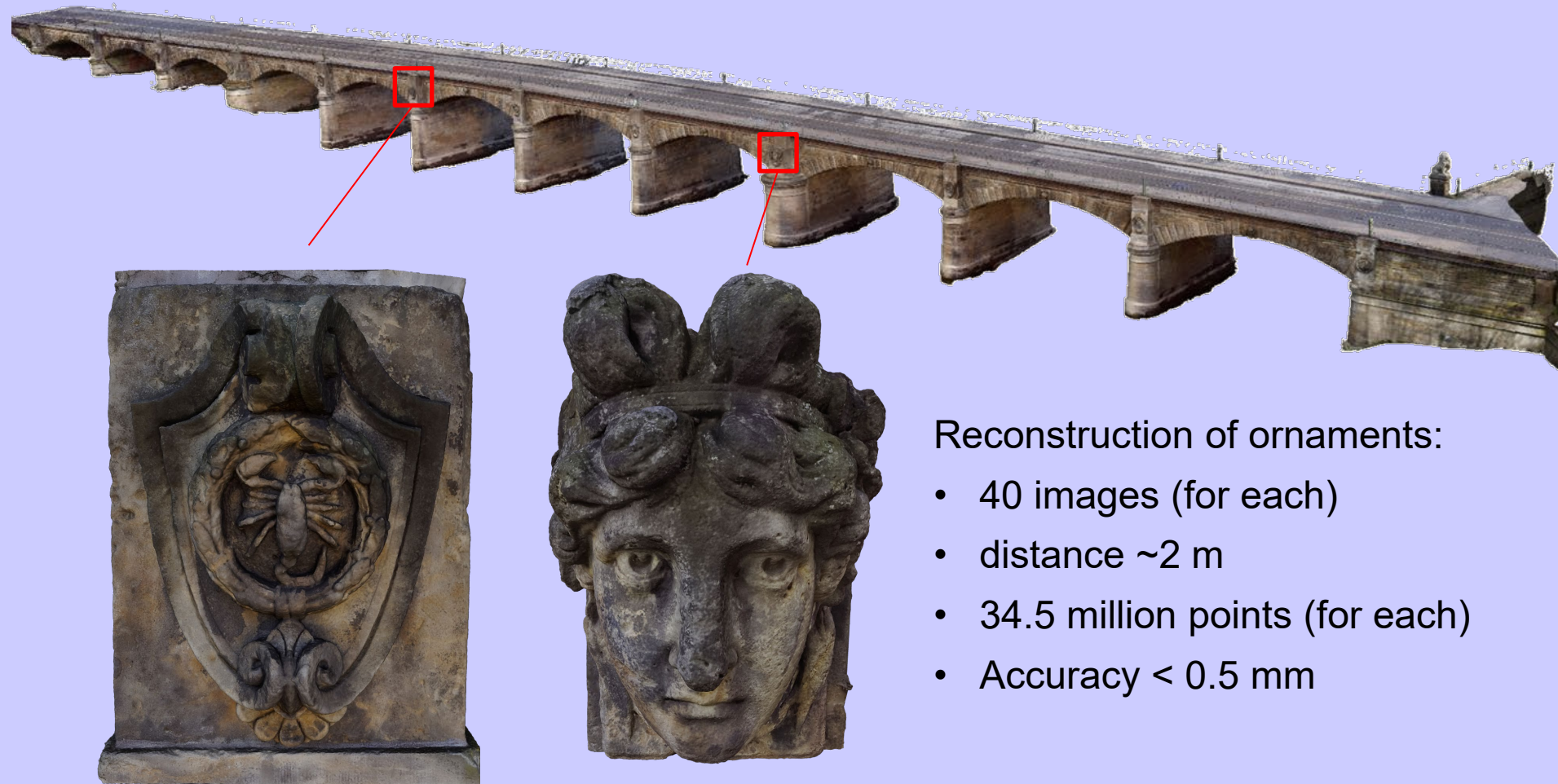
east

Video: Anna-Ebert bridge

ASCENDING
TECHNOLOGIES



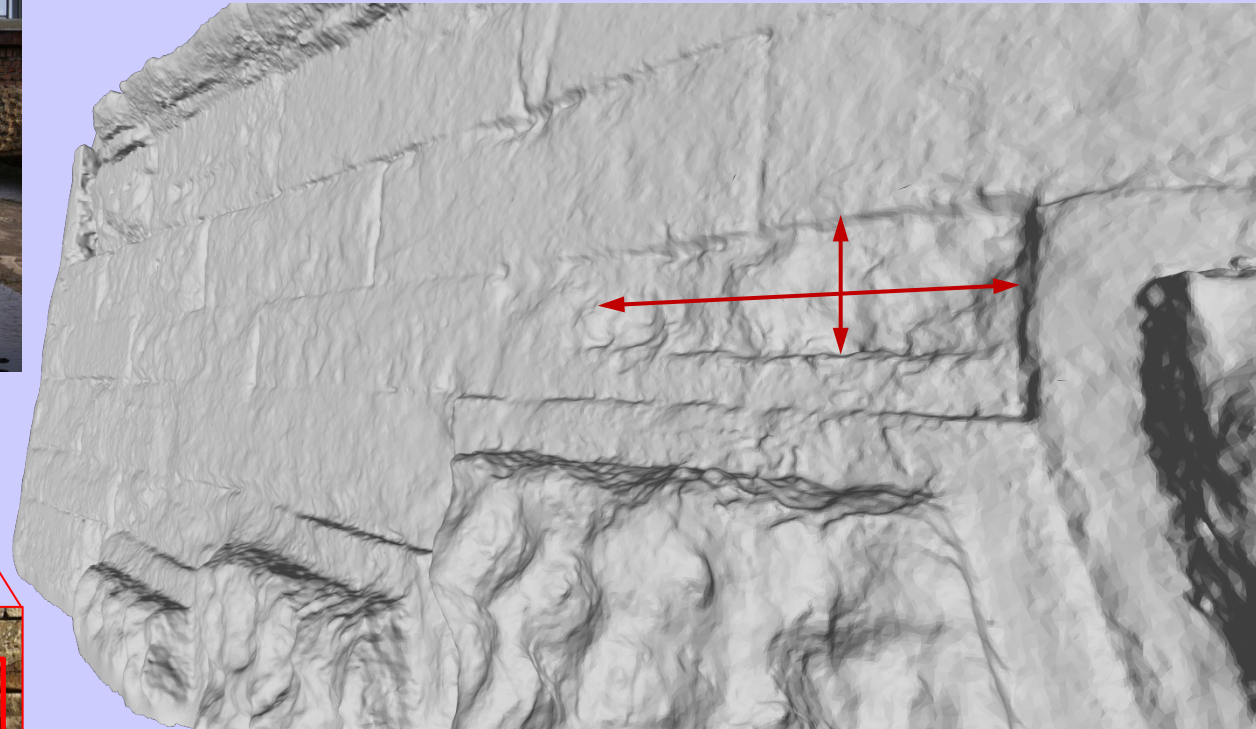
