Article no. 5

THE CIVIL ENGINEERING JOURNAL 1-2018

METRIC SURVEY DOCUMENTATION AS A BASIS FOR UNDERSTANDING THE DEVELOPMENT OF RURAL ARCHITECTURE

Zdeněk Poloprutský

Czech Technical University in Prague, Faculty of Civil Engineering, Department of Geomatics, Prague, Thákurova 7/2077 166 29 Prague 6 Dejvice, Czech Republic; zdenek.poloprutsky@fsv.cvut.cz

ABSTRACT

The paper deals with the use of metric survey documentation as a basis for Artistic and Historical Research of rural architecture. The Artistic and Historical Research focuses on a specific part, an element or a type of surveyed buildings in the selected time period. Its results can be further developed and interpreted in a wider cultural context of the respective rural region. In this way, it is possible to describe the cultural and social environment of the given rural region and external influences which have guided its future development in the given time period. The objective of metric survey documentation is to provide a reliable spatial and temporal framework for future analyses.

The article presents practical experience in using metric survey documentation of rural buildings. Its outputs can serve for e.g. drawings, 3D models, photographs, orthophotos, thematic maps and others.

KEYWORDS

Artistic and Historical Research, Cultural heritage, 19th and 20th century, Computer Aided Design (CAD), 3D model, Point cloud, Close range photogrammetry

INTRODUCTION

The beginning of the 21st century is associated with a rapid development of information and communication technologies (ICT), which have gradually affected most areas of human activity, including cultural heritage and land surveying. In the field of monitoring the development of rural architecture and landscape, total stations, GNSS stations, laser scanning, digital photogrammetry etc. can be used for spatial data collection, and geographic information systems (GIS) for spatial data post-processing. Currently, the outcomes of research projects are presented in an attractive way to professionals as well as the general public using web sites and databases.

Base maps are valuable data sources for landscape development analyses. It is possible to create very interesting analyses documenting the nature of land use changes using GIS tools, which are based on large scale maps and digital orthophotos (historical and contemporary) from different time periods.

In Bohemia and Moravia, the shape of rural architecture has been influenced by intense political, economic and social changes taking place since the second half of the 19th century. In particular, they involved the abolition of drudgery (1848), the establishment of the cadastre unit institute and building legislation, i.e. specification of construction management, fire regulations, and

the arrival of trained architects, etc. The gradual emergence of industries (19th century) and large population movements after the World War I and the World War II (20th century) had major influences on the development of villages. Furthermore, the appearance of rural architecture has changed rapidly since the end of the 20th century.

Nowadays, rural architecture and its evolution since the second half of the 19th century are interesting fields of research, particularly because of the large number of relevant sources, such as architectural plans, detailed maps, historical photographs, etc.

During the research of rural architecture, the main focus often aims at the Building Archaeology Survey and metric survey documentation of the oldest preserved medieval buildings and their fragments. The study of rural Baroque and Classicism architecture [1] also attracts a great deal of attention. Rural architecture of the second half of the 19th century and its development during the 20th century has been highlighted since the 1990s, see [2], [3], [4]. Recent book publications have contributed to its deeper understanding, see [5], [6], [7], [8]. Current research studies dealing with thematic changes of the landscape over time are often focused differently in their objectives, e.g. development and reconstruction of extinct villages in the Ústí Region, Czech Republic, see [9] and [10].

This paper presents practical experience in using the metric survey documentation of rural buildings, which serves as a basis for an artistic and historical survey of rural architecture. This activity is developed in the ongoing project "The Transformation of Rural Architecture with Emphasis on the Development of the 19th and 20th Centuries", which is devoted to the exploration of artistic and historical values of rural architecture in the Czech Republic.

METHODS

Researchers use the method of deeper Artistic and Historical Research, which is advisable to be divided into several stages. For Artistic and Historical Research, it is advantageous if individual processing stages are supported by spatial data, i.e. by metric survey documentation. The metric survey documentation must be adapted to the type of survey at that stage. Depending on the type of survey, technical parameters of the metric survey documentation are defined, such as the subject matter, reference scale, Level of Detail (LoD), Level of Accuracy (LoA), dimensions (2D or 3D), etc.

Artistic and Historical Research

Artistic and Historical Research focuses on a specific part, an element or a type of building under investigation in the chosen time period. Its results can further be developed and interpreted in a wider cultural context of the respective rural region. In this way, it is possible to describe the cultural and social environment of the given rural region and external influences which have guided its future development in the given time period, for an example see [11]. In the future, the results of Artistic and Historical Research can be used as a supplement to the Building Archaeology Survey, see [7] and [12].

