

Terrestrial Laser Scanning

6. Lecture

Applications

Ing. Tomáš Křemen, Ph.D.

Presentation was supported by 105 1052201A003 FCE CTU in Prague Internal Project

Contents

- Crane rails
- Road flatness
- Determination of volume
- Focus of the Chapel of the Holy Spirit

Crane Rails

- Water power plant in Gabčíkovo (Slovakia)
- Steel hall of the engine room
- Overhead travelling crane
 - length 241 m
 - projected span 17,7 m



Motivation

Verification of possibility to use the laser scanning for the static check of the crane rails

The main goal of crane rails measuring is checking their geometric parameters

ISO 12488-1 norm, STN 73 5130 norm

- Span of the crane rails
- Horizontal straightness of the rail head
- Vertical straightness of the rail head

Checking of crane rails - tolerances

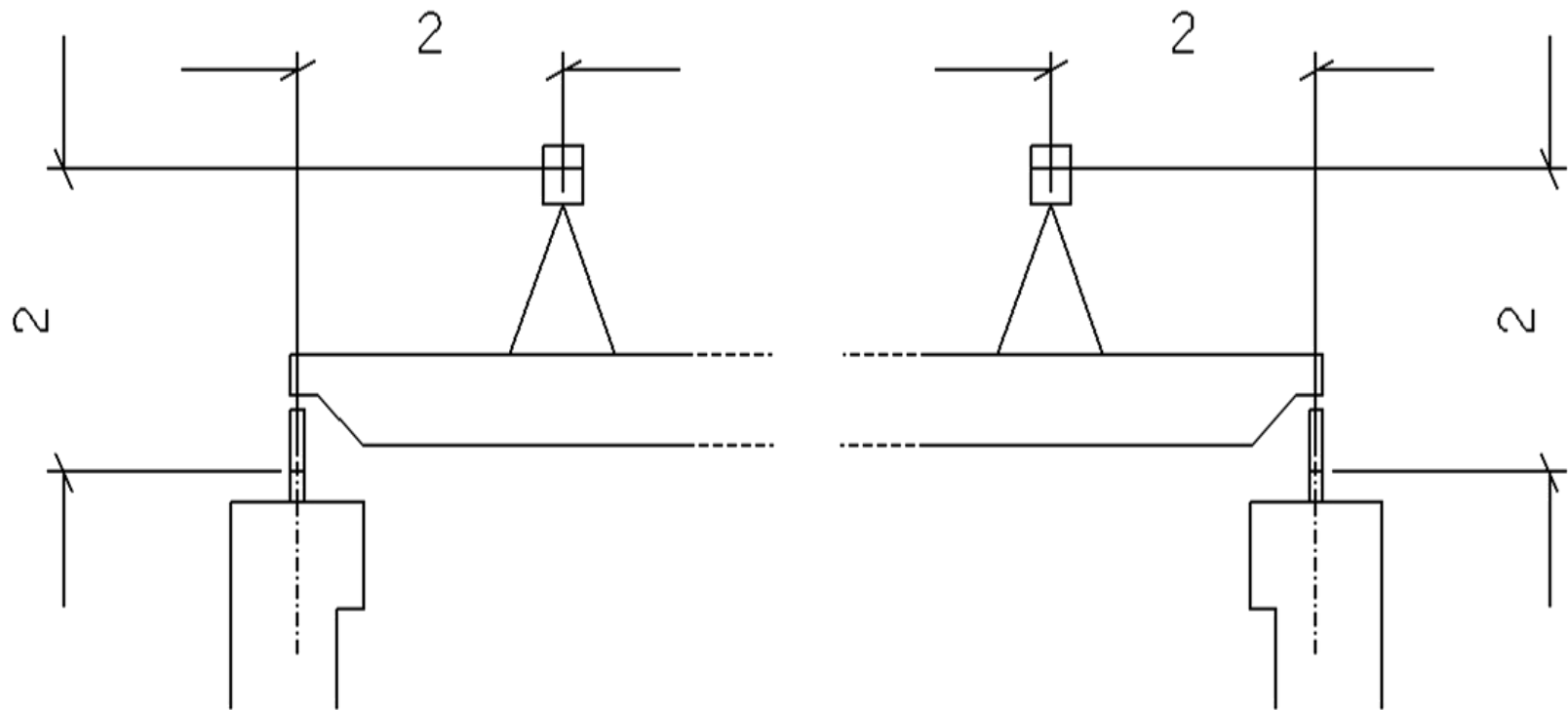
- Tolerance of span is 5,5 mm
- Tolerance of horizontal straightness of rail head is 10 mm
- Tolerance of horizontal straightness for length of 2 m is 1 mm
- Tolerance of vertical straightness of rail head is 10 mm
- Tolerance of vertical straightness for length of 2 m is 2 mm

Laser scanning

- Scanner Leica HDS3000
- 73 m long section was measured
- 4 stations
 - Placed in the crane platform
 - It was measured one rail in the distance of approximately 45 m from one station
 - After measuring both rails from one position of crane (2 stations), movement of the crane about 30 m and next measuring of both rails
- 6 identical points

Laser scanning

- Position of the scanner in the crane platform

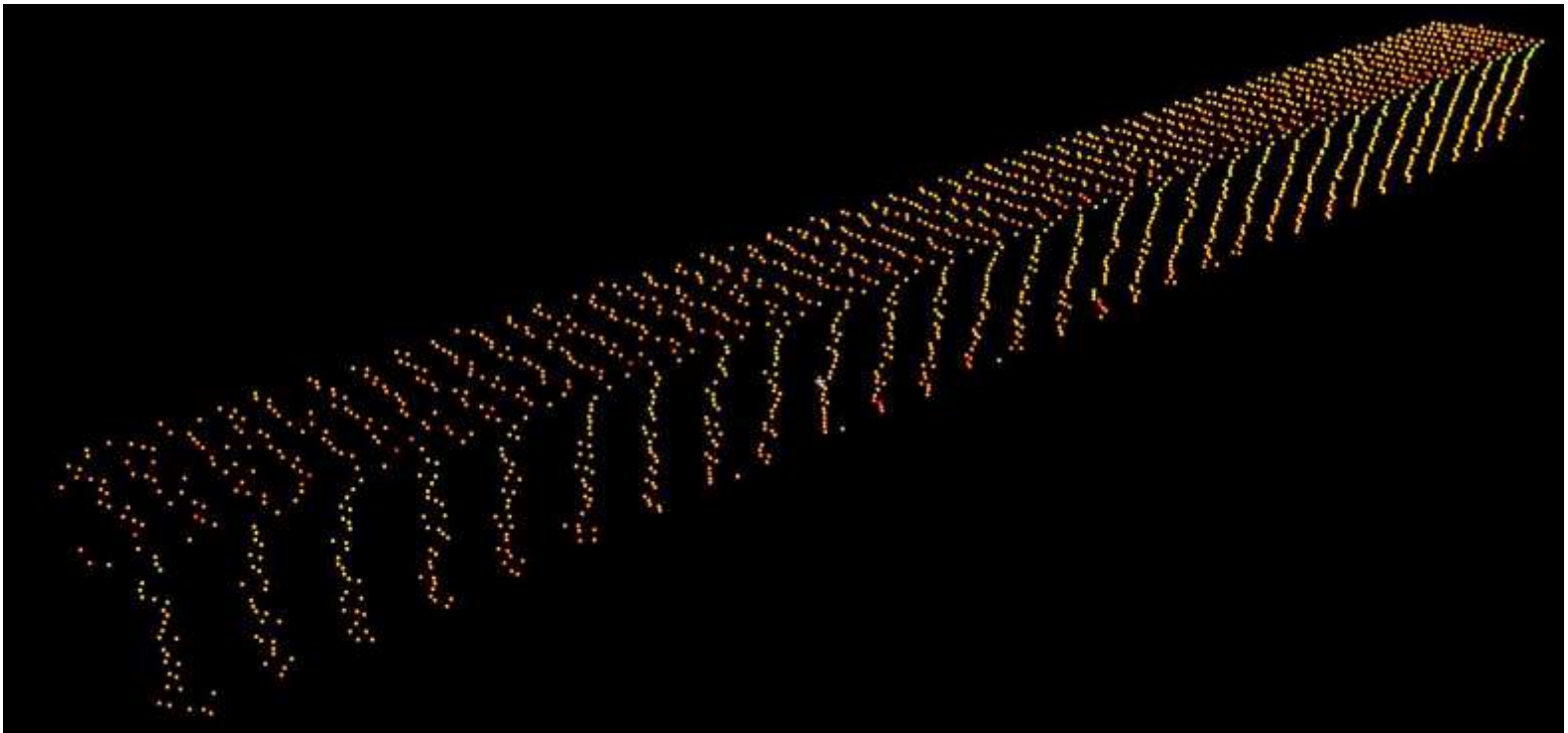


Processing

- Transformation and registration of measured point clouds, $\sigma_t = 0.8 \text{ mm}$
- Cloud cleaning
- Rail modelling
- Evaluation of crane track parameters
- Comparison with classical measurements

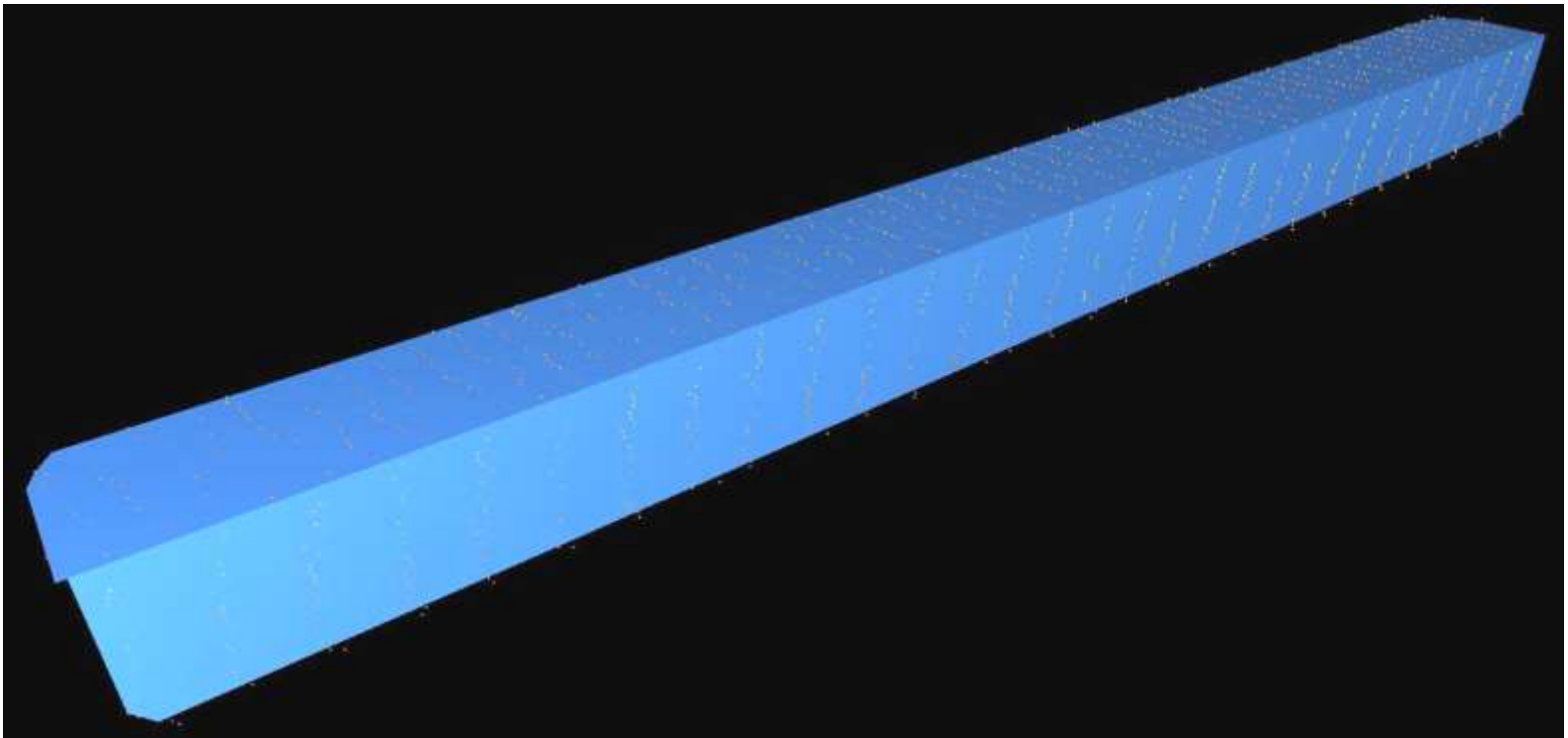
Processing

- Rails was segmented into one-meter sections in the stationing direction, totally 73 segments on each rail were obtained



