LASERSCANNING FOR CASTLE DOCUMENTATION

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Abstract:

The paper introduces realized projects of historical object documentation in the Department of Special Geodesy. It describes using of the Leica HDS3000 laser scanning system, photogrammetric procedures and measured data processing into final outputs. Several projects that were realized in years 2009 to 2011 are introduced in the paper.

The first mentioned project was measurement of a bailey wall of the Kost castle before reconstruction. The next realized project was measurement of the palace torso of the Dražice castle. The third project was the measurement of royal palace courtyard of the Zvíkov castle, which is surrounded by two floors gothic arcade. Next project was the measurement of basement part of the Hrubý Rohozec castle. The last mentioned project was the measurement of the Zlenice castle ruins.

The paper describes the measurement conditions and selected measuring procedures, for which their advantages, disadvantages and resulting recommendations are stated. It closely explains solutions of single measurements registration and creation of spatial models. Data volume and other demands on using or creation of secondary results as ground plans and cross-sections are reflected in created models. There are described possibilities of combination of measured data, which were obtained from laser scanning and photogrammetric measurement. There is put the accent on problematic parts and unusual procedure of processing in all stated examples.

1. INTRODUCTION

The department of Special Geodesy, Faculty of Civil Engineering, CTU in Prague had a possibility to create a measurement documentation of several Czech castles in the last years. Measurement works took place on demand of the individual organizations taking care of these castles and were realized within training of the branch of geodesy and cartography as final theses / dissertations. In the first four mentioned cases it was measurement and processing only of a certain selected part of the castle. In the last case it was creation of documentation masonry constructions and neighbouring terrain of the whole castle.

Laser scanning was the main method for data collection. Photogrammetry was an additional method. Polar method and levelling were used for connection of measurement into the national coordinate system and into the datum system. Equipment available in our department was used preferentially. The Leica HDS3000 laser scanner was used for scanning. It is full panoramic scanner, working on spatial polar principle. Accuracy is 6 mm and range is 134 m for 18% albedo. Measurement speed is up to 4000 points per second. The Topcon GPT 7501 total station was used for measurement of local networks. Angle accuracy is 0.3 mgon and distance accuracy is 2 mm + 2 ppm*d. Several types of digital cameras were used for photogrammetric measurement. The Leica C10 laser scanner was used in last mentioned project of Zlenice castle measurement. Accuracy and range of this scanner are the same as for HDS3000, but the measurement speed

is up to 50000 points per second and work is more comfortable. The owner of this scanner is the Gefos Inc. Company that lent the scanner with operator for this measurement.

2 BAILEY WALL OF THE KOST CASTLE

The gothic Kost Castle founded in the 14th century belongs among the best-preserved medieval castles in the CR. The castle is situated 80 km northeast of Prague near a town called Sobotka. The goal of the project of measurement on the Kost Castle was creation of data for reconstruction of the bailey wall. The reason was wrongly performed reconstruction and drainage of the wall in the fifties of the 20th century.

The object of the measurement was especially the middle part of the peripheral bailey wall on the east side of the castle center (Figure 1). Wall length is approximately 50 m. Wall height is 16 m and it gradually goes down in the direction to the entrance into the castle to 12 m. The wall is built of well-worked sandstone blocks.

Measurement with the Leica HDS3000 System was performed from three standpoints. Point density was selected 20mm x 20mm on 10 m. The wall was photographed with the Canon EOS 400D digital camera with the EFS objective 18-55 mm. 35 pictures with resolution 3888 x 2592 pixels were taken.

Processing of data from the laser scanning was performed in the Cyclone software. The measured clouds were connected using overlaps and transformed into the local system of coordinates and placed into the national height system BpV (Baltic Vertical Datum – after adjustment). The registered clouds were cleaned. Cleaning of the clouds was the most demanding stage from the time point of view. Grass usually in the form of several blades grew from many joints on the bailey wall. These blades could not be removed automatically. They had to be removed manually with subsequent check of the performed cleaning. The area was divided into two parts for purposes of the subsequent processing. TIN triangular networks (triangular irregular network) were created from both parts. These networks were reduced on 50%, 25 % a 10 % of the original volume of data and saved in “stl” format. Sections were generated from the TIN networks (Figure 1). Horizontal sections have interval 0.2 m. Vertical sections have interval 0.2 m in the middle part of the wall where deformation was supposed and 0.5 m in the remaining areas. Resulting sections were exported into “dxf” format and handed over to the castle administrator as data for the reconstruction.