Bridge & ornament reconstruction



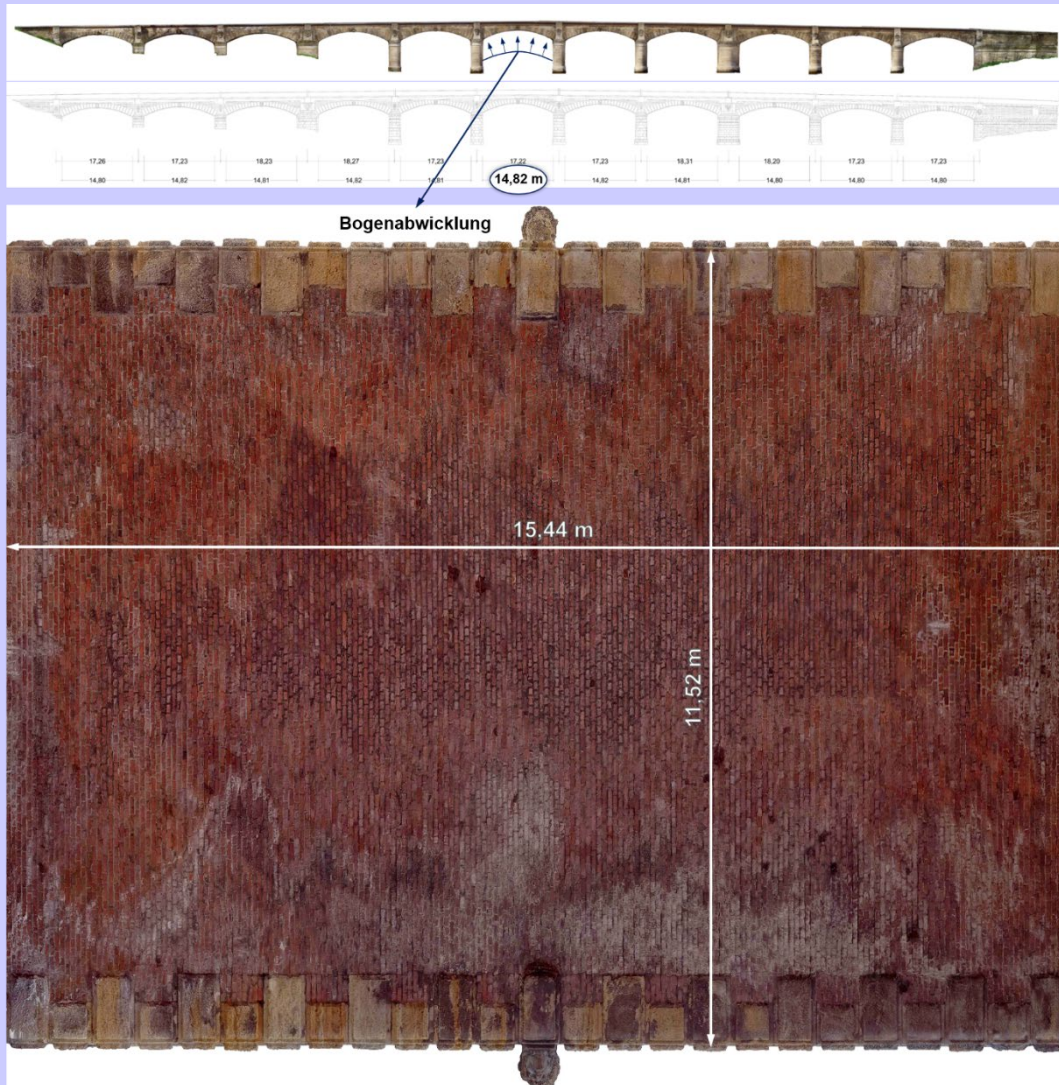
Reconstruction of ornaments:

