

APPLICATION OF GEOMATICS METHODS IN THE RESEARCH OF STRUCTURES OF HISTORICAL KITCHENS

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ABSTRACT

The article deals with metric survey documentation of medieval and early modern kitchens preserved in various types of buildings in the Czech Republic. Historic kitchens are important but still neglected technical monuments in terms of knowledge of their functional and structural aspects. As part of the student scientific project, surveys and metric survey documentation were carried out, which are the bases for the creation of diagrams of the spatial and structural arrangement of medieval and early modern kitchens. For the article, five very well-preserved kitchens were selected which represent three construction types of historical kitchens. For selected examples, their current metric survey documentation was evaluated. According to its quality and according to the character of a particular kitchen, the method of new metric survey documentation was chosen – 3D geodetic measurement (total station), Terrestrial Laser Scanning (point cloud and 3D model) and close range photogrammetry (point cloud and textured 3D model). The aim was to test and evaluate the informative possibilities of these technologies. Outputs are the description and the metric survey documentation of the selected kitchens. These outputs will be used in the passports of individual buildings to evaluate their construction development. The documentation will also allow the creation of generalizing schemes of spatial and structural arrangement of the individual types of kitchens.

KEYWORDS

3D modelling, Building Archaeology Survey (BAS), Computer Aided Design (CAD), Close-range photogrammetry, Geographic Information Systems (GIS), Historical kitchens, Terrestrial Laser Scanning (TLS)

INTRODUCTION

The article deals with metric survey documentation for research of historical kitchens in the Czech Republic. For a deeper knowledge of these parts of historical buildings, it is first necessary to obtain credible metric survey documentation that will allow the recognized facts to be correctly interpreted. As these are spatially complex systems, interdisciplinary cooperation is a necessity. Therefore, the article also evaluates the specifics and possibilities of application of digital 3D technologies in evaluating the spatial and structural arrangement of five selected kitchens. The outputs will be used as bases for passports of the individual buildings, for the evaluation of building development and the typology of the kitchens and for the presentation of results.

In terms of knowledge of their functional and structural aspects, the historical kitchens are important but still neglected technical monuments. Food preparation, its quality, quantity, level of

processing and culture of serving, in the past as well as today, have always been, still are and probably will be one of the main ways to present one's social status, etc. Therefore, the kitchen was an important place of a house or a residence, which was repaired, improved and modernized.

So far, the metric survey documentation of kitchens in the Czech Republic has been carried out mainly within the documentation and focus of the entire building or area. Therefore, only the basic documentation of floor plans, in some cases sections and views, and photo documentation prevails. Detailed metric survey documentation of the historical kitchen was carried out, for example, in the area of Grabštejn Castle as part of a university thesis in 2016 [1]. At present, the rapid development of technologies for documentation and visualization of monuments enables the creation of digital 3D models. For example, the kitchen of the ruins of Roupov Castle was processed in 2017. Schemes of the spatial and structural arrangement of medieval and early modern kitchens have so far been solved and presented abroad in the framework of popular-science literature or installations and sightseeing tours on specific buildings.

This article presents the specifics and pitfalls of surveying of historical kitchens and the possibilities of current measurement technologies for their documentation.

Types of structures of historical kitchens

Research into the functioning and construction development of kitchens and their documentation has not been at the forefront of research interest yet. The author dealt with the kitchens at medieval castles in Bohemia and France as a part of her studies and professional practice [2, 3]. In the Czech Republic, historians have been dealing with this issue since the 1990s. The initial interest in the study of court society [4–9] was transferred to the kitchens themselves [9–11] and attention was paid to them in the study of structural design of buildings [12].

The chosen method of smoke extraction had the greatest influence on the construction of the kitchens. Unfortunately, they are the vaults and chimneys that disappeared on the ruins soon after the trusses had collapsed, and on standing buildings they are often repaired or rebuilt after the onset of draft chimneys. Within the Czech Republic, only a few historical kitchens have been preserved without major reconstructions to this day. To determine the method of the smoke extraction from the kitchen, our team studies and compares individual kitchens and creates generalized schemes of their spatial and structural arrangement. So far, six basic types of smoke extraction have been defined¹:

Type 1: Kitchen, where the vault of the smoke-part of the kitchen forms the smoke-part of the chimney.

Type 2: Kitchen, where the smoke-part of the chimney passes through the ceiling of the kitchen and extends into the floor above the kitchen.

Type 3: Large kitchen with several chimneys located around the perimeter of the room on the floor above the kitchen.

Type 4: Large kitchen vaulted with 4-6 fields of cross vault, i.e. to 1-2 on pillars or columns. One vaulted field was omitted and replaced by a smoke-part of the chimney.

Type 5: Kitchen, where vault contributes to the direction of smoke into the chimney, e.g. a slightly rising barrel vault.

Type 6: Kitchen, in which the so-called Collar (Mantel) caught and discharged smoke into the chimney.

1 These conclusions were presented at the Castrum Bene 16 conference [13], the proceedings are in press currently.

The article presents five examples of very well-preserved kitchens, which illustrate the three types of structures of historical kitchens.