Processing

- Fitting of the planes by upside and inside of the rail in the section

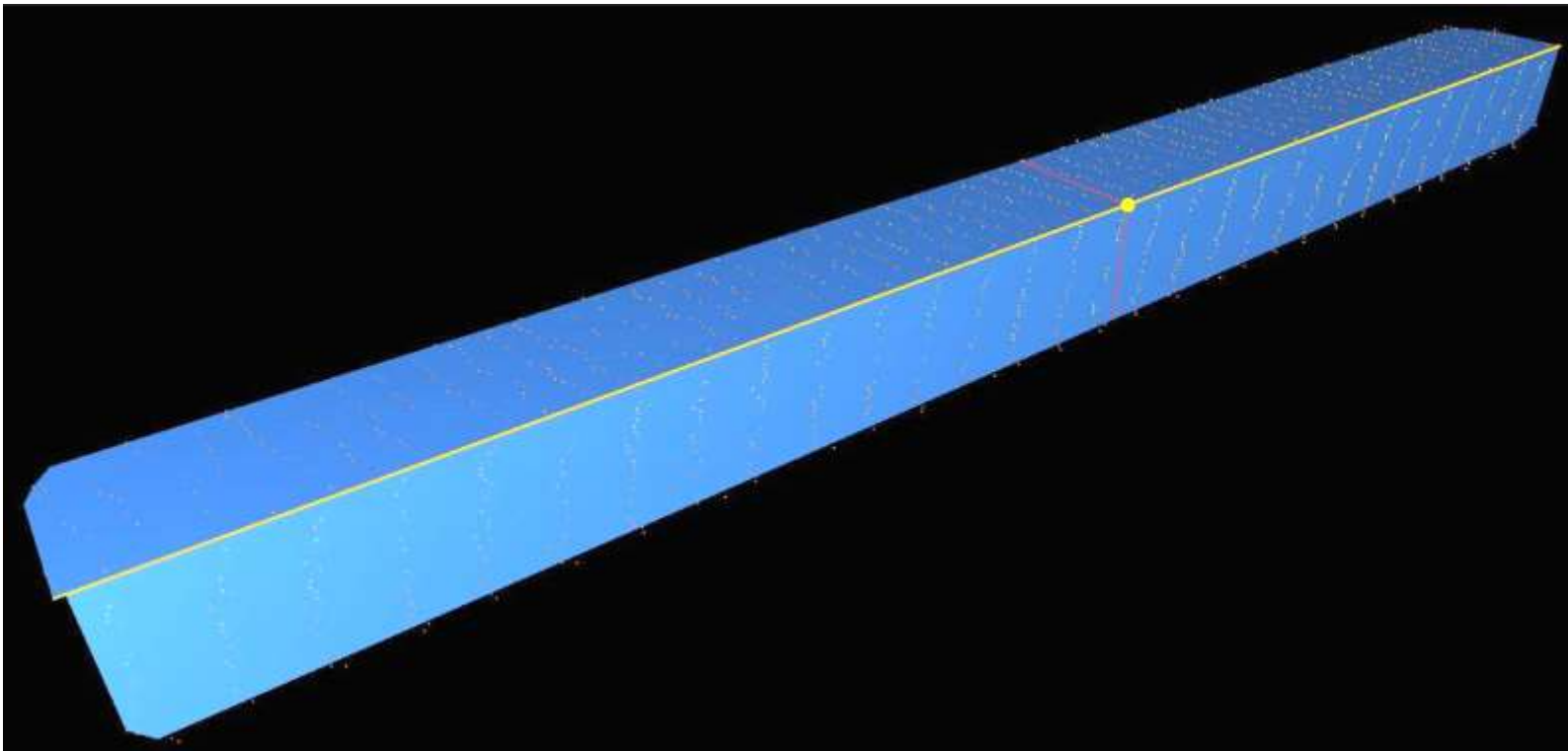


Processing

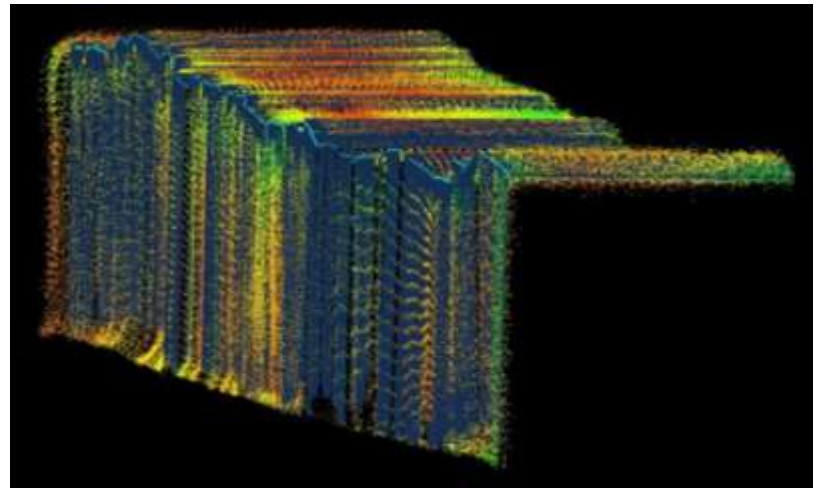
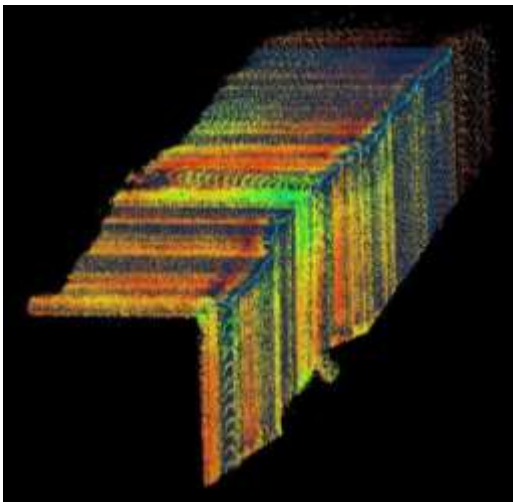
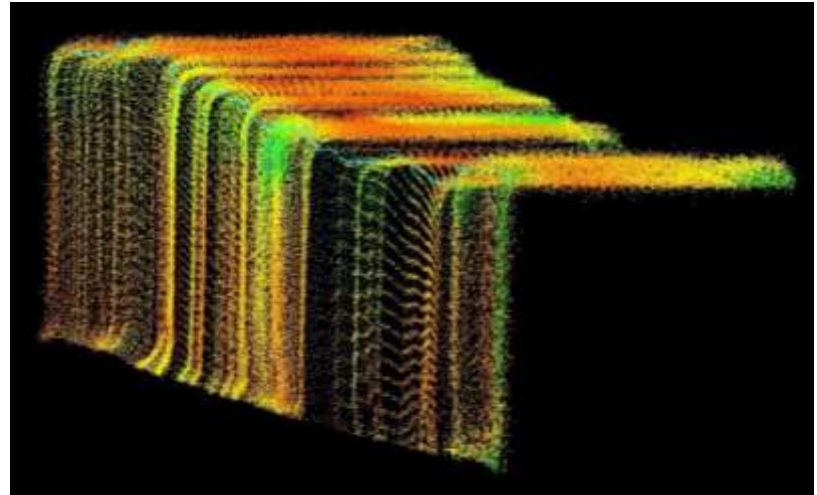
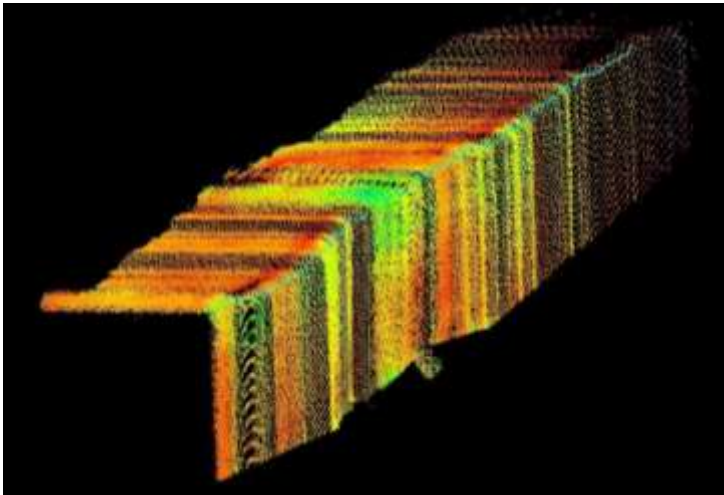
- Point in the intersection of this two planes and perpendicular plane to the axis of rail in the stationing $0,5 + (N - 1) \text{ m}$ where N is the section number was created
-
- These points (73 for each rail) were used for evaluation of measuring the crane rail

Processing

- Point in the intersection



Point cloud of the rails



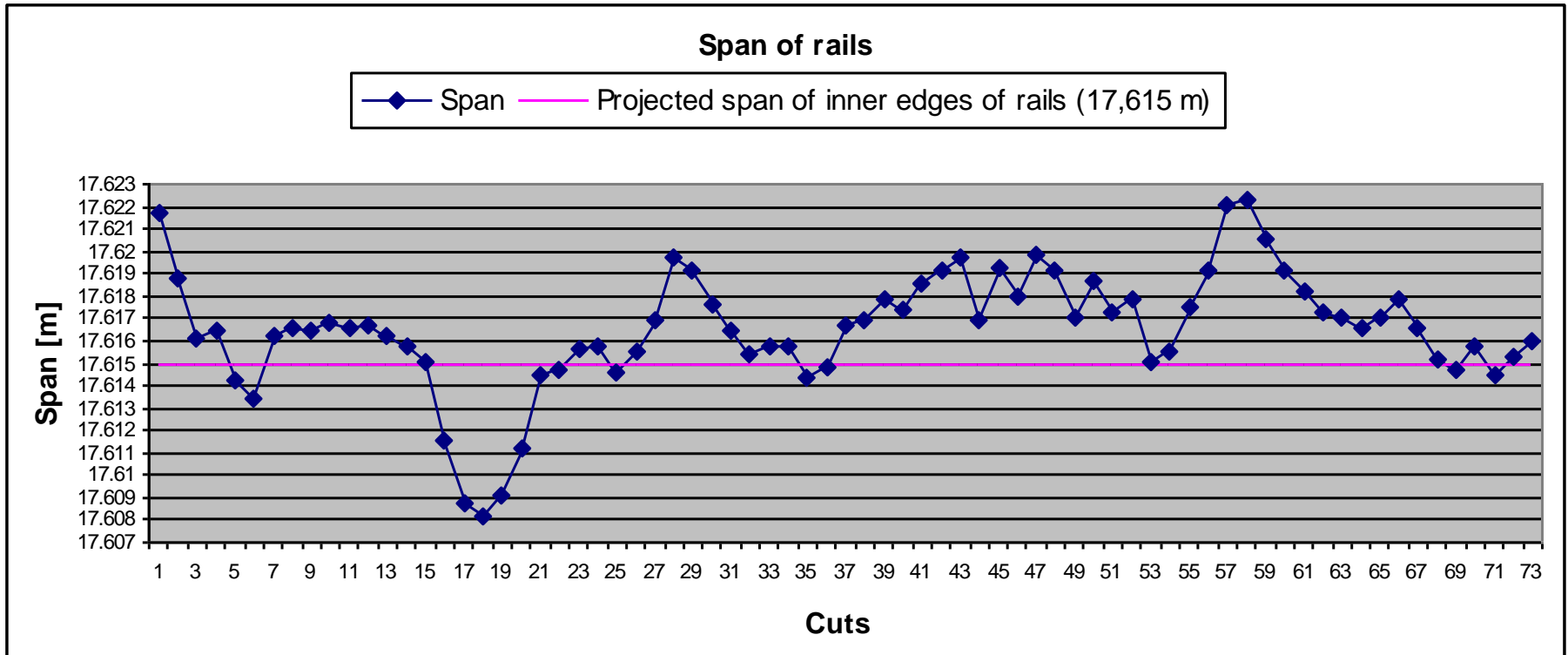
Results

3 outputs were obtained

- rail span
- height deviation of the running surface of the rail
- horizontal deviation of the rail centreline