4 photomaps in different scales were created from the selected photos. Check of the selected lengths measured on the photomaps and on the TIN networks was performed. The photomaps were handed over to the castle administrator as the documentation required by the National Institute for the Protection and Conservation of Monuments and Sites of the Czech Republic (NIPCMS).

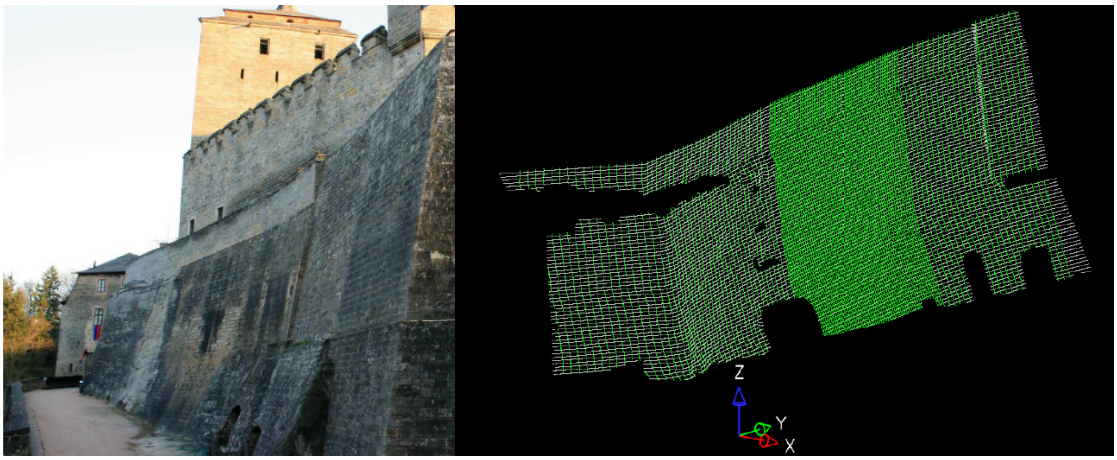

Figure 1: Bailey wall of the Kost Castle (left) and its horizontal and vertical cross-section (right)

Measurement of the bailey wall of the Kost Castle was a typical small order of surveying data for a project and for a photogrammetric documentation. Table 1 shows time demandingness of the individual operations. The same time demandingness for scanning and for photogrammetry results from it. If there were no vegetation present on the measured wall, then the scanning for such an order would be less demanding from time point of view. Time can be also spared by using a faster scanning system.

Table 1: Time consuming of operations

Operation	Time consuming [hour]
Scanning	4
Registration	0.5
Cleaning	10
Processing of point cloud	4
Levelling	1
Processing of levelling	1
Calibration of camera	1
Taking pictures	0.5
Creating photomaps	20

3 PALACE TORSO OF THE DRAŽICE CASTLE

The Dražice Castle is a ruin of a medieval castle overhanging on a rocky point on the right bank of the Jizera river in the middle of the village called also Jizera near Benátky nad Jizerou in the central-Bohemian. The castle was founded in the first half of the 13th century. The goal of the project was to record as detailed as possible state of the Dražice castle ruin, concretely measurement and creation of a space model of the rest of the main castle palace (Figure 2). The reason is strong erosion of the castle walling caused by acid rains and aggregate of poor quality. Erosion of aggregate reaches up to several centimeters per year (Figure 2).

Figure 2: Erosion of aggregate (on the left) and air photo of the Dražice Castle with outlining of the main palace (on the right)

The castle palace was measured from ten standpoints. Scanning density was 10mm x 10 mm on 10 m and for important architectonic details it was 5mm x 5mm on 10 m. The measurement was performed in the local coordinates system and control points were used. All the scanned surfaces were photographed from each standpoint with the Canon EOS 500D calibrated camera.

Processing started with registration in the Leica Cyclone software with using control points and also ICP method on the standpoints, where insufficient number of control points was measured. Basic cleaning of cloud from points outside the main palace was further carried in the Cyclone software and export in the sequence according to the individual standpoints was performed. The next processing was done in the Geomagic Studio 11 software. The following operations were performed here: Noise reduction, sampling unification (basic 1x1 cm, selected areas 5x5mm), triangulation, cleaning from vegetation and filling in smaller holes. Work with the triangulated model was done in sequence of the individual parts, because the whole model contained approximately 15 million triangles and it was almost impossible to work with it in 32 bit version of the Geomagic Studio software.