METHODS

For the research of medieval and early modern kitchen, the quality metric survey documentation is essential. This is also irreplaceable when comparing individual buildings and determining the development of both entire kitchens and certain structural elements. The metric survey documentation of the examined kitchen could usually be obtained in several ways:

1. Archival survey – finding available metric survey documentation
2. New detailed survey
3. Addition of older metric survey documentation with a new more detailed survey²

Since different types of data sets were combined with each other, it was necessary to establish uniform reference scale. The reference scale was selected 1: 50, which is most often used and can be very effectively applied when processing a 2D survey documentation (drawings), 3D point clouds or models [14–18].

Archival survey

We always start our work by finding and collecting archival metric survey documentation (most often in the archives of the territorially relevant heritage institute or building office or in the state archive). However, the accuracy of older plans is proportional to the time of origin and purpose of the acquisition, and thus requires a critical analytical approach³. While the plans from the 18th and 19th century mainly provide information on the construction development of the building, the plans from the second half of the 20th century tend to be of very high quality. Even here, however, we encounter problems, because the space of the kitchen is not often surveyed in detail enough or the situation has changed since the time of the survey. In such cases, it is usually sufficient to perform a detailed survey of the monitored area only and thus subsequently supplement the older metric survey documentation. If the older metric survey documentation does not exist or cannot be used, a new detailed survey must be performed.

Geographic Information System (GIS)

Digitized archival metric survey documentation can be transformed into any coordinate system, which is defined by a sufficient number of identical points. For georeferencing scanned plans, the *affine transformation* [19] can be selected, which takes into account the different distortion of the plan sheet in the longitudinal and transverse direction⁴. If the number of identical points is excessive (more than 3), the accuracy of the transformation can be estimated and the deviations in the position of the identical points can be compensated by the *least squares method*. Due to the fact that cadastral maps are available in digital vector form for almost the entire territory of the Czech Republic today [20], it was possible to georeference the archival metric survey documentation into

2 It was a detailed survey of the kitchen, for its location within the building, we used an older metric survey documentation.

3 The requirements and the most common shortcomings of metric survey documentation for the needs of heritage preservation are described in [14].

4 The use of a higher degree of transformation leads to smaller deviations at identical points, but to larger local deformations.

the S-JTSK system (EPSG: 5514). The corners of the building were chosen as identical points or the network of crosses was used, if available. We successfully used GIS software ArcMap, v. 10.7.1 [21] to process these data sets.

Computer Aided Design (CAD)

Current CAD software solutions enable vector drawing and direct modelling of spatial objects. They contain specialized functions for this purpose. They also support the layering of a drawing or 3D model into thematic data layers. We successfully used AutoCAD [22] and MicroStation [23] software solutions for vectorization of georeferenced archival metric survey documentation and for the elaboration of new plans⁵.

New detailed survey

Ideally, the detailed survey was carried out so that it is divided into two parts taking place in parallel, which allows their mutual coordination and complementarity:

1. New detailed survey, i.e. instructed 3D geodetic measurement of the building, according to [14].
2. Identification, photo documentation, description and dating of building structures, according to [24].

The first point is based on the geodetic measurements with the total station, which is used to determine the spatial coordinates of points of interest⁶. Their coordinates are calculated by the *spatial polar method* [25]. Other alternatives or extensions are Terrestrial Laser Scanning (TLS) and Close-range photogrammetry (Crp). The second point is based on a tour of building structures and an understanding of their functions within a specific architectural solution.

Terrestrial Laser Scanning (TLS) and Close-range photogrammetry (Crp)

TLS is automated, i.e. non-selective, spatial data collection process – point cloud⁷. 3D laser scanners of various designs are used for this purpose. Data collection, i.e. measurement, takes place non-selectively, therefore it is necessary to select objects of interest during post-processing. At present, it is popular to use TLS, among other things, in heritage preservation [17, 18].

Crp is currently applied by solutions, i.e. procedures and systems, that allow, among other things, to process a coloured point cloud and a textured 3D model [16, 26, 27]. This makes them an alternative to TLS. In our cases, commercial photogrammetric software was used – Agisoft Metashape Professional, v. 1.6.4 [28].

RESULTS

The final outputs of the metric survey documentation, including individual types of the kitchens, are presented in the following sections.

5 Typically, these are floor plans, vertical sections, views or orthophotomosaics (final adjustment).

6 That is, the points of interest are selected selectively during the survey and their coordinates X, Y and Z are measured at the same time. The calculations use the spatial polar method, whose mathematical foundations are well described in the literature, e.g. [25].

7 A set of points with known X, Y, Z coordinates, colours, etc.

The first type of the historical kitchens

The first type of historical kitchens are kitchens, where the vault of the smoke-part of the kitchen forms the smoke-part of the chimney. It was supported by peripheral walls or an arched waist, which divided the kitchen space into a smoke-part and a clean-part. The clean-part of the kitchen used to be vaulted or flat-ceilinged. The chimney could be plastered on the outside or covered with gutter-tiles, plastering is more likely in the case of reinforcement of the chimney ribs on the outside. There were no more floors above the kitchen. A protruding or monastery vault was used for the construction of the smoke-part of the chimney.