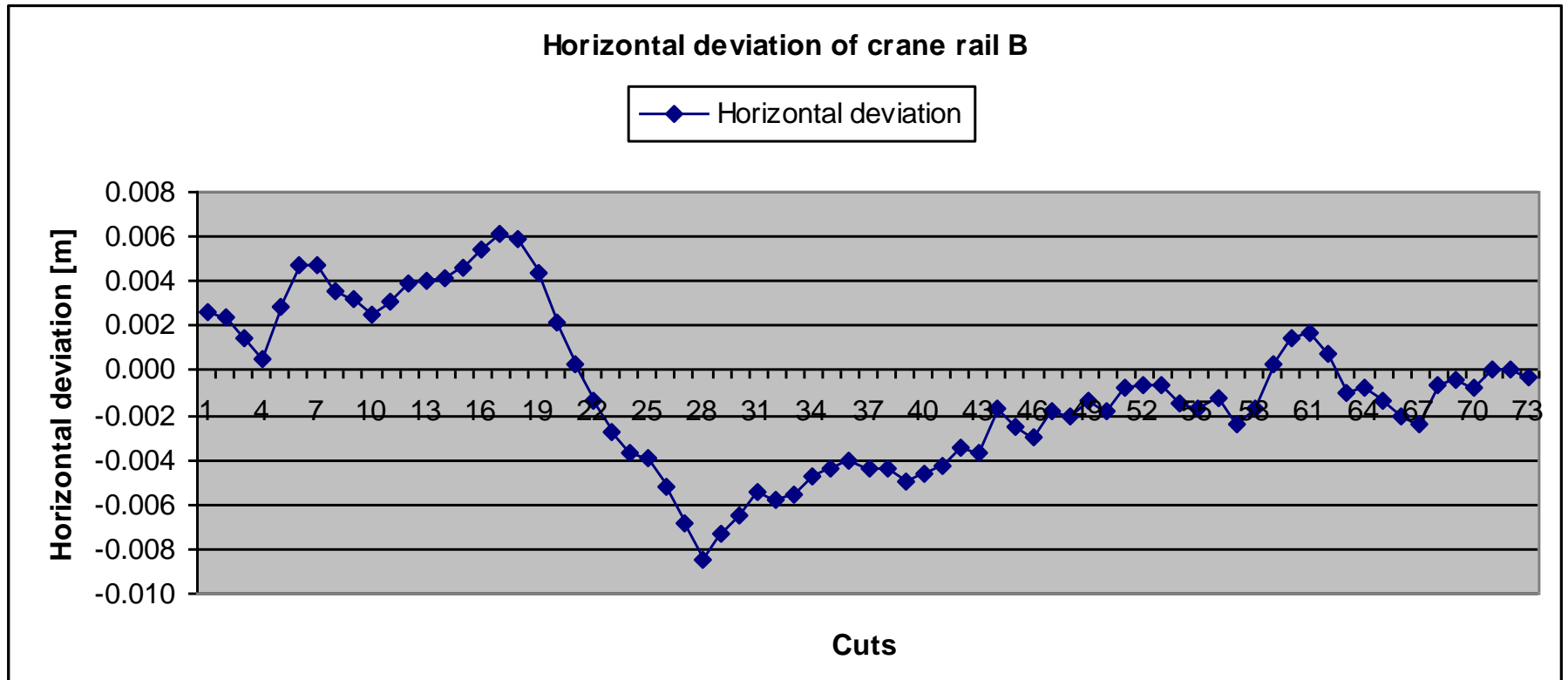
Rail span

- The maximum deviation of span for span up to 20 m is ± 5 mm
- The maximum deviation was exceeded



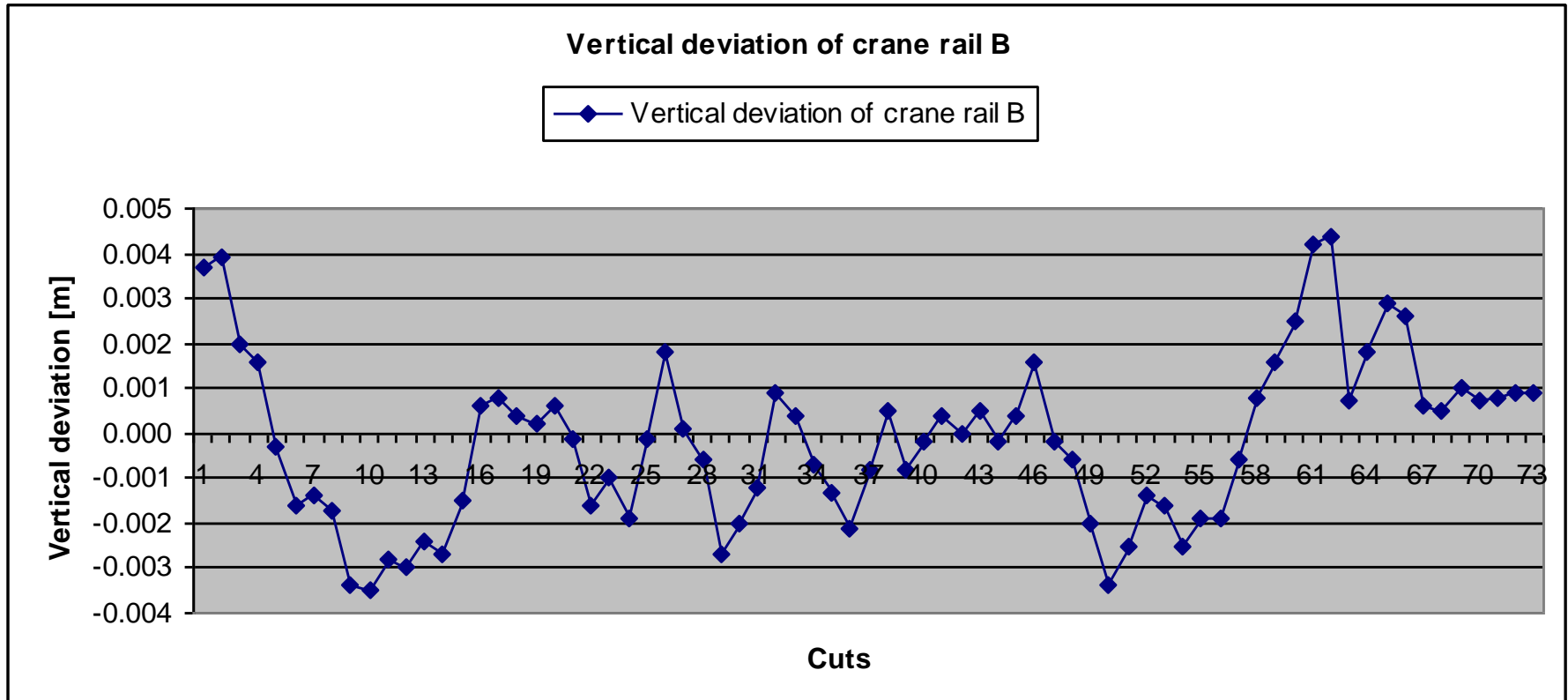
Horizontal deviation

- Maximum horizontal deviation is ± 10 mm
- The maximum deviation was not exceeded



Vertical deviation

- Maximum horizontal deviation is ± 10 mm
- The maximum deviation was not exceeded



Accuracy analysis

- Comparison between results of the laser scanning and the classical method was carried out
- Overlap of both measurement was approximately 60 m section
- Point coordinates were compared

	ΔS [m]	Rail A		Rail B	
		ΔH [m]	ΔX [m]	ΔH [m]	ΔX [m]
Average difference [m]	-0.003	-0.001	-0.003	0.000	-0.004
Standard deviation of measure differences [m]	0.003	0.001	0.003	0.001	0.005

Conclusion

- The experiment shows utility and suitability of the laser scanning technology for check of the crane rails
- It is possible to measure the rail in big distance under a very steep angle of incidence
- The accuracy of the laser scanning and classical method are comparable
- Measuring and processing time are also similar
- The main benefit is high density of measured data

Determination of Pavement Elevations by the 3D Scanning System and Its Verification

- Verification of the static terrestrial 3D scanning that was used for determination of road pavement roughness
- Design and realization of checking procedure for this verification
- Temporary test field

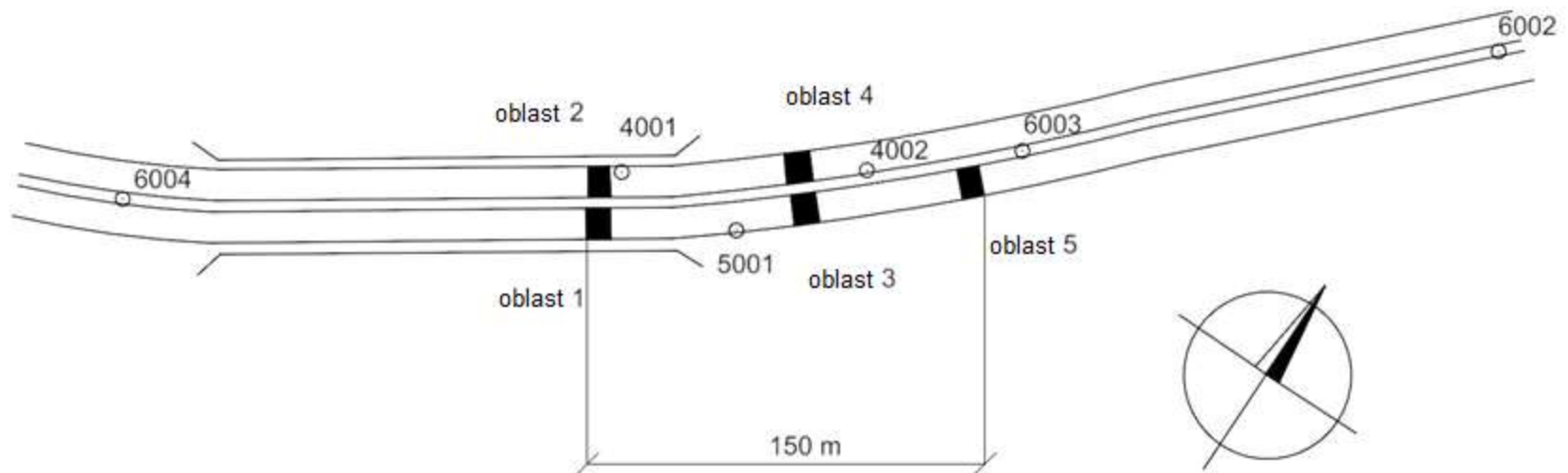
Locality

- New four-lane highway in southwest part of Prague



Temporary test field

- Five separate areas in 150 m long part of highway
- Size of each area was approx. 5 m x 8 m