The last processing stage was creation of texture. Approximately 170 pictures covering the modeled area were taken. All the pictures had to be orientated – outer orientation had to be determined.

Calculation by means of the Alltran library [1] was used for this purpose, on the basis of selection of at least four identical points in the picture and in the 3D model. Orientated and undistorted pictures were applied by the Precise Texture Mapping program [2] on the model.

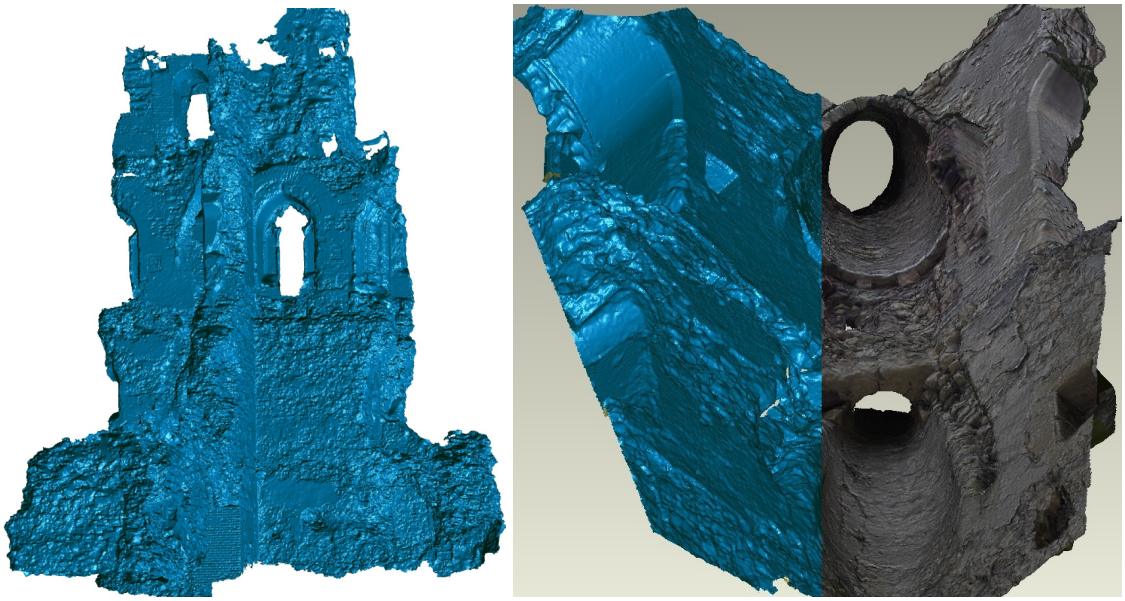

Figure 3: Final model (left), important architectonical details partly with texture (right)

The result of the project was a 3D model of the Dražice castle palace in the form of a triangular network (Figure 3). This model was handed over to prof. T. Durdík from Archaeological Institute.

4 ROYAL PALACE COURTYARD OF THE ZVÍKOV CASTLE

The royal gothic Zvíkov Castle was founded in the 13th century. In belongs among the most significant castles in the CR from the historical and construction point of view. The castle is located in south Bohemia at the junction of the Vltava and Otava rivers, 15 km north of the Písek town. The goal of the project was measurement of the royal palace courtyard for presentation and documentation purposes. Courtyard is surrounded by two floors of a gothic arcade, which were measured as well.

Courtyards and arcades were measured in total from 24 standpoints. 3 standpoints were placed on the courtyard and 21 standpoints were situated in the internal parts of the arcade galleries. Point density was 20mm x 20mm on 5 m. The measurement took 2 days and took place partly in the working condition, i.e. while tourists were visiting the castle (measurement time on the standpoint including moving was 40 minutes). From the most standpoints there was visibility on the marked part of the opposite side of the courtyard. Therefore it was decided that control points will not be used for time reasons. More than 20 million points were measured.