The monastery vault was used in the **St. Agnes Monastery in Prague**. The protruding vault was in the shape of a regular octagonal truncated pyramid, a regular quadrilateral truncated pyramid, or an irregular quadrilateral truncated pyramid. We documented the asymmetrical irregular four-sided vault of the kitchen in the **Old Palace in Jindřichův Hradec**. The construction of regular chimneys is the same as the construction of helmets used to roof the towers.

St. Agnes Monastery in Prague

St. Agnes Monastery is situated on the right bank of the Vltava river, in Old Town area called „Na Františku“. The monastery of Poor Clares of the Order of Saint Clare and Franciscans was founded around 1231. The kitchen, based on a square floorplan with the monastery vault and ribs connecting on a chimney at the top, was built between 1238–1245 [29, 30]. The kitchen has been recognized in the past and today it is a part of the exhibition. The chimney on the vault is a new formation, the original has not been preserved. This kitchen belongs to the few medieval kitchens frequented in the literature.

At present, it is a popular tourist attraction. Therefore, it was necessary to carry out the detailed survey outside the opening hours and in the shortest possible time. For detailed survey, we used Crp and TLS. For post-processing, we used RealityCapture software [31] and Metashape Professional software [28].

Old Palace in Jindřichův Hradec

The area of Jindřichův Hradec Castle and Château, which has grown to the area of today's three and a half hectares over the centuries, was gradually built on the site of an older Slavic fortified settlement, documented by archaeological research since the 10th century. The construction of a medieval castle, called "Novum castrum" (New Castle) in the oldest historical report from 1220, is associated with the name of Jindřich Vítkovec [32].

The so-called **Old Palace** is partly basement, it has three floors and two mezzanines. It has undergone a complex construction development. Around 1400, the kitchen was established during the building alterations that took place on the north-west side of the palace in a place where it is close to the round bergfrit. The older part of the palace was followed by a tract, which joined the tower on the north side. Above the kitchen, a massive chimney was topped by a decorative head. Sometime before 1492, the youngest tract of the **Old Palace** was raised by another floor. This new floor was located roughly at the height of the kitchen. This enabled its reconstruction. The older small kitchen became part of the chimney and the kitchen itself was moved to a newly built room, from which the entrance to the palace was established. Access to the kitchen for cooks and catering was through the porch.



Fig. 1 – Kitchen in the area of the St. Agnes Monastery in Prague, exterior, view to the North



Fig. 2 – Kitchen in the area of the St. Agnes Monastery in Prague, interior, orthophotomosaic, view to the North



Fig. 3 – Jindřichův Hradec, chimney of the castle kitchen in the Old Palace, exterior, view to the West



Fig. 4 – Jindřichův Hradec, kitchen in the Old Palace, interior, floor plan from TLS

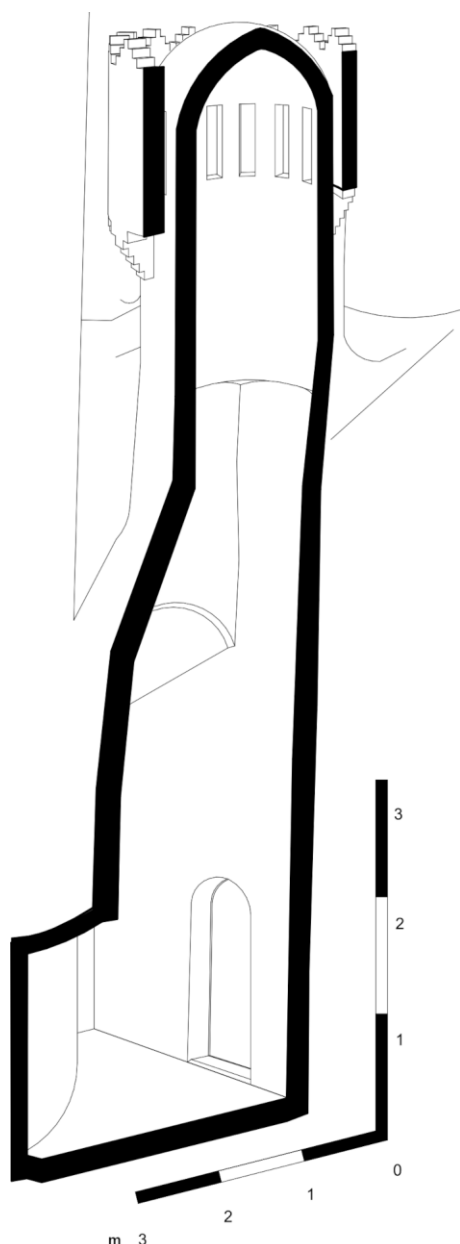


Fig. 5 – Jindřichův Hradec, axonometric section through the chimney of the kitchen in the Old Palace, state of knowledge and interpretation of found situations as of 11/2020

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Křivoklát

The Křivoklát Royal Castle was founded at the beginning of the second quarter of the 13th century, the first stage of its construction lasted until the 1380s. A major reconstruction took place under Wenceslas IV. (1378-1419). After the great fire of 1422, it was only temporarily repaired and a major construction intervention was carried out here by Jiří Poděbradský (1458-1471). It was magnificently rebuilt during the reign of Vladislav Jagellonský from the late 1470s to the 1520s. In 1643, the castle was destroyed by fire. In 1658, the heavily damaged castle was

pawned and sold shortly afterwards. A brewery was developed in the Lower Castle; the rest of the castle was only maintained. Another great fire damaged the castle in 1826. In the second half of the 19th century and the first third of the 20th century, the castle was restored. In 1970s, heritage modifications and surveys were started.