Temporary test field

- Checking points
- Precise trigonometric method
 - Measurement in one set
 - Automatic aiming
 - Flat peak on the bottom of the measuring rod
- Total station Trimble S6 HP robotic
- One station in the center of the test field

	entire field	1. area	2. area	3. area	4. area	5. area
number of points	161	50	35	27	28	21

3D scanning

- The highway was scanned with the Riegl VZ-400 scanner in all length – standard commercial measurement
- The temporary test field was scanned with the Leica HDS3000 scanner for comparison

3D scanning with Riegl VZ-400

- “Stop and go” 3D scanning technology
- Georeferencing by GNSS and total station measurement
- The scanner is mounted on the mast which is fixed to the car
- One station – area with radius 50 m
- Final density – bigger than 2000 points in m^2 on the ground

3D scanning with Leica HDS3000

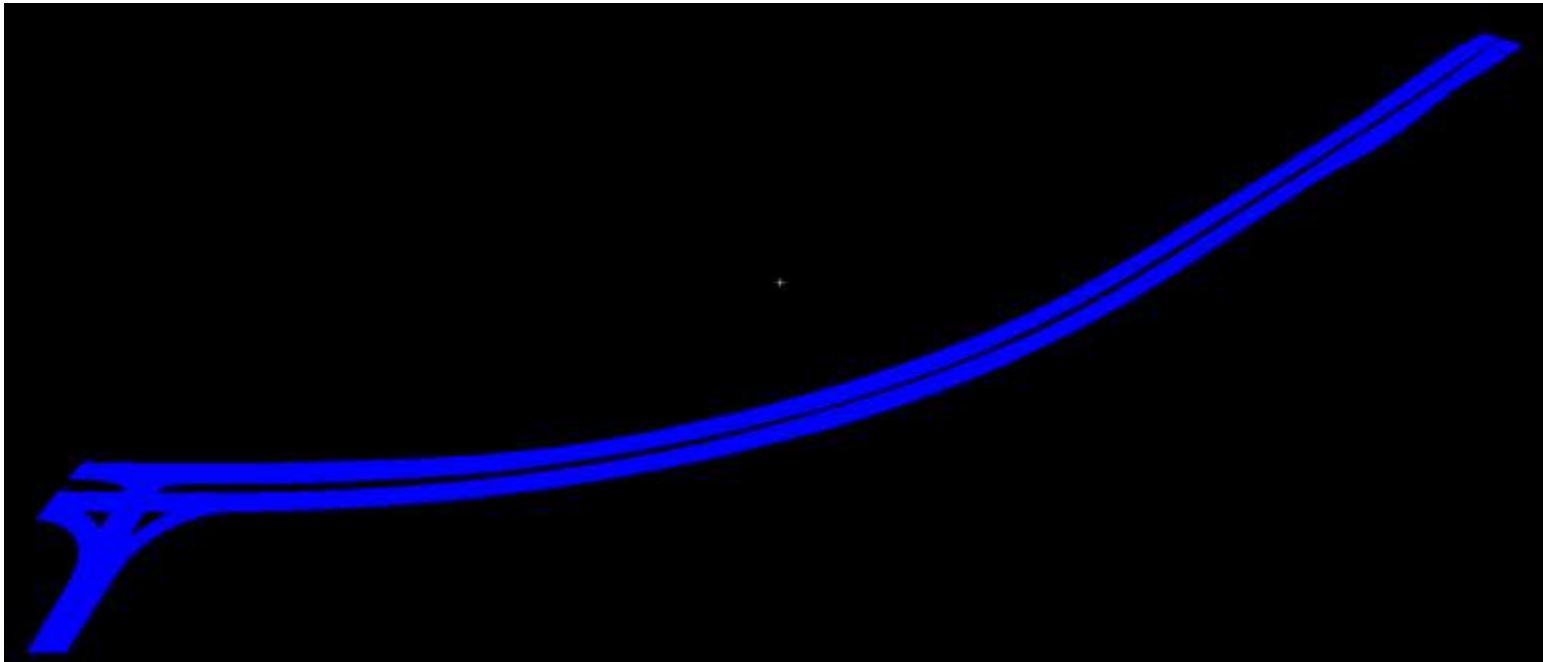
- Common static terrestrial measurement
- Used only for measurement of the test field
- Each area was measured from one position of scanner
- Control points measured by Trimble S6 total station were used for georeferencing
- Density 10 mm (Hz) x 5 mm (V) in the distance 10 m
- Maximum distance 11 m

Processing

- Determination of the test field checking points coordinates
 - Calculated in local coordinate system
 - Transformed into constructed road reference system
 - Elevations of the reference system were improved
 - Accuracy of checking point's heights are better than 1 mm
 - Improved reference system was used for processing of 3D scanning

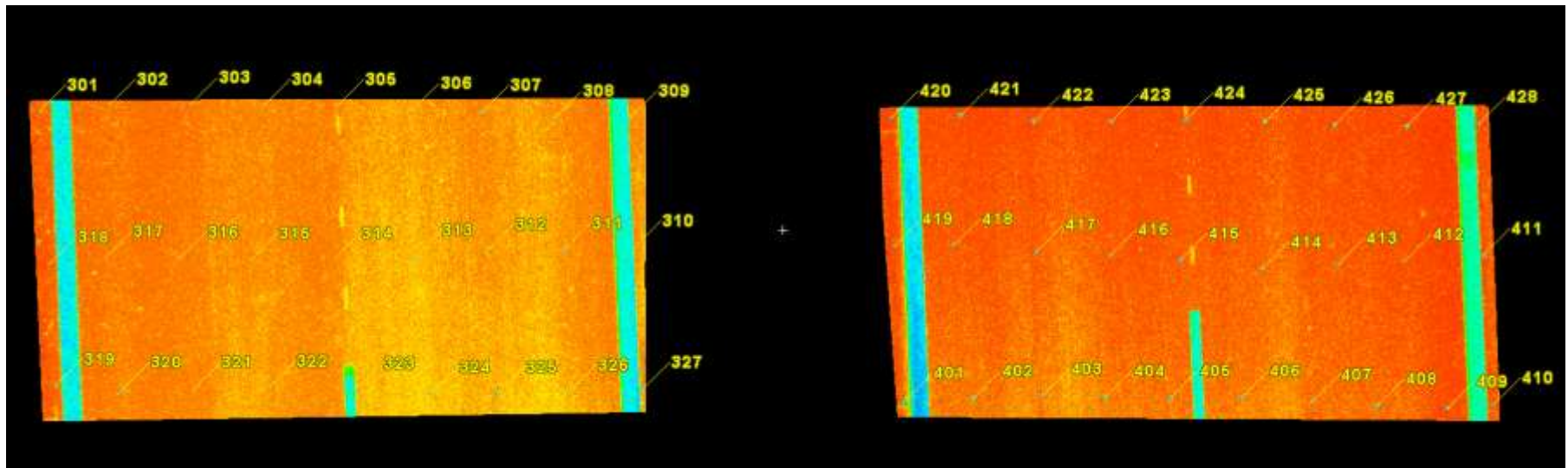
Processing

- Riegl VZ-400
 - measured data was transformed into reference system
 - Creation of DTM of the locality



Processing

- Leica HDS3000
 - measured data was transformed into reference system
 - Creation of DTM of the test field



Verification of laser scanning technologies accuracy

- Special software for comparison of elevations of the checking points and elevations of DTMs was created by our colleague Bronislav Koska
- high differences Δh_i between elevation of checking point and elevation of DTM in the same place were calculated
- High difference sample standard deviation $s_{\Delta h}$, arithmetic mean t (high systematic error) and precision p (high random error) were calculated

Results

- High differences in the 3. and 4. area for HDS3000 (in mm)

3. AREA

+1.59	+0.95	+1.03	+0.61	+0.49	+0.11	+1.45	+0.86	+0.9
+1.72	+2.02	+1.16	+1.82	+0.56	+0.18	+0.3	+0.31	+0.71
+0.61	+0.76	+0.5	+0.13	+0.07	+0.76	+0.94	+0.44	+0.87

4. AREA

+2.45	+2.01	+2.17	+1.37	+2.23	+1.91	+2.12	+1.59	+0.26
+1.91	+2.47	+1.39	+1.43	+0.48	+1.06	+1.69	+1.42	+2.46
+8.55	+1.61	+0.24	+2.1	+1.15	+0.48	+0.93	+1.7	+0.54
								+1.48

Results

Sample standard deviation $s_{\Delta h}$, arithmetic mean t and precision p

all values are in mm		entire field	1. area	2. area	3. area	4. area	5. area
HDS3000	$s_{\Delta h}$	1.57	0.72	1.26	1.08	1.45	3.39
	t	0.52	0.15	-0.21	-0.53	1.24	2.95
	p	1.48	0.71	1.24	0.94	0.72	1.54
VZ-400	$s_{\Delta h}$	4.04	4.40	5.03	1.36	2.09	5.63
	t	3.55	4.23	4.79	1.00	1.89	5.37
	p	1.90	1.07	1.29	0.89	0.81	1.19

Determination of the volume of the Borek Pit by 3D scanning system

- Documentation of a part of an abandoned mine after the collapse of the cover on entrance
- For the purposes of remediation of this accident

Lokalita

- Cutting pit No. III in the gold ore deposit Kasejovice - Bělčice
- The profile of the pit is approx. 4.5 m x 3.5 m, depth 60 m
- Flooded with water
- The entrance of unfilled pit was covered with a cover of steel beams and rails and covered with a pile of aggregate
- There was a collapse of the loft

View of the pit



Measuring

- The main objective of documenting the condition, shape and volume of the unlined part of the pit
- Scanned with a Faro Focus 3D x 330 scanner on a special tripod with an adjustable Nestle Manhole Tripod
- The scanner was lowered upside down under the tripod
- Three measurements - just above the top edge of the pit, 1.2 m below the edge and 3.5 m below the edge

Measuring

- Measurement time 3 minutes
- Change scanner position 3 minutes
- Total measurement time 30 minutes
- The instrument was controlled wirelessly using a tablet
- Scan connections were planned over overlapping areas