- 40 images (for each)
- distance ~2 m
- 34.5 million points (for each)
- Accuracy < 0.5 mm

Damage detection



Cylinder unrolling



Deformation measurements

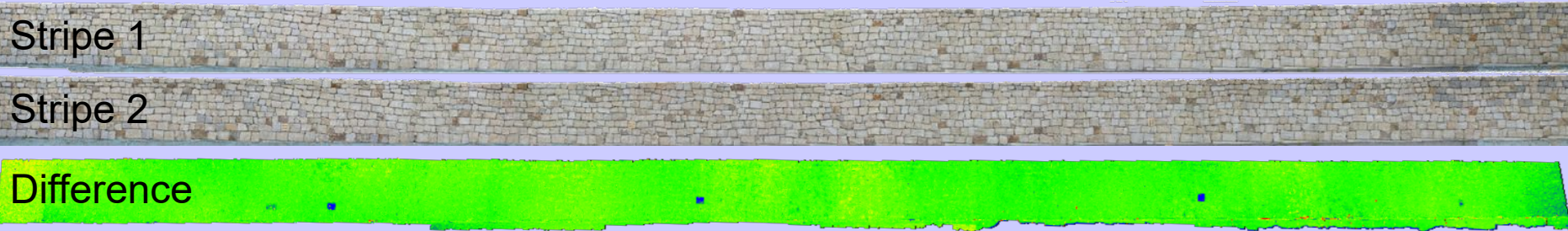
Retaining wall of the Jagdberg tunnel (BAB 4)



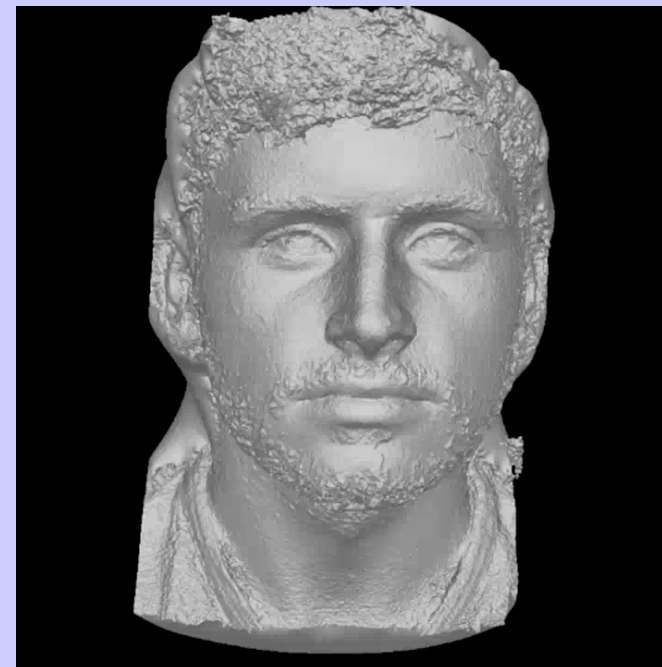
Stripe 1

Stripe 2

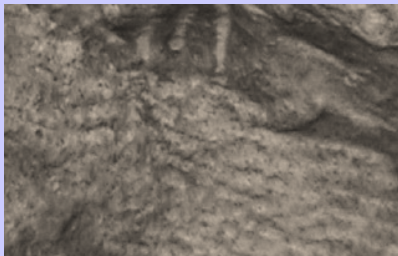
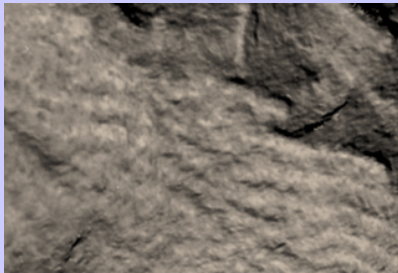
Difference



Motion analysis using video cameras



Material properties



Thank you ...



... for your attention!