We know the kitchens in Křivoklát from the Vladislav reconstruction only. Until now, a small kitchen is preserved on the first floor of the tower Huderka. From the status of the castle before and after the fire of 1643, it is known the form of two kitchens in the northern front of the Lower Castle

[34]. The first completely disappeared. The second is partially preserved in the mass of the house No. 132, which is adjacent to the complex of palaces of the Upper Castle.

The BAS [35] was carried out for the house, which was deepened by our team members as part of the preparation of the scheme. In the part of the building where the kitchen was, there is a shop with a warehouse currently, so the rooms are filled with furniture and goods. Therefore, we used the quality metric survey documentation of the castle from 1966-67 to create plans [36].

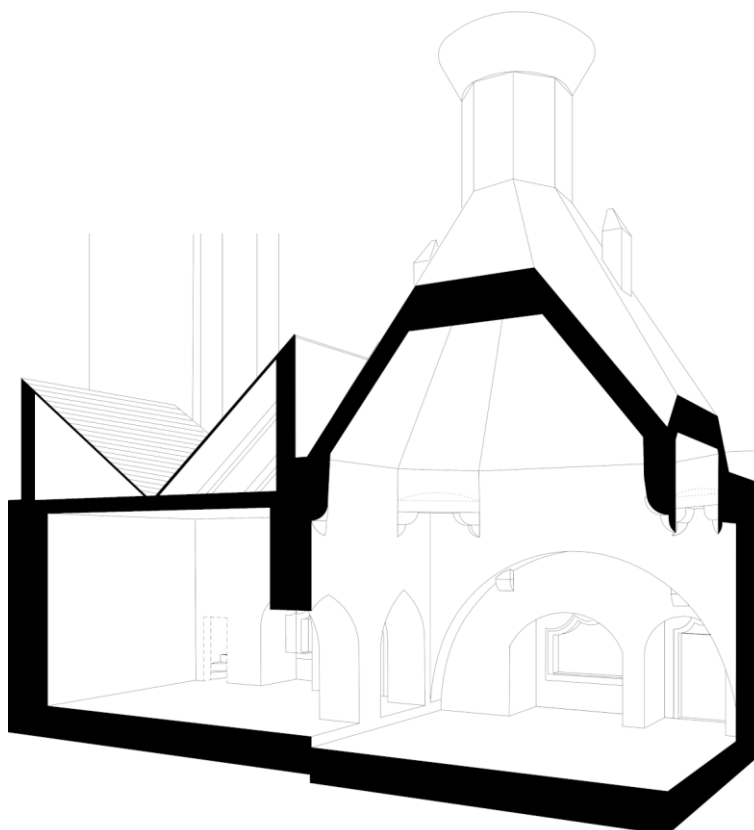


Fig. 6 – Křivoklát, axonometric section through the kitchen, reconstruction of the original appearance, state of knowledge and interpretation of found situations as of 11/2020

The second type of the historical kitchens

The second type of historical kitchens are kitchens, where the smoke-part of the chimney passes through the ceiling of the kitchen and extends into the floor above the kitchen. These kitchens are so large that the central chimney could not cover their entire space. In that case, the open fire-platform was located in the centre of the room. There were columns or pillars⁸ around it. Waists or lintels were mounted on them, which carried the chimney, so that the fire-platform was accessible from all sides. The smoke-part of the chimney penetrated the floors above the kitchen. Structurally, it was a regular quadrilateral truncated pyramid formed by a protruding vault. An example is the kitchen at the castle in **Brtnice**.

⁸ For the older period, we have documented 4, for the younger period, we have documented up to 6.

Brtnice

The château in Brtnice stands on the site of a late Gothic castle, which was first mentioned in 1436. The extensive layout surrounds three courtyards and is surrounded by Gothic-Renaissance fortifications. The château buildings were built gradually. The late Gothic castle was rebuilt and completed in the Renaissance style, the expansion continued in the late Renaissance. Renovations of the château took place after the Thirty Years' War, after 1760, when the château burned down [37], and before the middle of the 19th century [38]. During the renaissance reconstruction, the kitchen was inserted into the ground floor of a Gothic tower in the wing separating the first and second courtyards. It was completed before 1604.

At present, it is not so frequented tourist attraction, i.e. with occasional tourist tours. This condition provided enough time for detailed survey and allowed the application of all measurement methods. Archival metric survey documentation from 1967-9 in the reference scale of 1 : 100 was georeferenced in the current cadastral map in GIS software. Using the archival metric survey documentation, it was possible to connect a new detailed survey with a total station to the S-JTSK (EPSG: 5514). The output of the detailed survey was the current floor plan in the reference scale of 1:50 and the coordinates of the control points for Crp and TLS. In this case, it was desirable to document also on the adjacent surroundings of the kitchen, i.e. selected adjoining rooms. TLS was used for this. Furthermore, it was desirable to document the interior of the kitchen using Crp in order to create orthophotomosaics capturing the vertical structures of the fireplace. From the point clouds created by TLS and Crp, a combined point cloud was created, which was used to drawing the new floor plan.