The artistic and historical research consists of four basic parts:

1. background research of available historical sources and literature, see Figure 1 and Figure 2;
2. analysis of the urban development based on the analysis of large scale maps since the second half of the 19th century to the present, see Figure 3;

3. survey of rural buildings in the region and selection of the building which formally and stylistically best characterizes rural architecture in the region, see Figures 5 - 7;
4. interpretation, presentation and archiving of the results.

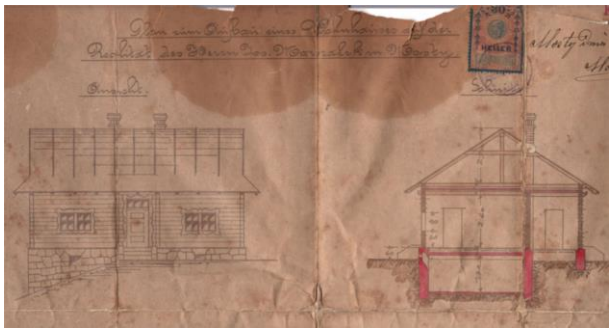

Fig. 1 - Example of a historical source: Unbuilt project of a timbered house (1910); Private archive of K. Mezihoráková

Fig. 2 - Example of a historical source: Report of construction management; Private archive of K. Mezihoráková

Analytical map outputs

Maps are important sources of information for the analysis of the urban development of the studied area. The workflow can be divided into several phases.

In the first phase, large scale maps from the second half of the 19th century to the present are searched and provided. Mainly, these are maps of the stable cadastre (1817-1918) - mandatory imperial imprints, correction sheets, maps of the cadastre of lands (1931-1956), maps of the real estate registration (1964-1992) and current maps of the real estate cadastre of the Czech Republic.

In the second phase, the georeferencing of digitized map sheets takes place into the selected coordinate system, S-JTSK; EPSG: 5514. For this purpose, identical points are used. Identical points are manually searched on the map sheets, e.g. corners of important buildings, crossroads, significant refractions of cadastral borders, etc.

In the third phase, there is manual vectorization of the sites and other selected planimetric components of a map, their classification and arrangement into the geodatabase.

In the final phase, the base maps are analysed using GIS tools.