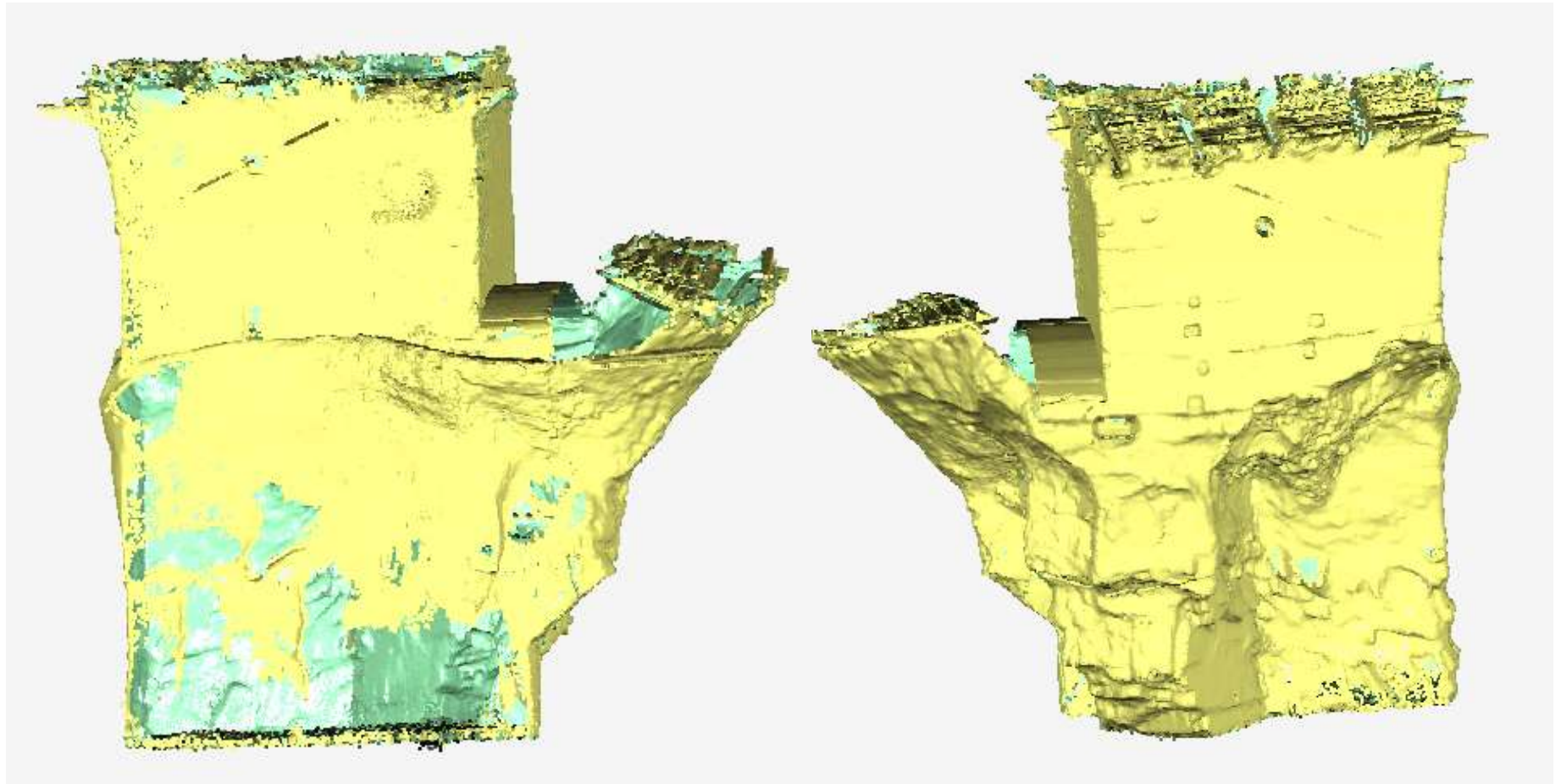
Tripod with extended center bar and view into the scanner pit



Processing

- Measured clouds were exported in X, Y, Z, n_x , n_y , n_z format
- Loaded into Geomagic software
- Cleaning
- Dilution to a density of 30 mm
- Registration over overlay area
- Again diluted to a density of 30 mm - the resulting cloud contains 153,891 points

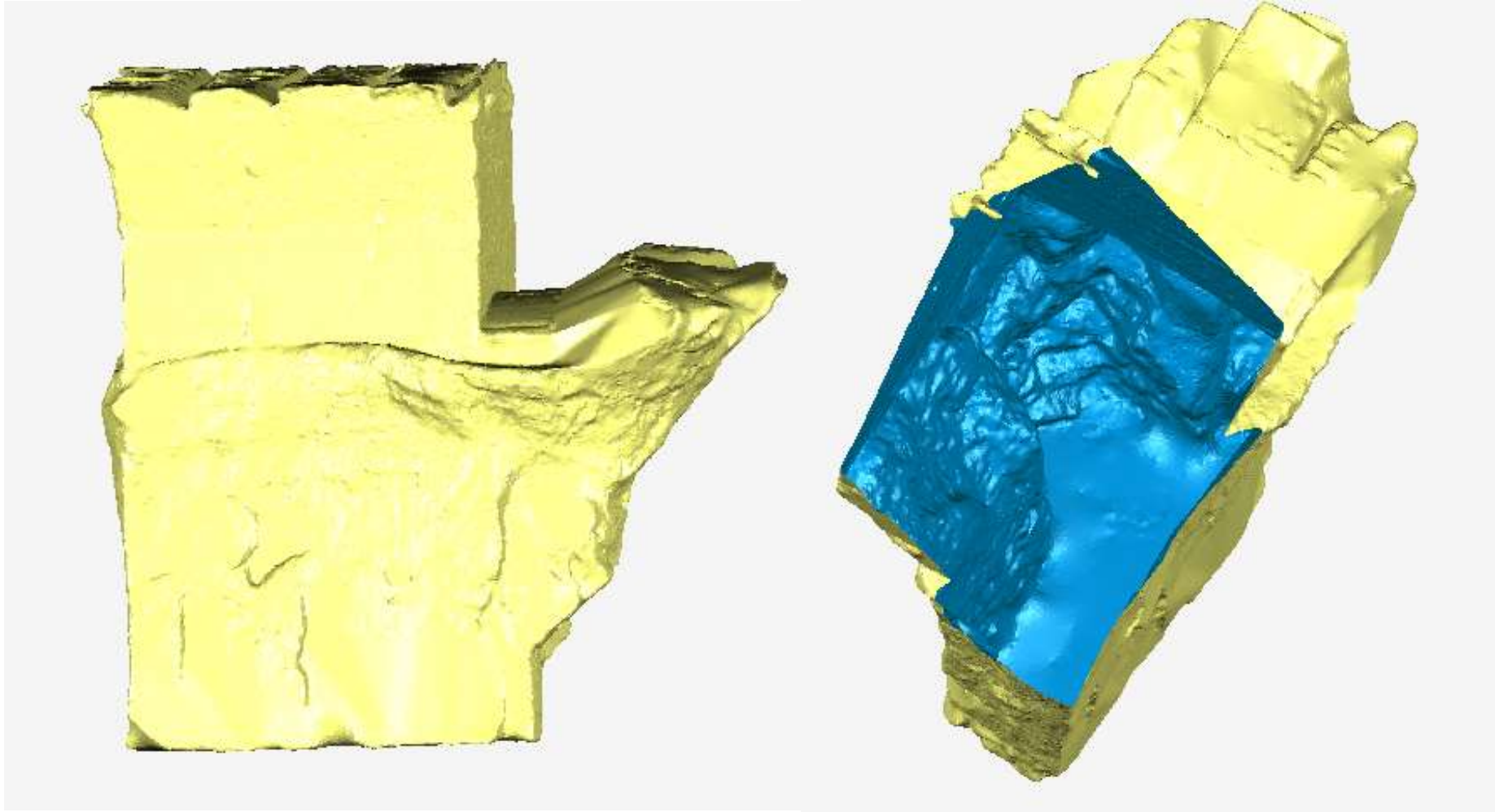
Point cloud



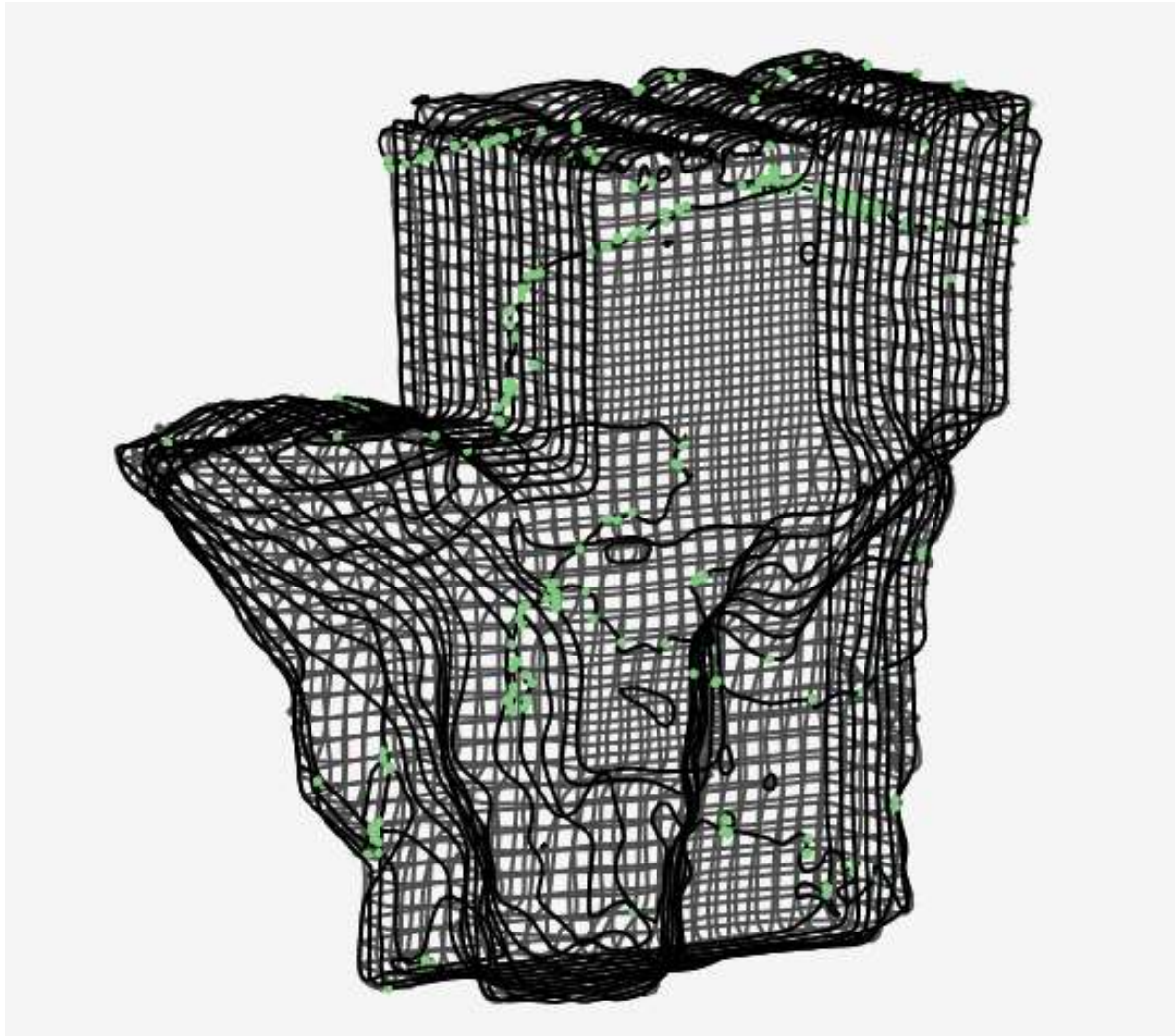
Processing and results

- 3D triangular mesh created
- Created solid cuts in all three axes at 20 cm
- Calculated the volume of 106 m^3 and the area of 173 m^2 of such a closed solid

Mesh



Cuts



As biult documentation of the Chapel of the Holy Spirit in Liběchov



Goals

- The building is in a disastrous condition - reconstruction is necessary
- Surveying of the building by 3D scanning system
- Crypt, ground floor and first floor surveyed
- Creation of drawing documentation
- Creation of a spatial model