The third type of the historical kitchens

The third type of historical kitchens are large kitchens with several chimneys located around the perimeter of the room on the floor above the kitchen. The kitchen is vaulted, in the corners or in the centres of the sides of the kitchen there are openings in the vault, which led smoke into the chimneys located on the outside of the perimeter walls of the building. The so-called *Menhartka in Jindřichův Hradec* (around 1500), probably the most famous Czech castle kitchen, has chimneys in the corners. It functioned unchanged until the 19th century.

Menhartka in Jindřichův Hradec

The mass of the Menhartka tower, in which the kitchen is located, contains three vertical parts of approximately the same height. The plinth section has heavier masonry projecting 90 cm in front of the middle part. The protrusion is terminated by a sloping flat covered with gutter-tiles and stone slabs. The middle part is architecturally divided by corner chimneys of the kitchen and bays. The upper part consists of a tent roof covered with gutter-tiles. The plinth and middle part form the space of the kitchen. In the upper part, a representative room called "Courtroom" was, according to the fresco decoration [39].

Detailed survey was carried out during the same campaign as in the Old Palace. We used TLS for detailed survey. Due to the fact that it was a high building with black ceilings (from soot) and insufficient lighting⁹, it was the only measuring technology that made sense to apply under the given conditions. Geomagic Wrap 2017 software was used for post-processing.

⁹ It was a combination of insufficient natural light and the unavailability of sufficient artificial lighting.

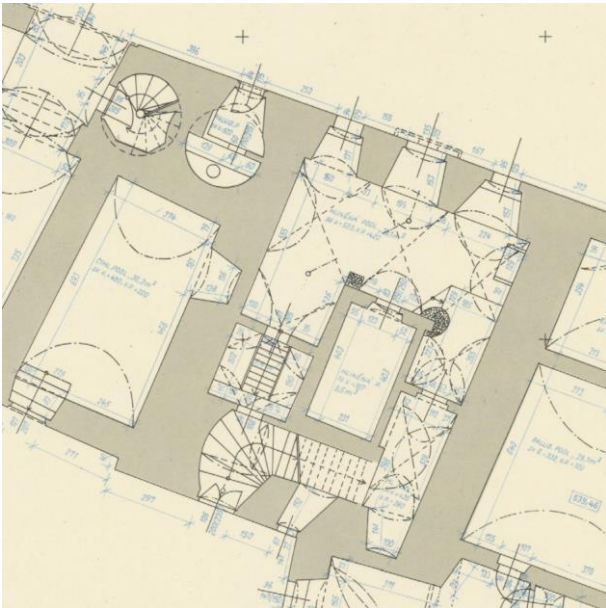


Fig. 7 – Kitchen in Brtnice - floor plan 1:100, 1967-1969



Fig. 8 – Kitchen in Brtnice - floor plan 1:50, present



Fig. 9 – Kitchen in Brtnice, orthophotomosaic 1:20 - view to the East

CONCLUSION

During the solution of our project, our own work-flow for the implementation of metric survey documentation and selection of measurement technologies proved to be successful:

1. The aim of the archival survey is to find and collect suitable archival metric survey documentation.
 - a) There is a high-quality archival metric survey documentation¹⁰ that can be georeferenced into the reference coordinate system, and which can be further used as a basis, only supplemented by additional surveys of some details, see ***Křivoklát***.
 - b) There is a quality archival metric survey documentation that can be georeferenced to the reference coordinate system. However, its Level of Detail in the monitored kitchen-space is not sufficient. Therefore, it is necessary to supplement it with further detailed survey. The type of this survey depends on the character of the documented space, see ***Brtnice***.
 - c) There is no suitable archival metric survey documentation, see ***St. Agnes Monastery in Prague, Old Palace*** and ***Menhartka in Jindřichův Hradec***.
2. The aim of the detailed on-site survey is to get to know the object and, as a result, may influence the way of surveying.
 - a) The existing archival metric survey documentation¹¹ is used, see ***Křivoklát***.
 - b) The existing archival metric survey documentation is supplemented, see ***Brtnice***.
 - c) A new 3D geodetic survey of the building¹² is being implemented, see ***St. Agnes Monastery in Prague, Old Palace*** and ***Menhartka in Jindřichův Hradec***.
3. The aim of the post-processing of the detailed survey is to create comprehensive sets of spatial data that can be further analysed according to the purpose of acquisition, see Figure 4 and Figure 11.
4. The aim of processing of final outputs is to create a comprehensive set of outputs that concisely describe and display the examined space, see Figure 5, Figure 6, Figure 8, Figure 9, Figure 11 and Figure 12.