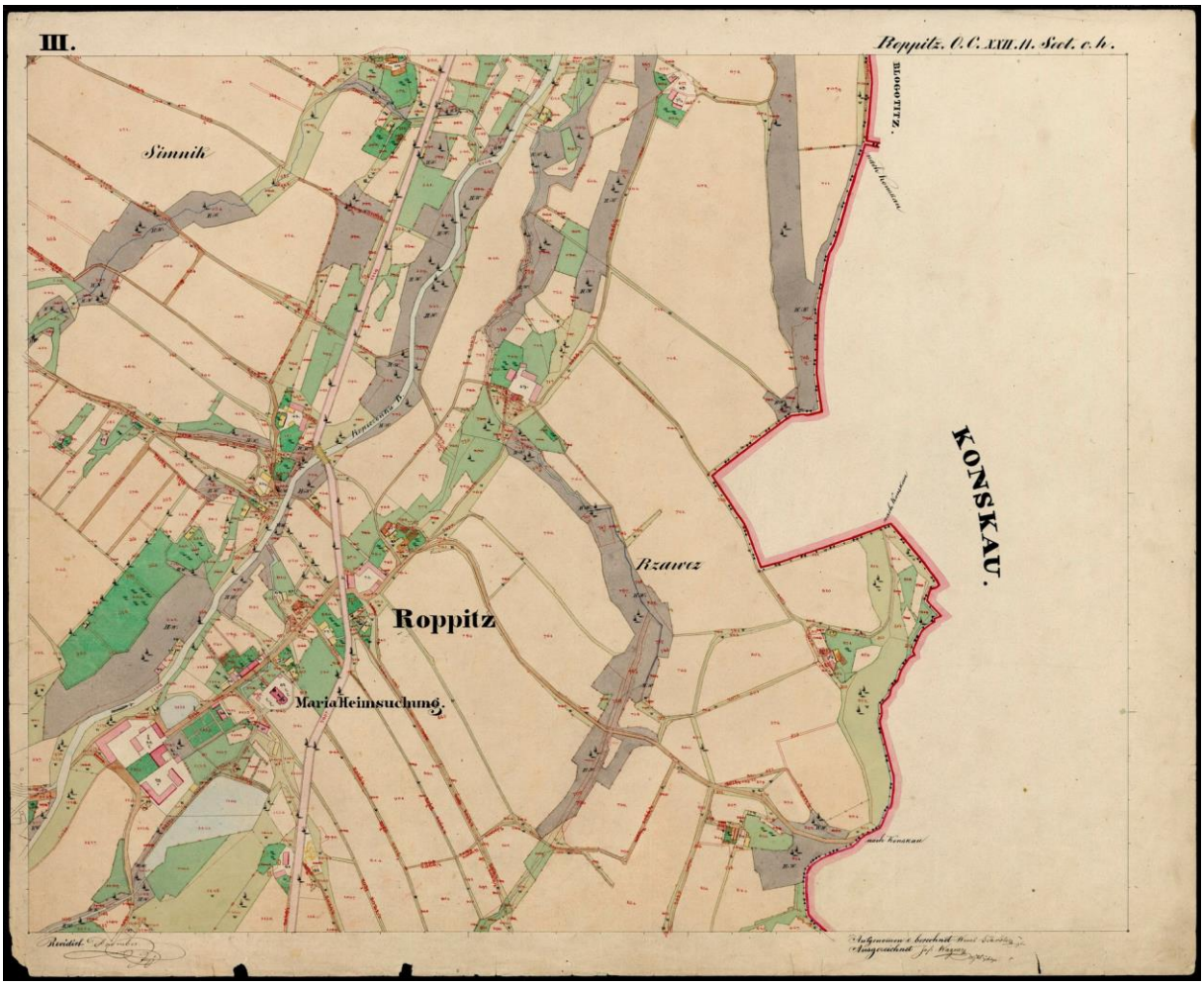

Fig. 3 - Example of a historical source: Map sheet of the Ropice stable cadastre (1836), Frýdek-Místek District, Czech Republic

The outputs are thematic maps capturing the development of the urban area in the given village or its selected parts. The basic-map-output shows the state of the urban area in all the processed time periods. The another-map-output shows the development of the urban area in the second half of the 19th century. See [13] in more detail.

Digital ortophoto

Nowadays, digital orthophotos based on aerial survey photographs are one of the most frequent photogrammetric outputs. This type of outputs can be used, for example, as a data layer in GIS. For the creation of orthophotos, it is possible to use current digital aerial survey photographs or digitized, i.e. analogue, aerial survey photographs.

Regular aerial photography for military purposes was introduced in Czechoslovakia before the World War II. Currently, The Military Geographic and Hydrometeorological Office (VGHMÚř) in Dobruška manages the archive of about 750 thousand aerial survey photographs from 1936-2002. These photographs have been digitized in co-operation with the Czech Office for Surveying and Cadastre (ČÚZK) and some are available for consultation in the National Archives of Aerial Survey

Photographs, see [14]. Within this project, digital orthophotos are created from digitalized aerial survey photographs for several selected villages, see Figure 4.

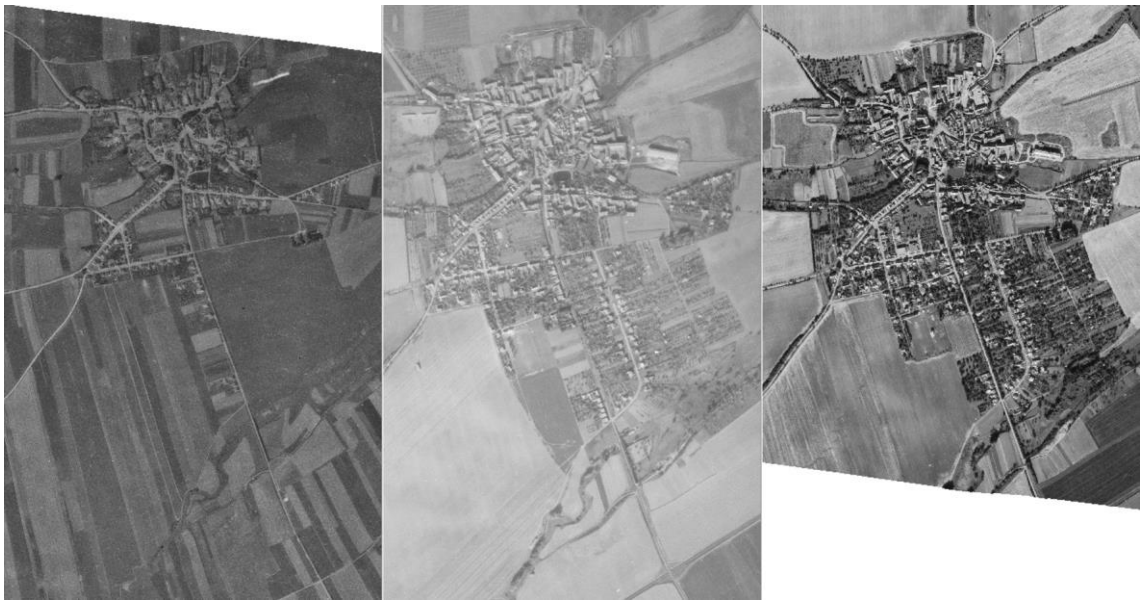

Fig. 4 - Examples of digital orthophotos based on digitized analogue aerial survey photographs (1938, 1969, 1983); Hostouň (Kladno District, Czech Republic)