Scanning

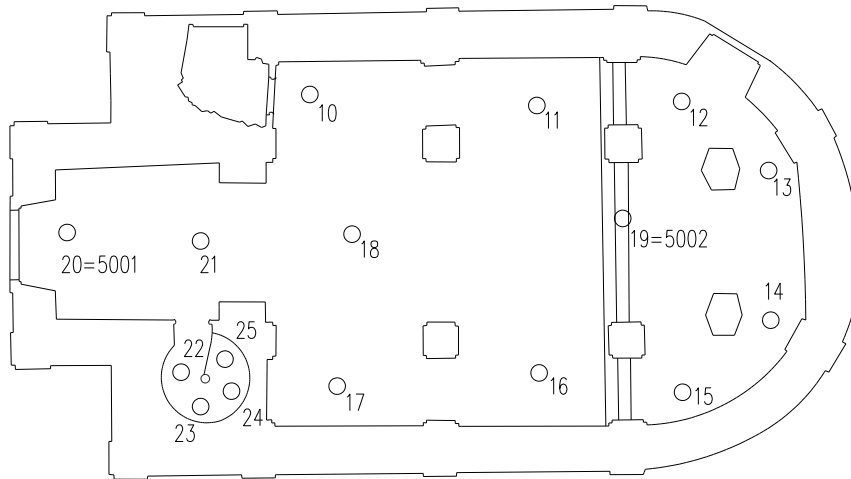


Scanning

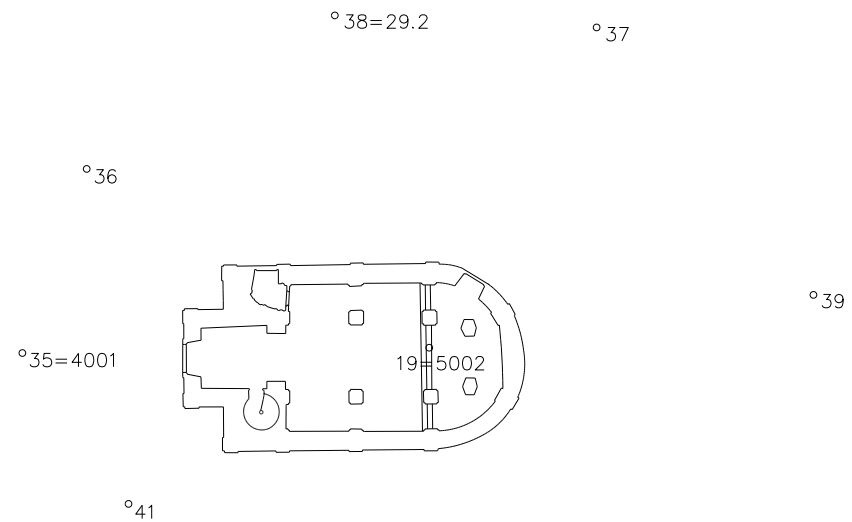
- FARO Focus 3D scanning system
- 42 positions
- No camera was used

Scanning

location of ground floor stations



positioning of sites in the surroundings of the building



°40=4002

Photogrammetry

- Used to obtain point clouds of the roof and upper parts of the object
- Gron DJI Spark
- Olympus E-300 digital SLR camera, ZUIKO DIGITAL lens
- Complications during taking photos

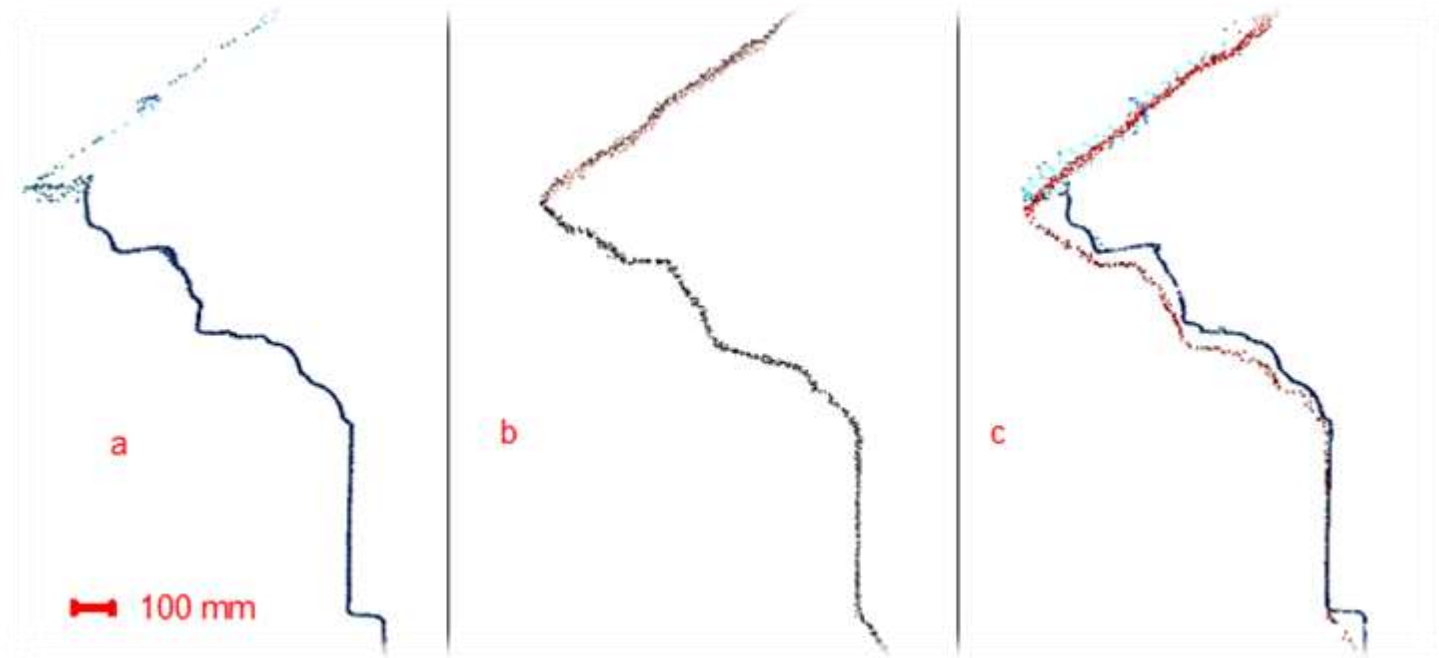


Photogrammetry

- Processing in Agisoft Photoscan software
- 96 images
- Spatial position and dimension - photogrammetric points
- Cloud exported in *.txt format

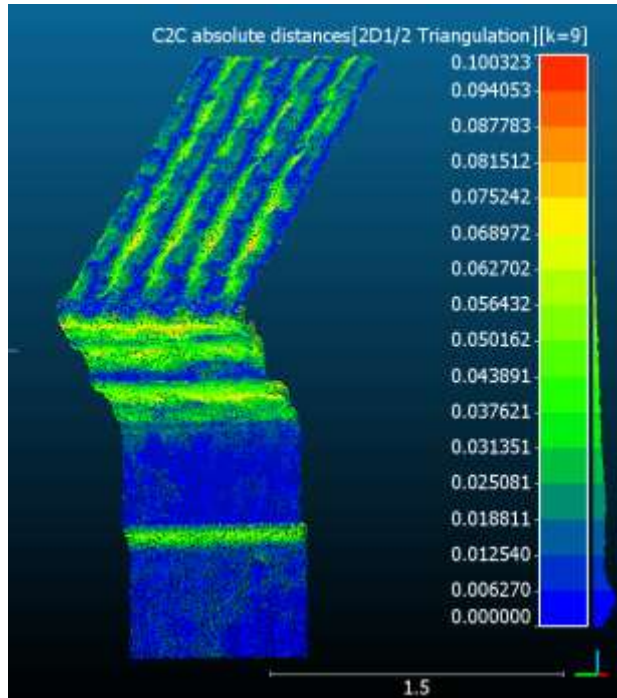


Comparison of point clouds between scanning and photogrammetry - visually



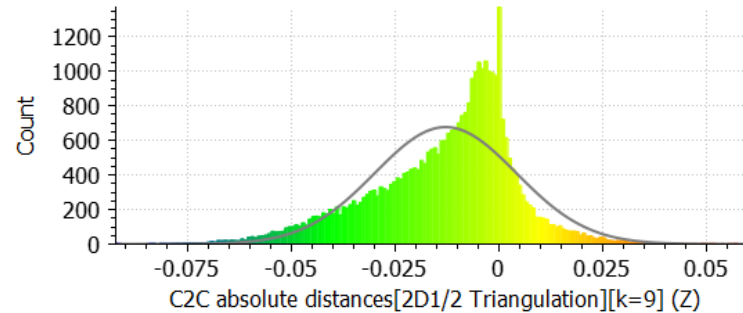
- a) point cloud with LSK b) point cloud with PHTGRM c) both
- Visual inspection (Cyclone program)
- Guided thin section through the roof cornice

Point cloud comparison between scanning and photogrammetry - numerical analysis

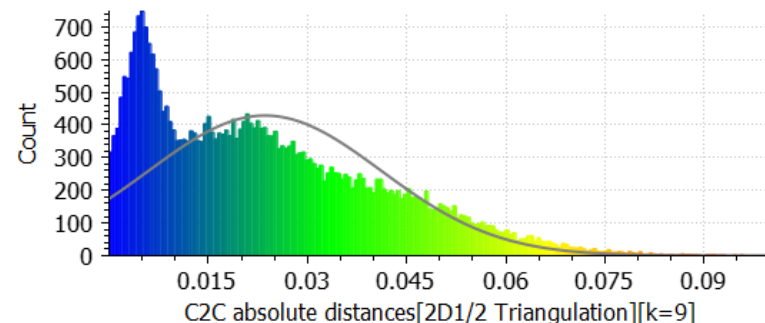


- CloudCompare
- Roof cornice cut (1 m wide)
- Comparison using the function - Cloud-to-Cloud Distance

Gauss: mean = -0.012959 / std.dev. = 0.016992 [189 classes]



Gauss: mean = 0.023723 / std.dev. = 0.017483 [189 classes]