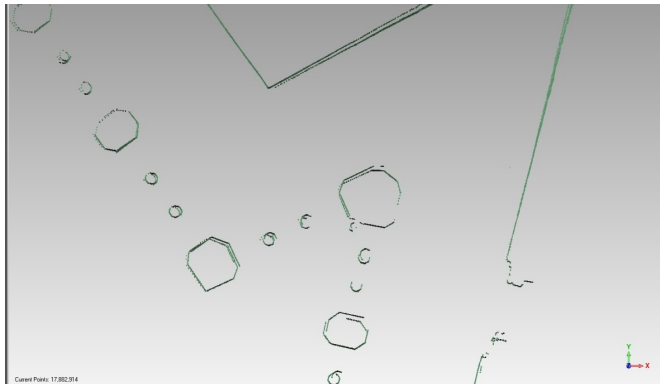

Figure 4: Horizontal cross-section after registration in Geomagic Studio

The measured data from the individual standpoints were cleaned in the Cyclone program and exported into the Geomagic program. Connection of the individual standpoints by means of overlaps with the “manual

registration" and "global registration" instruments was performed in the Geomagic program. Result of this registration was not satisfactory in spite of all effort and several repetitions. Several-centimeter shifts among the individual point clouds were found during check (Figure 4).

Therefore it was come up to another procedure of registering the point clouds. The first step was performed in the Cyclone software. Planes used as control points were modeled in the individual point clouds. The result of this registration was much better than the previous one, but there still remained apparent drawbacks. The individual registered point clouds in the Cyclone software were exported in the form of organized data in "ptx" format into the Geomagic software. Global registration was performed here, this registration went already correctly and residual differences among the point clouds were eliminated (Figure 5). Advantage of "ptx" format was in significantly faster global registration process, which did not exceed 30 minutes. But part of points was lost when using "ptx" format. This was solved by saving the transformation matrices of the individual point clouds after global registration and by using these matrices on point clouds in disorganized "txt" format.

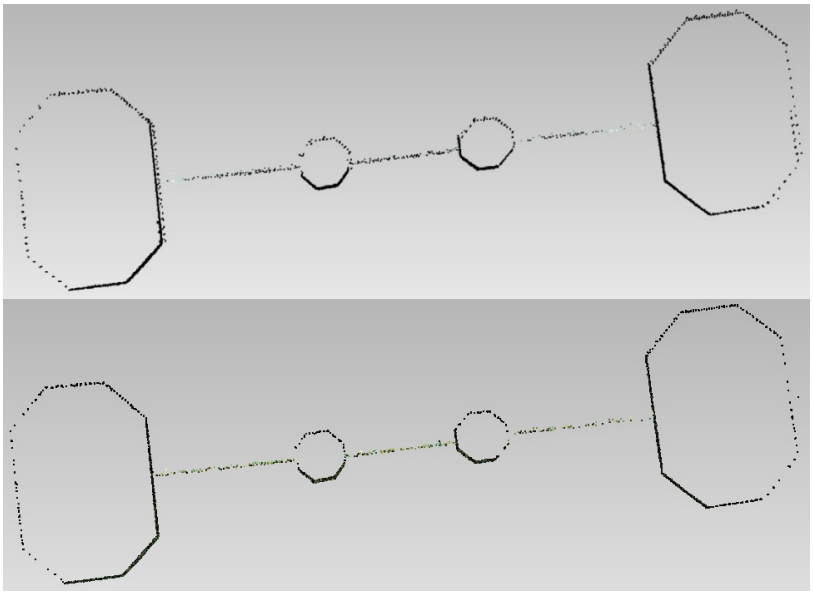

Figure 5: Before global registration (above) and after (below)

A registered point cloud acquired in this way was one of the required measurement results. Creation of the triangular network in the Geomagic software was the further processing. The point cloud was divided into two parts, ground floor and the first floor for reasons of the calculation data demandingness. 3 resulting models of the courtyard with 4.5 million of triangles, 2 million of triangles and 1 million of triangles (Figure 6) were created.

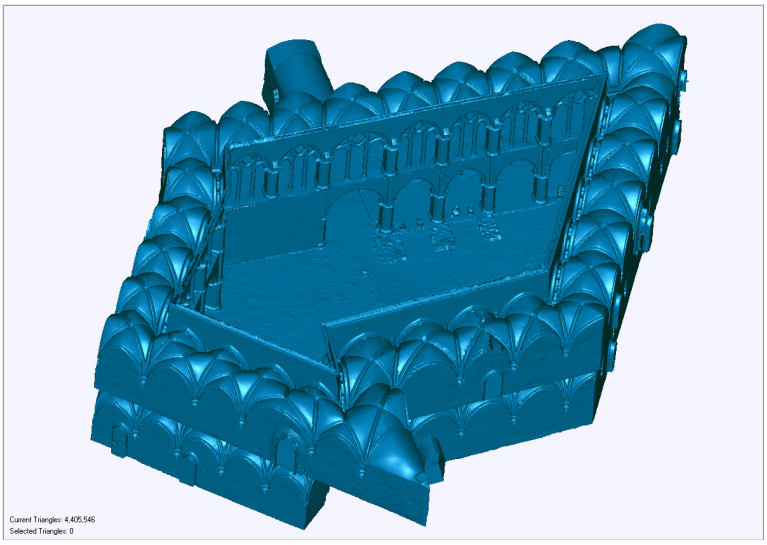

Figure 6: Model of the courtyard (4.5 millions triangles)