Naturally signalizing Ground Control Points (GCPs) are used to process digital orthophotos. Their spatial coordinates are obtained by subtracting from the existing map data sources and the Digital Terrain Model of the Czech Republic of the 5th generation (DMR 5G). The exact camera parameters the pictures were taken with are not available and their approximate values are entered into the calculations. The PhoTopoL digital photogrammetric workstation [15] is used for orthophoto processing. The accuracy of the outputs is verified at checkpoints. The Root-Mean-Square Error (RMSE) ranges between 1-1.5 m depending on the age and the image quality of the aerial survey photograph used.

Fig. 5 - Example of the type of building under examination, Vigantice (Vsetín District, Czech Republic)

Fig. 6 - Example of the type of building under examination, Stříbrnice (Šumperk District, Czech Republic)

DOI 10.14311/CEJ.2018.01.0005

Fig. 7 - Example of the type of building under examination, Kostelec nad Vltavou (Písek District, Czech Republic)

Metric survey documentation

In this project, selected rural buildings are documented by the ground plans of ground-floors and point clouds from the outside. The final output is the digital spatial model of a rural building that can be interactively presented on the web in the future.

For field data acquisition, the commonly used instruments are the Canon EOS 450D - calibrated DSLR, a tripod, paper sheets (6x6 cm), Leica Disto – hand-operated laser range-finder, a folding rule and a tape measure.

Metric survey 2D documentation

The most common output of 2D documentation is a drawing. The drawing shows a comprehensive overview of the documented situation and should be geometrically and dimensionally faithful to its real artwork. It is therefore possible to redefine the layout of the building and control measures, such as lengths and angles, among the building structures that are not easily identifiable in the field. In the context of metric 2D documentation, four basic categories of LoD can be defined [16]:

1. Tentative - mostly sketches and plans, LoD corresponds to a reference scale of 1 : 100 and below;
2. Basic - usually metric survey documentation with side measures, LoD corresponds to a reference scale of 1 : 50 and below;
3. Detailed - based on a full geodetic measurement, LoD corresponds to a reference scale of 1 : 50;
4. Shape trustworthy - based on advanced measurement techniques, such as geodetic measurements, laser scanning, photogrammetry etc., LoD corresponds to a reference scale of 1 : 20.

The drawings document primarily the ground-floor layout of individual rural buildings. The georeference and the basic dimensions of the buildings, i.e. length and width, are derived from the

current cadastral map. The outline of the buildings is controlled in situ and further by a section of the point cloud during post-processing. The construction and cross measure were used by the metric survey documentation of the interiors. Ground plans are produced in a reference scale of 1 : 50. Their LoD and LoA correspond to the basic metric survey documentation, see point 2.