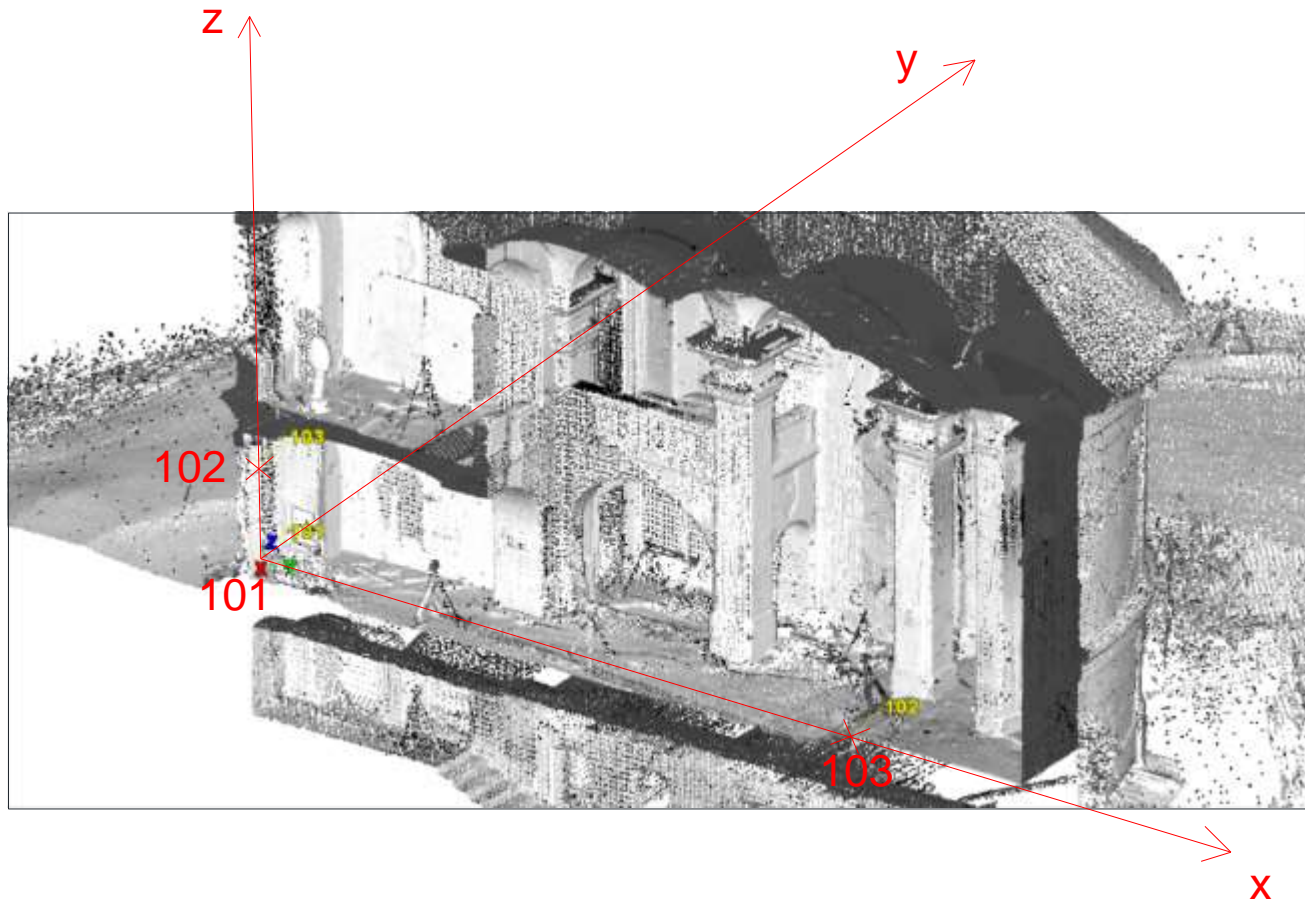


Processing

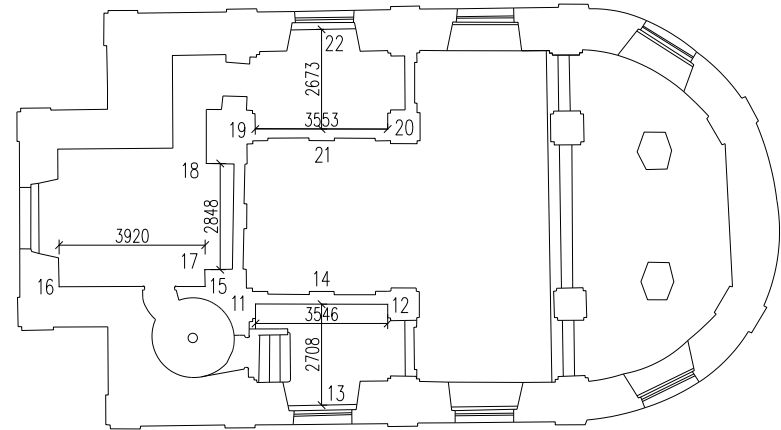
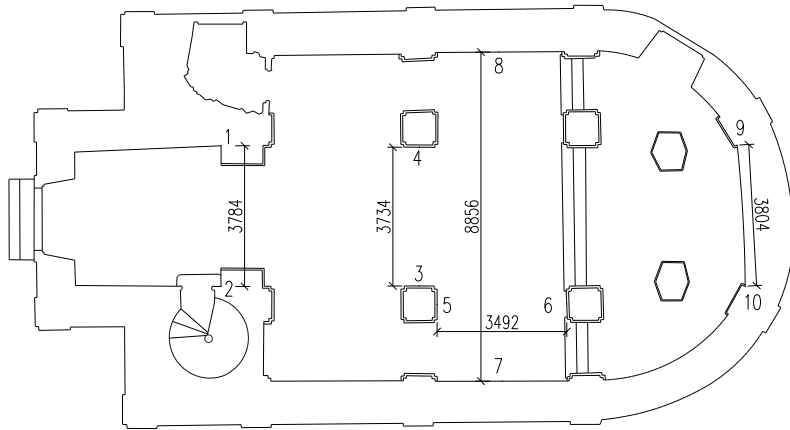
- calculation of traverse and detail points
 - - Groma program
- data editing, scan registration, cloud connection check
 - - Leica Cyclone
- Transformation to S-JTSK and Bpv
- Transformation to local system

Processing

- Local coordinate system



Checking



Point	Distance tape[m]	distance model [m]	difference [mm]
1-2	3,770	3,784	14
3-4	3,725	3,734	9
5-6	3,490	3,492	2
7-8	8,840	8,856	16
9-10	3,800	3,804	4
11-12	3,540	3,546	6
13-14	2,715	2,708	-7
15-16	3,915	3,920	5
17-18	2,850	2,848	-2
19-20	3,550	3,553	3
21-22	2,670	2,673	3

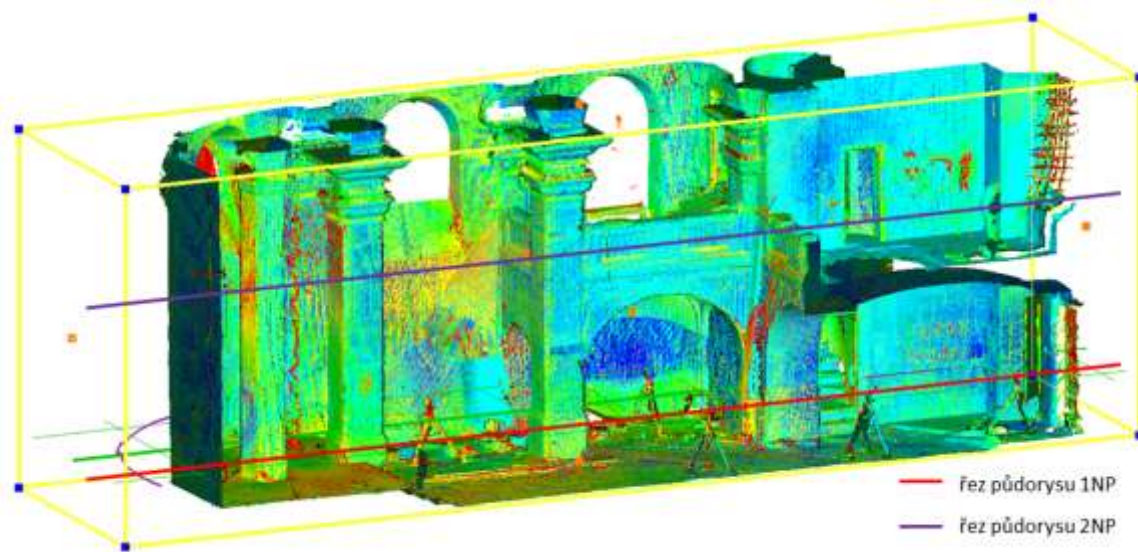
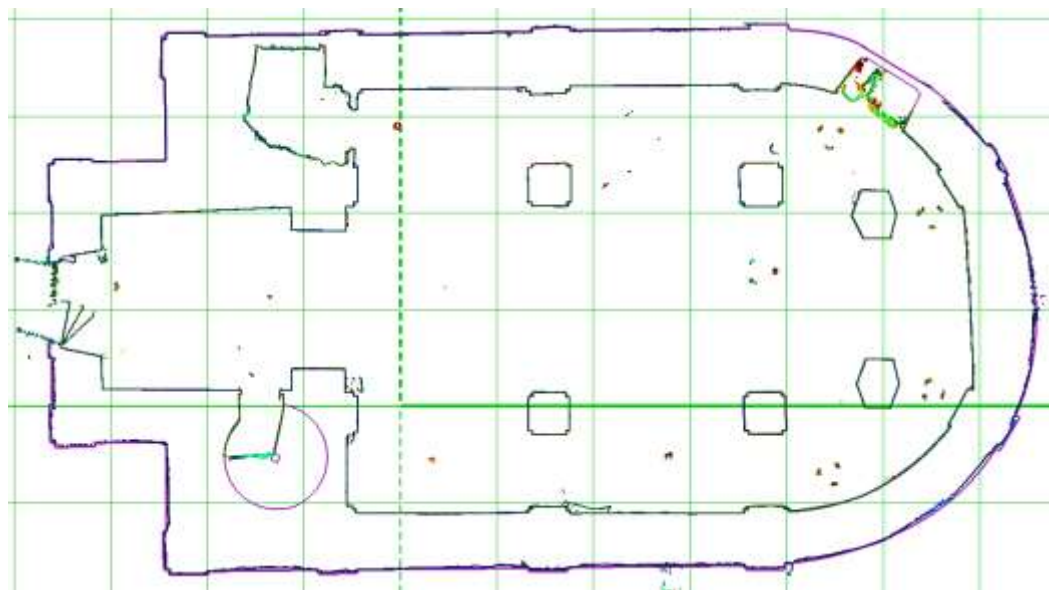


point	Distance total station [m]	Expected distance accuracy [mm]	Distance scanning [m]	difference [mm]
101-114	16,039	1,9	16,050	11
101-119	13,957	2,1	13,956	-1
101-127	9,861	3,0	9,853	-8
114-119	4,104	2,7	4,112	8
114-127	17,882	3,0	17,903	21
119-127	14,088	2,6	14,100	12

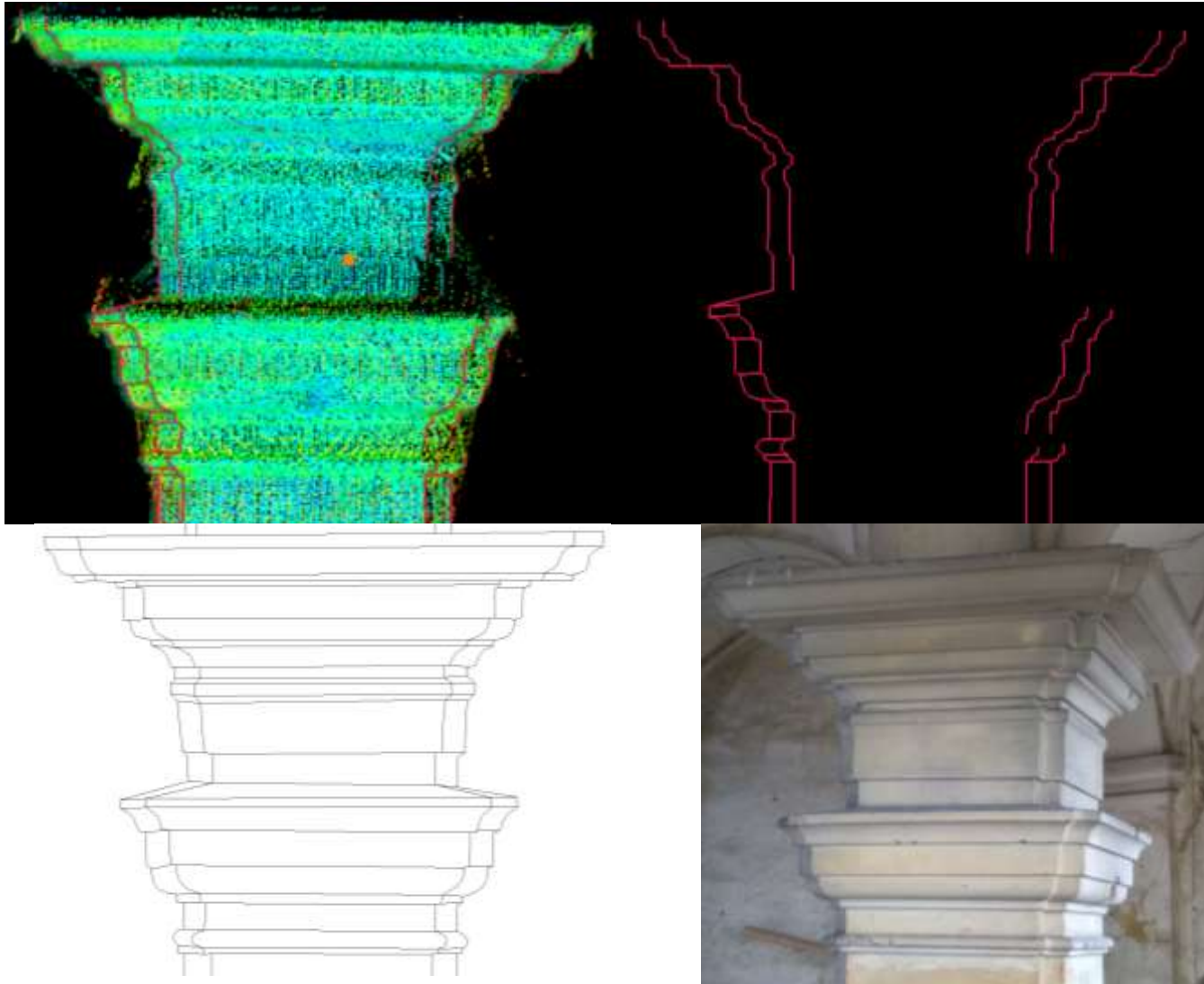
Drawings

- 2 steps
- 1) point cloud vectorization in Cyclone software - reference plane (one cut level), cutplane (cut the point cloud around the reference plane of a given thickness), limit box (display a part of the cloud)
- 2) Export vectorization to AutoCAD where the final drawings were created.
- The plan views are in two versions - with vault elevations and with elevations of other elements