Results of project were handed over to the NIPCMS, which is the administrator of the object. This object is interesting owing to demandingness of the transformation procedure and registration of the individual standpoints into one unit. Control points were not used on the basis of reconnaissance that the object shape and segmentation and size of overlaps are suitable for connection of the individual standpoints by means of overlaps. Time conditions of the measurement played its role here as well. But in spite of the stated difficulties, the project was led to its happy conclusion and the customer was satisfied with the results.

5 BASEMENT PART OF THE HRUBÝ ROHOZEC CASTLE

The Hrubý Rohozec Castle founded in the 13the century underwent in the past several reconstructions and it is a significant national cultural monument of the CR. The castle is situated 90 km northwest of Prague on the edge of the Turnov town. The goal of the project was measurement and creation of documentation of the real state of the part of the castle dungeon for representation purposes and extension of "The Architectural and Historical Survey" (AHS) of the Hrubý Rohozec Castle.

Measurement object were six cellar rooms and three passage ways under the east wing of the castle including nine stone portals, the most valuable components in the basement. Details – traces of engineering constructions (crib), stonemason marks, built-in holes and rests of metal components were further measured and recorded.

The dungeon was scanned from 15 standpoints. Point density was set 50mm x 50mm on 5 m and for portals 50mm x 50 mm on 15 m. Control points were not used. The dungeon was pthotographed with the Canon EOS 400D digital camera. 350 pictures with resolution 3888 x 2592 pixels were acquired. Part of the pictures was used for creation of photomaps; part was used only for documentation purposes.

Data from the laser scanning were cleaned in the Cyclone software and exported into the Geomagic software. Next cleaning and connection of the individual standpoints by means of overlaps was performed here. A triangular network was created from the resulting point cloud (Figure 7). Number of triangles in the network was lowered so that size of the resulting models were 100 MB, 50 MB a 10 MB. 8 portal models were created afterwards and they were textured (Figure 7).

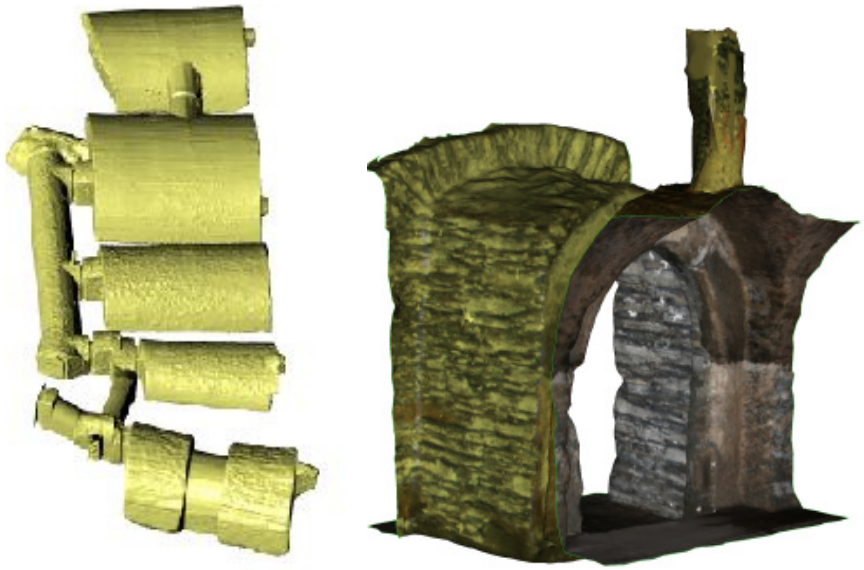

Figure 7: General view on the basement model (left) and portal model (right)

The result of the photogrammetric measurement was a file of 17 photomaps of the individual portals from both sides on a scale 1:20. Design documentation on a scale 1:50 was done afterwards for each portal. The designs contain view from the front, view from behind, a section and a ground plan. A register of photomaps and designs was created as well see Figure 8.