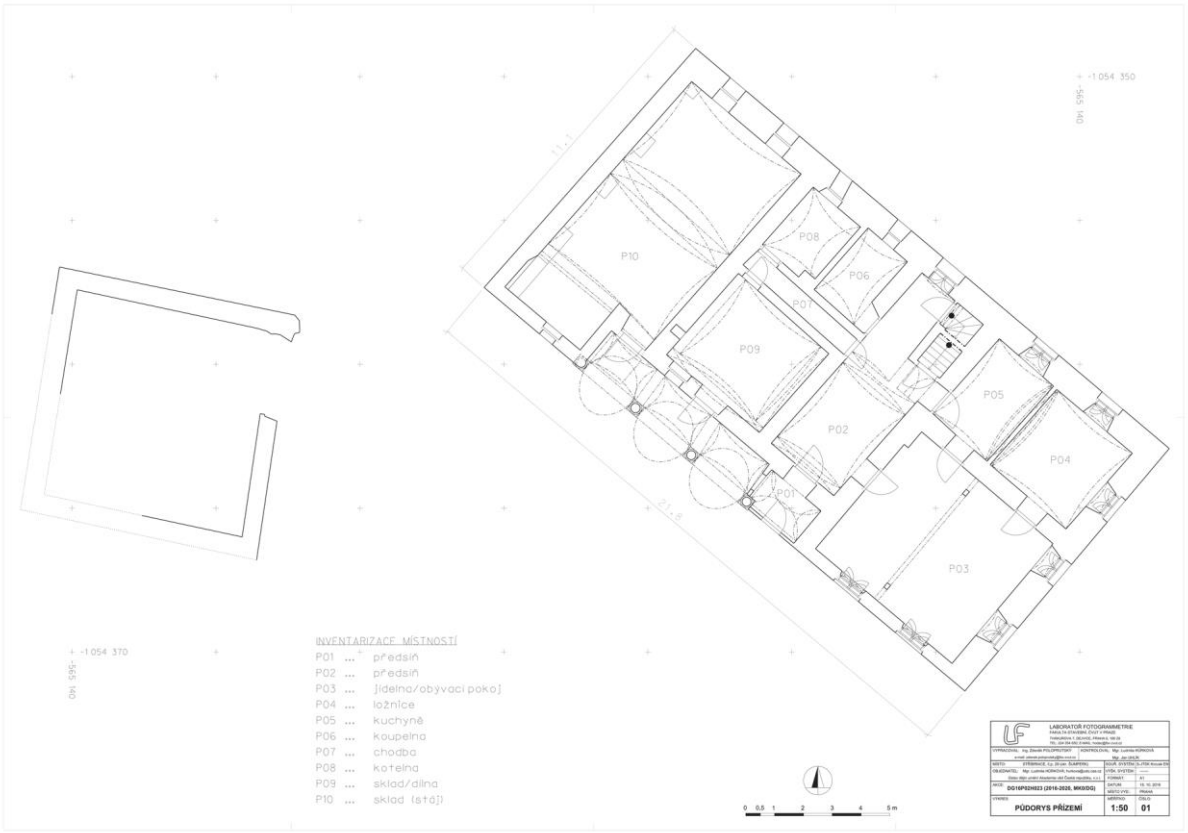

Fig. 8 - Example of the ground plan of a ground-floor, Stříbrnice (Šumperk District, Czech Republic)

Metric survey 3D documentation

Metric survey 3D documentation is made up of schematized 3D models of interesting rural buildings. Spatial models are based on the ground plans of ground-floors and point clouds.

Due to the requirement for the creation of schematized 3D models, it is possible to apply a standalone photogrammetric solution in the Agisoft PhotoScan software [17] for data acquisition and processing, i.e. without the support of geodetic measurements by the total station. The photographing guidelines are observed during the survey activities recommended by the manufacturer.

RESULTS

The current results are the ground plans, see Figure 8, point clouds, see Figure 9 and Figure 10, and schematized 3D models of documented buildings, see Figure 11.

Fig. 9 - Example of the point cloud, front view, Kostelec nad Vltavou (Písek District, Czech Republic)

Fig. 10: Example of the point cloud, front view, Stříbrnice (Šumperk District, Czech Republic)