The detailed on-site survey can be usually complicated in several types of building spaces:

- inaccessible spaces – an example is the middle vertical part of ***Menhartka***, where it is not visible through the ledge and into the chimney orifices, so terrestrial measurements cannot be used.
- confined spaces where it is not possible to get a sufficient distance, see ***Old Palace*** and ***Křivoklát***

10 Ideally, we were looking for older metric survey documentation processed by the measuring group of SÚRPMO, or another organization according to the requirements of SÚRPMO employees, because it is usually of high quality.

11 According to the evaluation of the documented space, it is necessary to choose the method of supplementing - updating or correcting the older metric survey documentation or creating a new one, if the older one is not usable.

12 The construction of some buildings may be such that the total station is the most efficient for the survey, i.e. buildings in good construction and technical condition without major reconstructions. For others, it may be the most effective to perform the survey using TLS or Crp.



Fig. 10 – Jindřichův Hradec, Menhartka kitchen, exterior, top view to the North-West



Fig. 11 – Jindřichův Hradec, Menhartka kitchen, interior, vertical section of 3D model from TLS, view to the North-West

- used spaces, i.e. living rooms, warehouses or shops, where spaces are cramped due to furniture, goods, etc., see **Křivoklát**
- spaces with dark to black walls – generally, complicate targeting when surveying with a total station and form monochromatic spaces, which are unsuitable for close photogrammetry; examples are the lower and middle vertical part of **Menhartka** and some parts of **Brtnice**
- spaces with significant architectural elements – examples can be, for example, vaulted ribs in the **St. Agnes Monastery in Prague**

Detailed survey using the total station is a universal solution. It is advantageous to apply it in cases where the required outputs are drawings – floor plans, etc., because it allows adapting the workflow of the survey to the desired output. When surveying larger or more complex buildings and combining different measurement technologies, it is necessary to create a uniform spatial framework, i.e. a survey net, for the whole campaign. When archival metric survey documentation is used, it is possible to focus on identical points in this way, which will enable the connection of data and surveys in GIS. In cases, where TLS or Crp is used, it is possible to measure the control points in this way. Its disadvantage is the time-consuming process of the survey, so its larger application is not advantageous in time pressure.

Detailed survey using the TLS is a fast automated solution that offers high demands on detailed shape fidelity during time pressure for the survey. Its advantages are the possibility of independent application without the support of other technologies, independence from lighting

conditions when surveying and a colour of the scanned object. In some cases, it may be advantageous to measure several identical or control points in order to be able to connect to the survey with archival metric documentation or other performed surveys. Confined and inaccessible spaces and spaces with dark to black walls are usually advantageous to survey using TLS. There are usually crucial a shape and a structure of constructions not colour. Its disadvantage is the time-consuming post-processing of large amounts of spatial data. Furthermore, in some cases, the export of bases for the elaboration of drawings¹³ – floor plans, vertical sections, etc. can be complicated.

Detailed survey using the Crp is an alternative to TLS. In our practical experience, it is advantageous if the control points are measured using the total station. Its disadvantages are the dependence on the lighting conditions during the survey and colour of the photographed object, when monochromatic surfaces are problematic. On the contrary, its advantage is that it allows the creation of orthophotomosaics, which can be supplemented with drawings. This is especially true for vertical views and sections, which thus increase their informative value.

The historical kitchens, together with smoke-extracting structures, are spatially very complex. In addition, due to frequent modifications, the found situations in the kitchens are also very complicated. The presented detailed surveys show that it is possible to create clear 3D models and provide documentation with maximum data retention.

The detailed metric survey and the clarification of constructions will allow defining basic features of historical kitchens, which can be recognized both in the ruins (especially castles, fortresses) and in a standing but rebuilt building. This will then assist in the identification of the remains of the original kitchens during the Building Archaeology Surveys (BAS) of the buildings as well as in the design of building modifications and repairs.

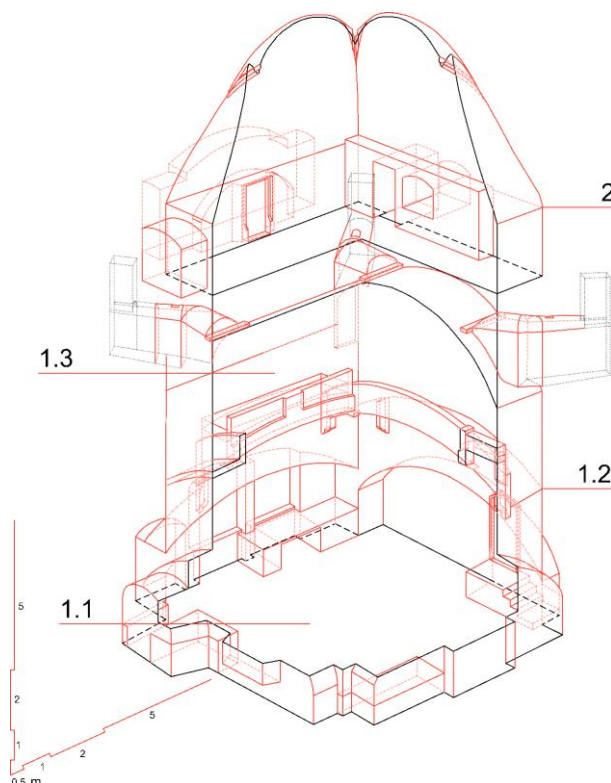


Fig. 12 - Jindřichův Hradec, axonometric section of Menhartka kitchen (1.1 - space under segmental waists; 1.2 - waists; 1.3 - chimney orifice; 2 - Courtroom), state of knowledge and interpretation of found situations as of 11/2020

¹³ Historical buildings usually have an irregular floor plan. In the metric survey documentation of historical buildings for the needs of heritage preservation, it is a common practice that to increase its informative value, vertical sections of the building are inclined in floor plan, e.g. parallel to the selected wall, or divided into partial parts, which are shifted relative to each other in floor plan.