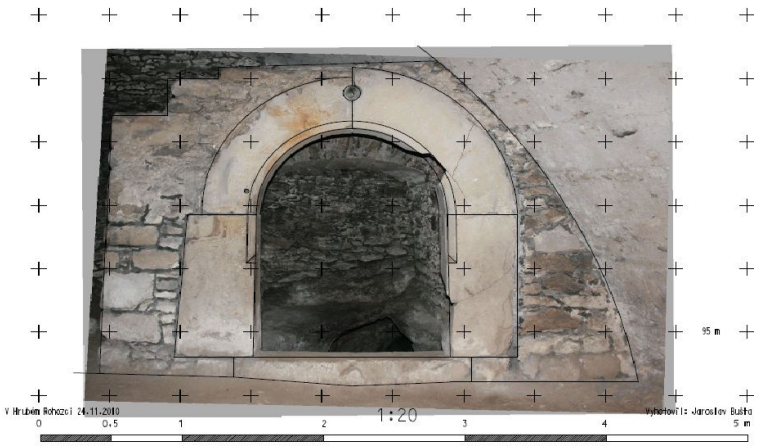

Figure 8: Photomap and plan of the portal

The methods of laser scanning and photogrammetry were suitably combined in this project. The result was creation of the spatial models of the dungeon for presentation of the object, increase in quality of promotional materials and completion of AHS of the castle with results in the digital form (the original AHS was in the paper form). The results of the project were handed over to the NIPCMS and to the castle administrator.

6 ZLENICE CASTLE RUINS

The ruin of the Zlenice Castle, which was founded at the end of the 13th century, is situated 30 km southeast of Prague near Čerčany. The goal of the project was measurement of the castle with the scanning system. These data were used for extension of the castle measurement documentation. Measurement objects were all the visible walled constructions of the castle, palace, gate, main tower and several parts of castle walls and neighboring terrain.

In the first stage of the project the existing control point network, which was used for the previous measurement of the castle, was renewed. The Topcon GPT-7501 total station was used for the measurement. Coordinate standard deviation of points was smaller than 2 mm. Measurement of the castle with the HDS300 scanning system followed afterwards. Measurement took place in two days in total from 11 standpoints. Point density was set 10mm x 10mm on 5m. Measurement with the C10 scanning system, which was lent by the Gefos Company together with operator, took place in the second day. The main tower was measured from 6 standpoints, together with part of castle walls of the palace with the C10 scanning system. Point density was at least 10mm x 10mm on the measured objects (Figure 9). The data size from C10 scanner was three times bigger than data size from HDS3000 scanner and time for scanning for C10 was three times smaller than time which HDS3000 needed.

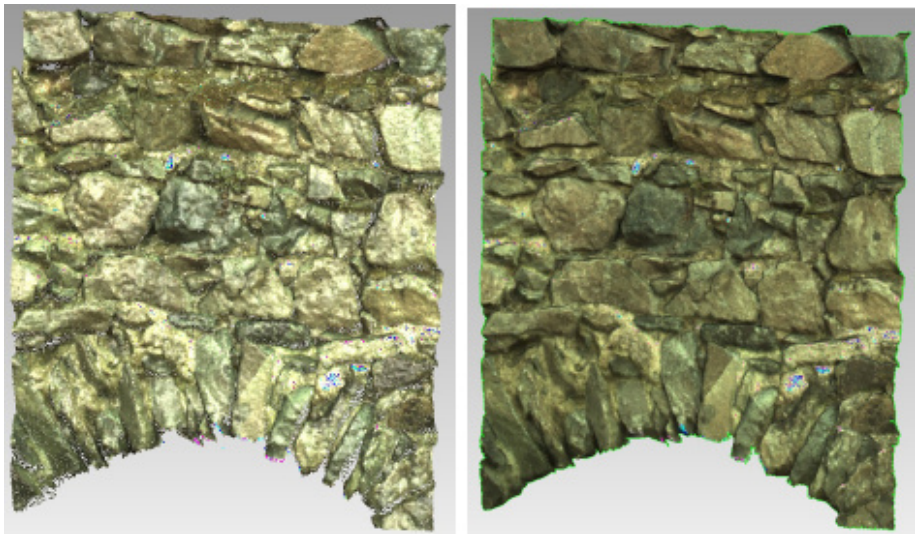

Figure 9: High detailed model of wall, points (left), triangular network (right)

The measured data were processed at first in the Cyclone program. Transformation of all measurements into the S-JTSK coordinates system and into the BpV height system was performed. The connected point cloud was cleaned from vegetation and other objects outside our interest. The cleaned cloud was exported into the Geomagic Studio software in the sequence of the individual standpoints. The cloud was here divided into the individual objects, which were processed separately (Figure 10). The reason was data size. The results of this processing were very detailed 3D models of the individual walls of the castle and their neighbouring terrain in the form of triangular networks.