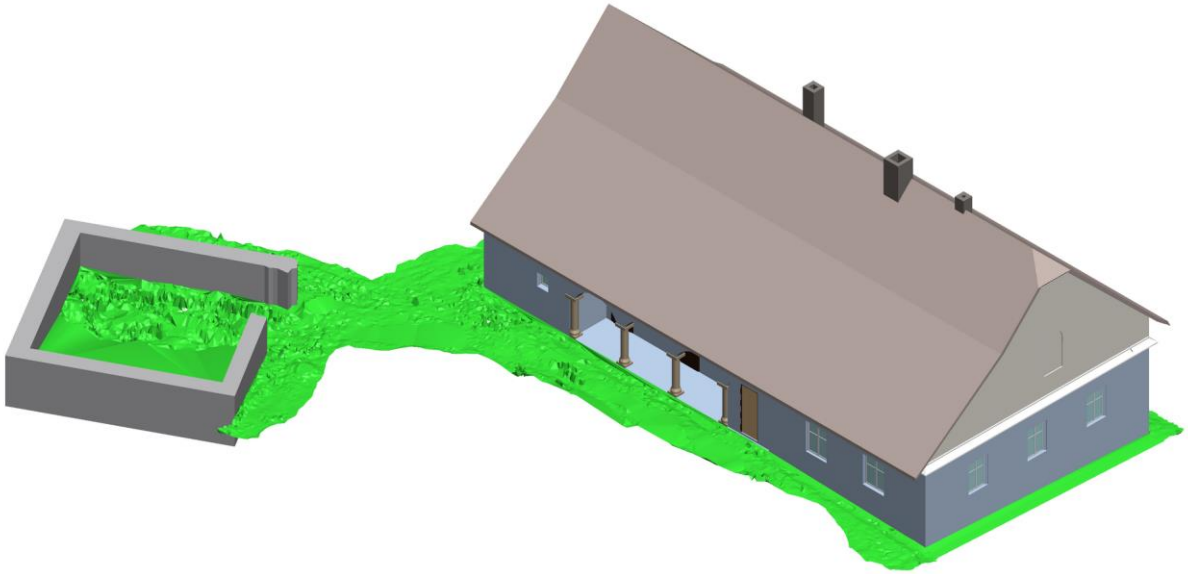

Fig. 11 - Example of a spatial model, isometric view, Stříbrnice (Šumperk District, Czech Republic)

DOI 10.14311/CEJ.2018.01.0005

The Level of Accuracy of photogrammetric outputs is summarized in Table 1, which uses the PhotoScan software terminology that uses several terms to describe the Level of Accuracy [17]:

1. Markers - used for setting up a coordinate system, photo alignment optimization, measuring distances and volumes within the scene and for marker based chunk alignment; defined by their projections on the source photos; should be placed on at least 2 photos.
2. Ground Control Points (GCPs):
   a. *Error (m)* - root mean square error for X, Y, Z coordinates for a GCP location or check point,
   b. *Error (pix)* - root mean square error for X, Y coordinates on an image for a GCP location or check point averaged over all the images,
   c. *Total* - implies averaging over all the GCP locations or check points,
3. Scale bars:
   a. *Error (m)* - difference between input and estimated values for scale bar length,
   b. *Total* - implies averaging over all the scale bars in Control or Check section.

Tab. 1 - Evaluation of accuracy achieved in PhotoScan software

No.	Village	Markers Count	GCP Count	GCP Total Error [m]	GCP Total Error [pix]	Scale bars Count	Scale bars Total Error [m]
1	Ropice	26	24	0.119	1.019	0	-------
2	Vigantice	10	3	0.022	0.698	9	0.026
3	Stříbrnice	25	3	0.003	0.457	11	0.011
4	Jezeřany	36	34	0.043	0.601	0	-------
5	Myslov	36	27	0.123	5.169	0	-------
6	Rudník	24	10	0.049	10.284	27	0.035
7	Ovesné Kladruby	15	6	0.040	17.436	16	0.034
8	Stvolínky	15	4	0.048	7.883	7	0.011
9	Kostelec nad Vlt.	19	6	0.065	5.435	19	0.010

Lines 1 and 5 in Table 1, i.e. the post-processing of the villages of Ropice and Myslov, show a lower level of accuracy than the other lines. In the first case, this is a pilot study where data acquisition in the field and its post-processing were tested. The gained experience helped to improve the methodology of work and the quality of the results. In the second case, it is a farmstead whose outlines were taken from the current cadastral map. In this case, the outline of the building on the cadastral map was different from the real state, which was reflected in a lower level of accuracy of the outputs. The outputs are, nevertheless, usable for Artistic and Historical Research.

The cadastral map is a large scale planimetric map showing all cadastral units and real estate that are subject to cadastral registration. Buildings are projected on it by the projection of their outline onto the terrain with a Level of Detail of up to 10 cm. This may give rise to some

confusion in the post-processing of the metric survey documentation, see Figure 12. During this process, the continuous monitoring and critical comparison of the results are necessary.