Vectorization - reference plane, limit box

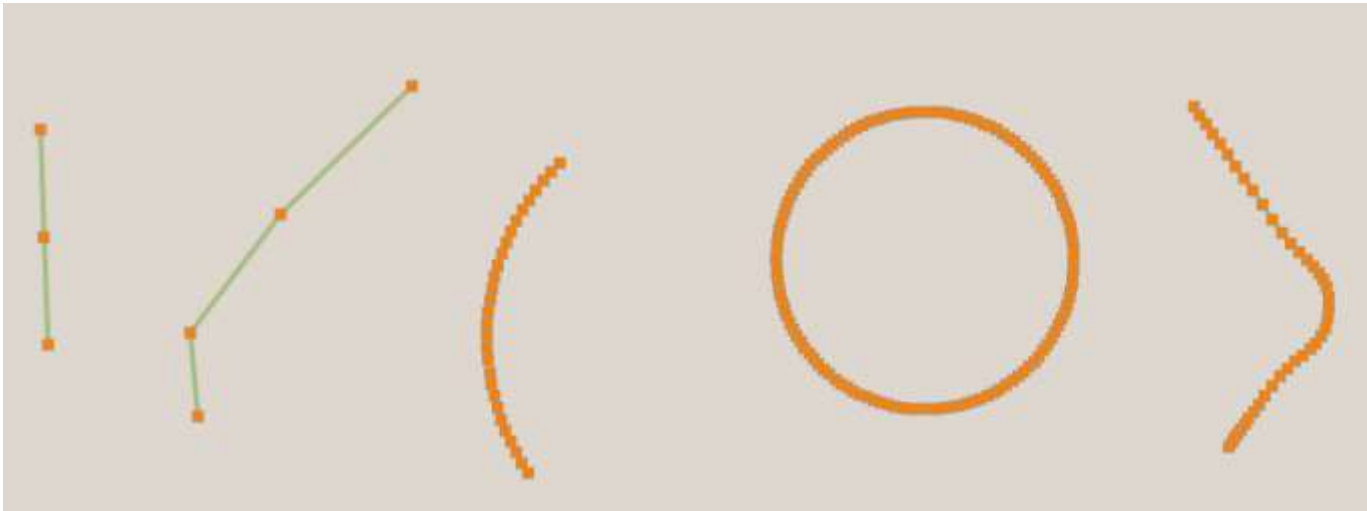
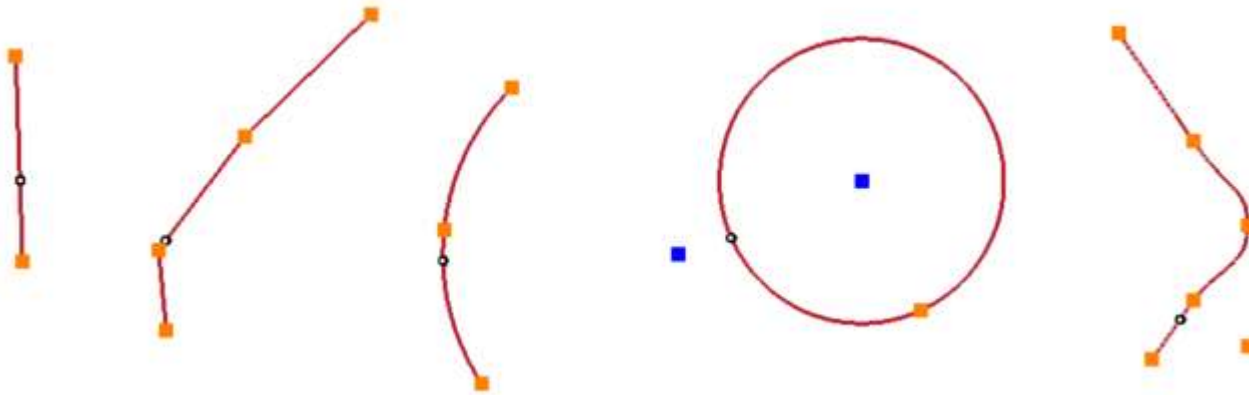


Vektorization – Cyclone, AutoCAD



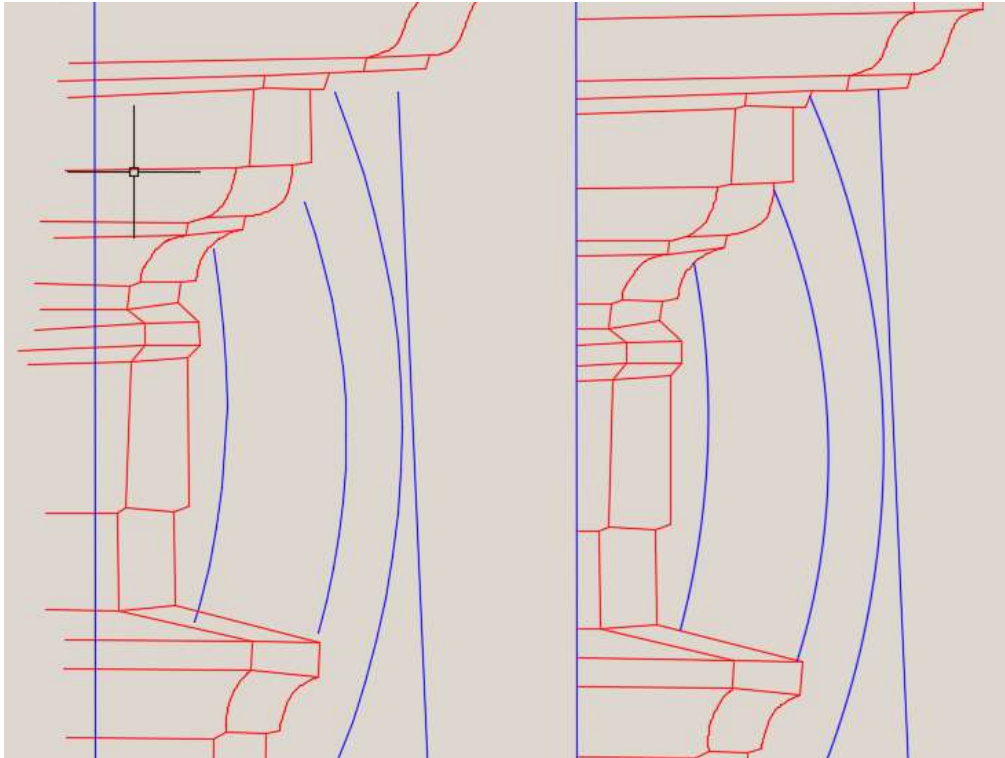
Export

➤ Cyclone → Export in DXF format → AutoCAD

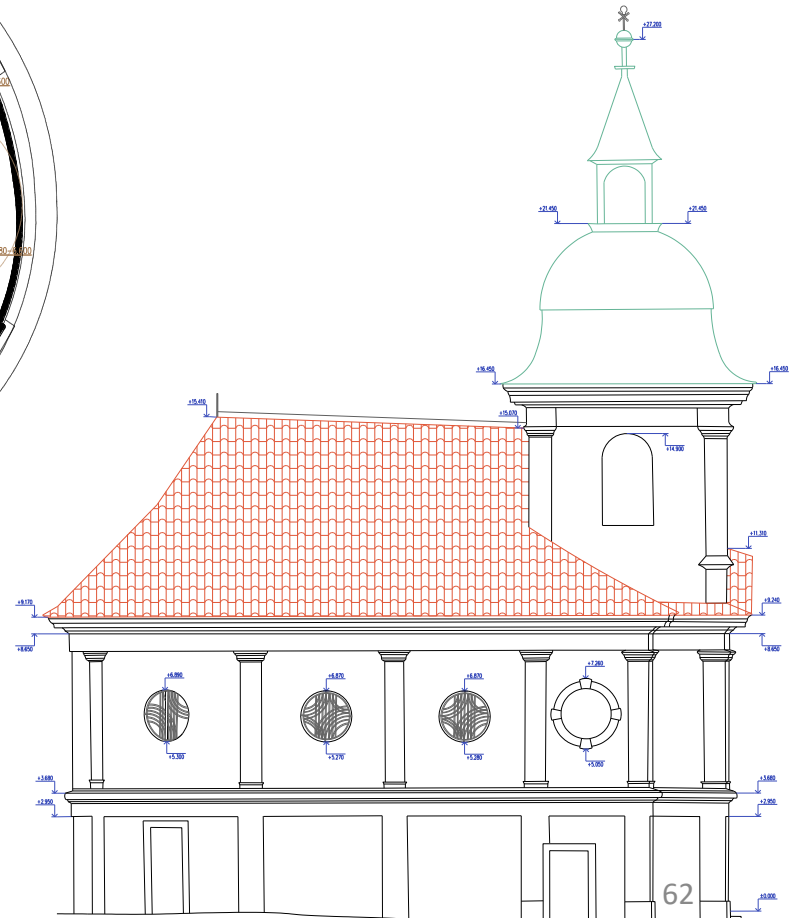
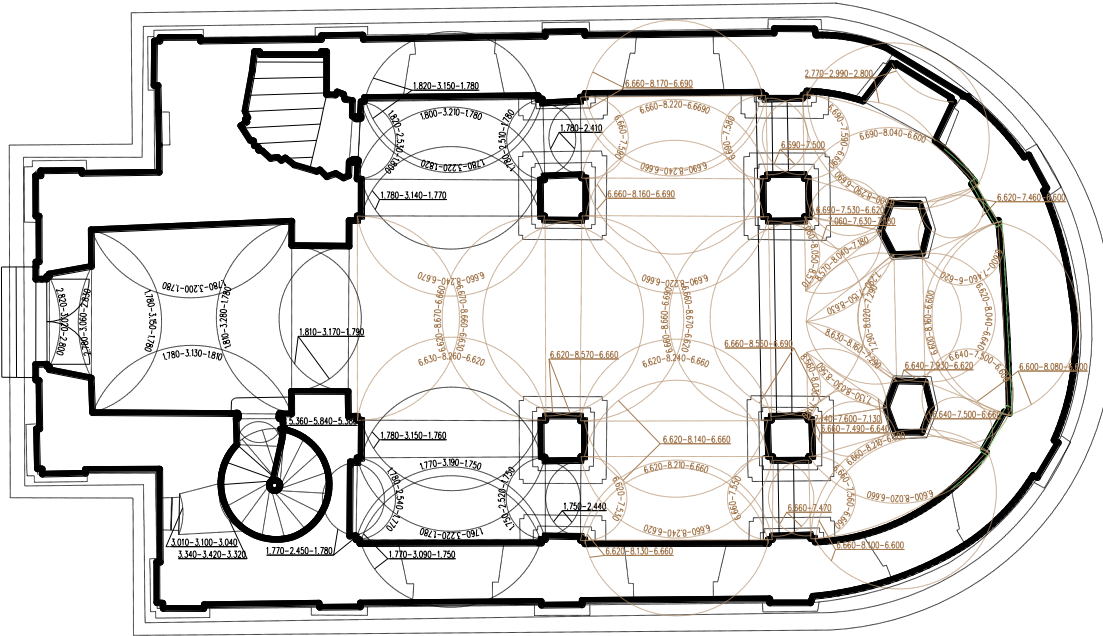


AutoCAD - editation

- Complication - no grips, only nodal points
- Adding/removing a node point - only for lines



Final drawings



Videos

- External source

Thank you for your attention!