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REFERENCES

- [1] PEXA, Ladislav. *Grabštejn castle (Liberec) - metrical documentation of selected part*. Prague, 2016. BACHELOR THESIS. FCE CTU in Prague, Departments of Geomatics.
URL: <https://dspace.cvut.cz/handle/10467/78841>
- [2] CEJPOVÁ, Miroslava. Nástin vývoje české hradní kuchyně. In: *XVIII. celostátní konference středověké archeologie: Archaeologia Historica*. Brno: Muzejní a vlastivědná společnost, 1987, 367–374. ISBN 0231-5823.
- [3] CEJPOVÁ, Miroslava. Topenišťe dochovaná v hradních kuchyních. In: *1. konference SHP – Vývoj a funkce topenišť, 4. – 6. června 2002, Zahrádky u České Lípy: Sborník příspěvků z 1. konference stavebně historického průzkumu 4. - 6. 6. 2002 v Zahrádkách u České Lípy. Vývoj a funkce topenišť: věnováno památce Romana Kursy*. Praha: Unicornis, 2003, 85–94. ISBN 978-80-86562-00-1.
- [4] BŮŽEK, Václav, ed. Život na dvoře a v rezidenčních městech posledních Rožmberků. *Opera historica: časopis pro dějiny raného novověku*. 1993, 3. ISSN 1805-790X. URL: <https://www.opera-historica.com/>
- [5] BŮŽEK, Václav, ed. Poslední páni z Hradce. *Opera historica: časopis pro dějiny raného novověku*. 1996, 6. ISSN 1805-790X. URL: <https://www.opera-historica.com/>
- [6] BŮŽEK, Václav, ed. Aristokratické rezidence a dvory dvory v raném novověku. *Opera historica: časopis pro dějiny raného novověku*. 1999, 7. ISSN 1805-790X. URL: <https://www.opera-historica.com/>
- [7] BŮŽEK, Václav, ed. Slavnosti a zábavy na dvorech a v rezidenčních městech raného novověku. *Opera historica: časopis pro dějiny raného novověku*. 2000, 8. ISSN 1805-790X. URL: <https://www.opera-historica.com/>
- [8] HRDLIČKA, Josef. *Hodovní stůl a dvorská společnost: strava na raně novověkých aristokratických dvorech v českých zemích*. Vyd. 1. České Budějovice: Historický ústav Jihočeské univerzity, 2000. Monographia historica, sv. 1. ISBN 978-80-7040-462-1.
- [9] DUCHOŇOVÁ, Diana a Tünde LENGYELOVÁ. *Hradné kuchyne a šľachtické stravovanie v ranom novoveku: radosti slávností, strasti každodennosti*. Bratislava: Veda, vydavateľstvo SAV, 2016. ISBN 978-80-224-1538-5.
- [10] KORBELÁŘOVÁ, Irena, Miroslava CEJPOVÁ, Hana FABIÁNOVÁ, Petra KANIOVÁ, František KOLÁŘ, Barbara MARETHOVÁ, Kateřina BŘEČKOVÁ, Dalibor PRIX, Romana ROSOVÁ, Hedvika SEDLÁČKOVÁ a Romuald TURAKIEWICZ. *S knížaty u stolu kuchyně a kultura stolování na středověkých vévodských dvorech v Opavě a Ratiboři*. Ostrava, Czech Republic: Národní památkový ústav, 2018. ISBN 978-80-88240-08-2.
- [11] ŠTAJNOCHR, Vítězslav. *Zámecké kuchyně: zámecké kuchyně v kontextu evropského vývoje*. Praha: Národní památkový ústav, 2017. ISBN 978-80-7480-093-1.
- [12] ŠKABRADA, Jiří. *Přehled vývoje historických stavebních konstrukcí*. Pardubice: Univerzita Pardubice, 2016. ISBN 978-80-7395-992-0.
- [13] CEJPOVÁ, Miroslava. Die Bauform der Burgküchen in den böhmischen Ländern im 13. – 16. Jahrhundert. In: *The 16th International Castellological Conference: Castle and Economy: Castrum Bene 16 - Castle and Economy: Book of Abstracts and Fieldtrip Guides*. Kutina – Sisak, Croatia: Muzej Moslavine Kutina, Povijesna udruga Moslavina (PUM), 2019. ISBN 978-953-7135-62-1.
URL: http://www.ffzg.unizg.hr/pov/pov2/files/10obavijesti/2019/castrum_bene_final.pdf
- [14] VESELÝ, Jan. *Metric survey documentation of historic buildings for use in heritage management*. Prague: National Heritage Institute, 2014. ISBN 978-80-86516-79-0.