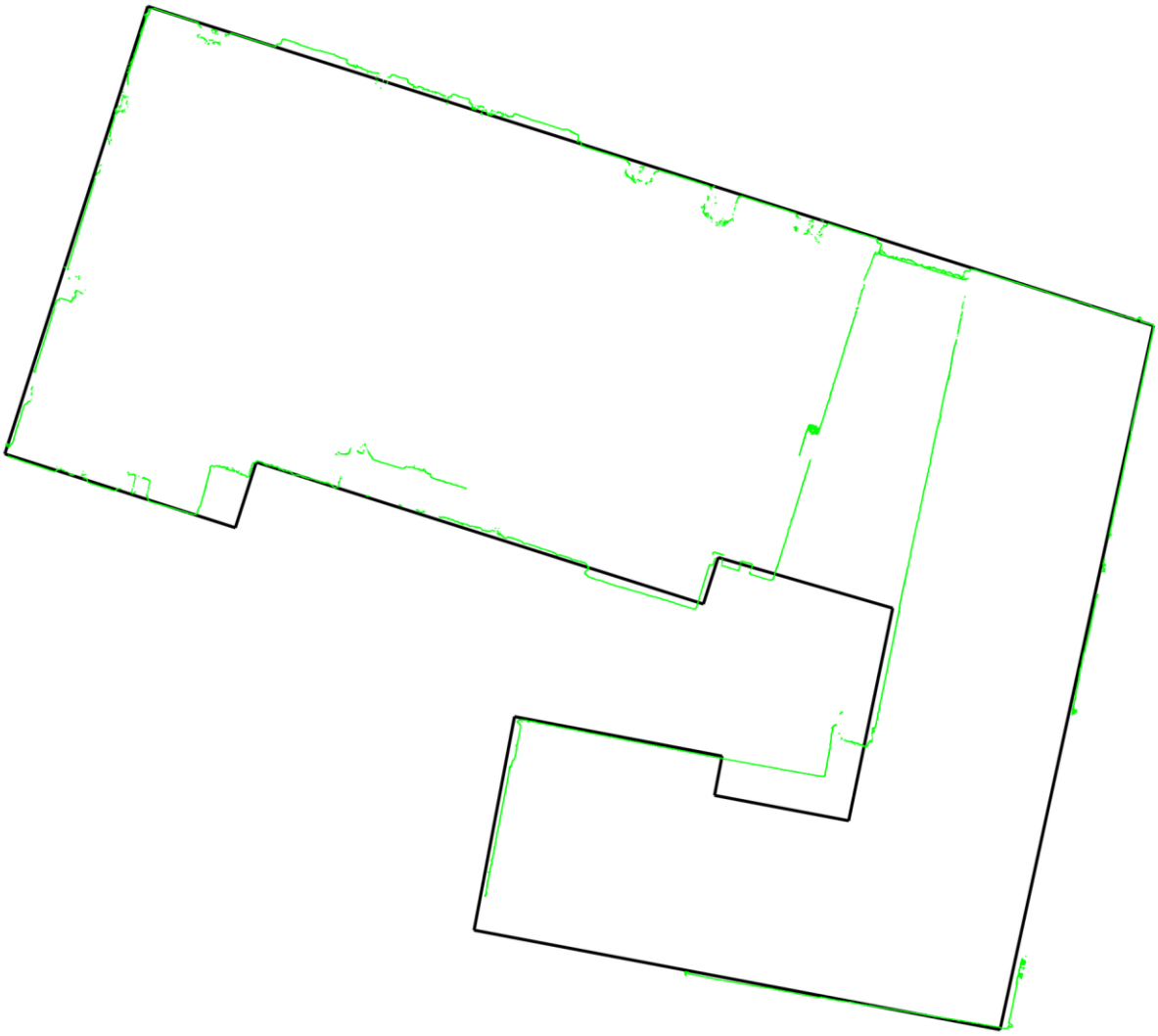

Fig. 12 - Example of differences between the cadastral map and the point cloud, Kostelec nad Vltavou (Písek District, Czech Republic)

CONCLUSION

Analytical map outputs are useful bases for researchers for describing the building history of individual buildings or the village as a whole. Maps capture the transformation of the ground plans of buildings. Consequently, interesting facts can be drawn from them:

- Ground plan of the building has not changed - it is likely that the original core is preserved in the building, although the facades of the building can be completely changed;
- Ground plan of the building has changed - the construction changes that have taken place can be approximately dated;

- Ground plan of the building has shifted on the plot - it is possible to date the construction and destruction of the building;
- Change of the building plot - change of building materials.

This knowledge is very important in the cases where no further documentation to the building is. However, it must be used with caution, because there are lot of buildings that have preserved their ground plan, but have been rebuilt from the foundations.

The metric survey documentation of rural buildings, i.e. ground plans and 3D models, helps researchers to understand their development in more detail. Metric survey documentation helps to recognize the building core from its built parts and to identify other inconsistencies that may not be easily detectable on the spot, but the survey will detect them and display subsequently, e.g. different wall strengths. Metric survey documentation also allows comparing the layout of different buildings with each other, including their internal structure, size, shape, etc. Finally, metric survey documentation allows a better presentation of researched buildings for professionals as well as laymen, such as illustrative presentations at exhibitions and conferences.

Base maps, drawings and 3D models need to be supplemented by studying sources like written documents, plans, photographs and literature. Unfortunately, it often happens with rural architecture that there is nothing at all - building plans and photographs are mostly not preserved at all or exist for younger renovations only; professional literature often does not even deal with them. In those cases, the above outputs are the only metric survey documentation available that can be used for Artistic and Historical Research.