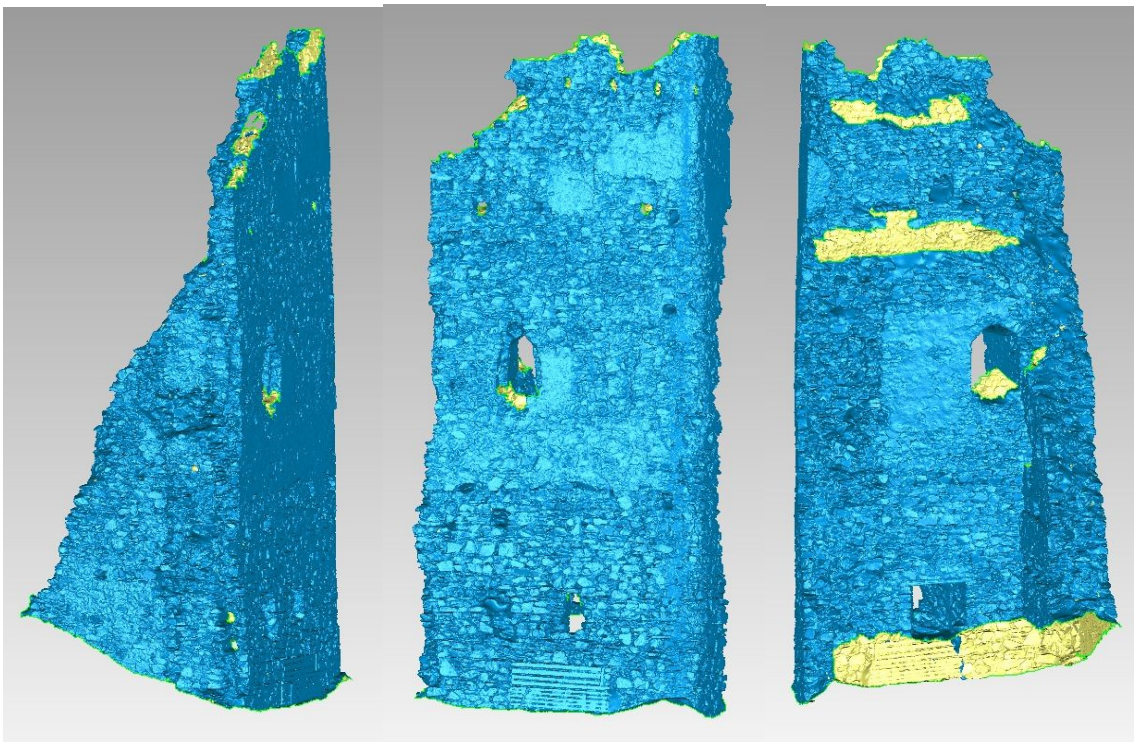

Figure 10: Main tower, side, front and inside

Results of this project were handed over to "Association for protection of cultural heritage – Zlenice", which is taking care of the ruin.

7 CONCLUSIONS

The realized projects of castle documentation at the department of Special Geodesy were introduced in the paper. The main practical problems we dealt with were elimination of vegetation, especially of grass, using point clouds overlaps for registration and working with large data volumes. Data size grew up steeply with demands on high detailed 3D model. Data size and model details are important for possibilities of its future using. This problem was mostly significant at Zvíkov castle and Zlenice castle projects. It is necessary to mentioned here, that scanning time demandingness is mostly solved with using of new scanning instruments. It is documented on Zlenice project. The possibilities of laser scanning and photogrammetry mutual complementation were also mentioned in the paper.

ACKNOWLEDGEMENTS

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[2] Koska, B.: *Precise Texture Mapping*. [online]. 2010 [cit. 2011-04-30]. Available on WWW: http://k154.fsv.cvut.cz/~koska/software/ptm/ptm.php>.