ACKNOWLEDGEMENTS

This work was supported by the Ministry of Culture of the Czech Republic from the Program for the Support of Applied Research and Development of National and Cultural Identity for the years 2016 to 2022 (NAKI II), grant project "The Transformation of Rural Architecture with Emphasis on the Development of the 19th and 20th Centuries", No. DG16P02H023. For more information about this project, visit the project website http://venkov.fsv.cvut.cz/projekt.

REFERENCES

[1] MENCL, Václav. Lidová architektura v Československu. Praha: Academia, 1980.
[2] DITTRICH, Tomáš. Stavebně historické průzkumy pražských vesnic (Zličin, Lysolaje, Ďablice, Klukovice). Staletá Praha. 1990, 56–81. ISSN 0231-6056.
[3] KUČA, Karel a Věra KUČOVÁ. „Ošklivé káčátko“ našeho venkova? Zprávy památkové péče. 1995, **55**(3), 105–110. ISSN 1210-5538.
[4] ŠKABRADA, Jiří. Lidové stavby: architektura českého venkova. Praha: Argo, 1999. ISBN 978-80-7203-082-8.
[5] ŠKABRADA, Jiří. Konstrukce historických staveb. Praha: Argo, 2003. ISBN 978-80-7203-548-7.
[6] PEŠTA, Jan. Encyklopedie českých vesnic: vesnické památkové rezervace, zóny a ostatní památkově hodnotná vesnická sídla v Čechách. Praha: Libri, 2003. ISBN 80-7277-147-7.
[7] PEŠTA, Jan. Area research into vernacular architecture and rural settlements. Professional and methodical publications. Prague: National Heritage Institute, 2014. ISBN 978-80-86516-78-3.
[8] ŠKABRADA, Jiří a Martin EBEL. Chalupy v Čechách na historických stavebních plánech. Praha: Argo, 2014. ISBN 978-80-257-1358-7.
[9] BRŮNA, Vladimír, Jiří CAJTHAML, Jitka ELZNICOVÁ, Jakub HAVLÍČEK, Arnošt MÜLLER, Jan PACINA a Růžena ZIMOVÁ. Paměť krajiny Ústeckého kraje ukrytá v mapových archivech: metody rekonstrukce a zpracování dat v oblastech zaniklých obcí. B.m.: Univerzita J. E. Purkyně v Ústí nad Labem, Fakulta životního prostředí, 2015. ISBN 978-80-7414-981-8.
[10] BRŮNA, Vladimír, Jiří CAJTHAML, Jitka ELZNICOVÁ, Jakub HAVLÍČEK, Arnošt MÜLLER, Jan

PACINA a Růžena ZIMOVÁ. Paměť krajiny Ústeckého kraje ukrytá v mapových archivech: případové studie. B.m.: Univerzita J. E. Purkyně v Ústí nad Labem, Fakulta životního prostředí, 2015. ISBN 978-80-7414-981-8.

[11] HŮRKOVÁ, Ludmila a Klára MEZIHORÁKOVÁ. House with a Column Arcade in Ropice. In: Památky Těšínského knížectví. Prague: Artefactum, 2016, s. 179–191. ISBN 978-80-86890-93-7.

[12] BERÁNEK, Jan a Petr MACEK, ed. Building Archaeology Survey: A Methodology. Prague: National Heritage Institute, 2015. 70. ISBN 978-80-7480-037-5.

[13] POLOPRUTSKÝ, Zdeněk, Petr SOUKUP a Josef GRUBER. Development of rural settlements in the 19th and 20th centuries: creation of analytical map outputs. In: 18th International Conference DĚJINY STAVEB 2017: DĚJINY STAVEB 2017. Pilsen, Czech Republic: Klub Augusta Sedláčka, 2017, s. 235–243.

[14] LAND SURVEY OFFICE. Aerial survey photographs - overview [online]. 2018 [cit. 2018-02-14]. Available from: http://lms.cuzk.cz/lms/

[15] TOPOL SOFTWARE. PhoTopoL. TopoL Software: GIS and photogrammetry [online]. 2016 [cit. 2018-02-15]. Available from: http://www.topol.eu/articles/photopol

[16] VESELÝ, Jan. Surveying of historic buildings. In: Metric survey documentation of historic buildings for use in heritage management. Prague: National Heritage Institute, 2014, s. 18–69. ISBN 978-80-86516-79-0.

[17] AGISOFT. Agisoft PhotoScan User Manual: Professional Edition, Version 1.2 [online]. B.m.: Agisoft. 2016 [cit. 2016-11-05]. Available from: http://www.agisoft.com/pdf/photoscan-pro_1_2_en.pdf