- [15] PÖCHTRAGER, M., G. STYHLER-AYDIN, M. DÖRING-WILLIAMS a N. PFEIFER. AUTOMATED RECONSTRUCTION OF HISTORIC ROOF STRUCTURES FROM POINT CLOUDS – DEVELOPMENT AND EXAMPLES. *ISPRS Annals of Photogrammetry, Remote Sensing and Spatial Information Sciences*. 2017, **IV-2/W2**, 195–202. ISSN 2194-9050. DOI: 10.5194/isprs-annals-IV-2-W2-195-2017
- [16] CHIABRANDO, F., M. LO TURCO a F. RINAUDO. MODELING THE DECAY IN AN HBIM STARTING FROM 3D POINT CLOUDS. A FOLLOWED APPROACH FOR CULTURAL HERITAGE KNOWLEDGE. *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*. 2017, **XLII-2/W5**, 605–612. ISSN 2194-9034. DOI: 10.5194/isprs-archives-XLII-2-W5-605-2017
- [17] TOMMASI, C., C. ACHILLE a F. FASSI. FROM POINT CLOUD TO BIM: A MODELLING CHALLENGE IN THE CULTURAL HERITAGE FIELD. *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*. 2016, **XLI-B5**, 429–436. ISSN 2194-9034. DOI: 10.5194/isprs-archives-XLI-B5-429-2016
- [18] LUHMANN, T., M. CHIZHOVA, D. GORKOVCHUK, H. HASTEDT, N. CHACHAVA a N. LEKVEISHVILI. COMBINATION OF TERRESTRIAL LASERSCANNING, UAV AND CLOSE-RANGE PHOTOGRAMMETRY FOR 3D RECONSTRUCTION OF COMPLEX CHURCHES IN GEORGIA. *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*. 2019, **XLII-2/W11**, 753–761. ISSN 2194-9034. DOI: 10.5194/isprs-archives-XLII-2-W11-753-2019
- [19] LUHMANN, T., Stuart ROBSON, Stephen KYLE a Jan BOEHM. *Close-range photogrammetry and 3D imaging*. Berlin: De Gruyter, 2014. De Gruyter textbook. ISBN 978-3-11-030269-1.
- [20] CZECH OFFICE FOR SURVEYING, MAPPING AND CADASTRE. *Atom download service* [online]. 2018 [2018-05-16]. URL: <http://atom.cuzk.cz/>
- [21] ESRI. *ArcMap: ArcGIS Desktop* [online]. 2020 [2020-09-02]. URL: <http://desktop.arcgis.com/en/arcmap/>
- [22] AUTODESK. *Autodesk Knowledge Network* [online]. 2020 [2020-09-02]. URL: <https://knowledge.autodesk.com/>
- [23] BENTLEY SYSTEMS. *Bentley - Infrastructure and Engineering Software and Solutions* [online]. 2020 [2020-09-02]. URL: <https://www.bentley.com/en>
- [24] BERÁNEK, Jan a Petr MACEK, ed. *Building Archaeology Survey: A Methodology*. Prague: National Heritage Institute, 2015. ISBN 978-80-7480-037-5.
- [25] MCCORMAC, Jack, Wayne SARASUA a William J. DAVIS. *Surveying: 6th Edition*. Hoboken, N.J.: Wiley, 2013. ISBN 978-0-470-49661-9.
- [26] MARČIŠ, Marián a Marek FRAŠTIA. Photogrammetric Measurement of a Wooden Truss. *Slovak Journal of Civil Engineering*. 2018, **26**(4), 1–10. ISSN 1338-3973, 1210-3896. DOI: 10.2478/sjce-2018-0022
- [27] WESTOBY, M.J., J. BRASINGTON, N.F. GLASSER, M.J. HAMBREY a J.M. REYNOLDS. ‘Structure-from-Motion’ photogrammetry: A low-cost, effective tool for geoscience applications. *Geomorphology*. 2012, **179**, 300–314. ISSN 0169555X. DOI: 10.1016/j.geomorph.2012.08.021
- [28] AGISOFT. *Agisoft Metashape User Manual: Professional Edition, Version 1.6* [online]. 2020 [2020-09-02]. URL: https://www.agisoft.com/pdf/metashape-pro_1_6_en.pdf
- [29] WIKIPEDIA. *Convent of Saint Agnes (Prague)* [online]. 2020 [2020-10-01]. URL: [https://en.wikipedia.org/w/index.php?title=Convent_of_Saint_Agnes_\(Prague\)&oldid=947230221](https://en.wikipedia.org/w/index.php?title=Convent_of_Saint_Agnes_(Prague)&oldid=947230221)
- [30] SOUKUPOVÁ, Helena. *Anežský klášter v Praze*. Praha: Odeon, 1989. ISBN 978-80-207-0046-9.
- [31] CAPTURING REALITY. *RealityCapture: Mapping and 3D Modeling Photogrammetry Software* [online]. 2020 [2020-10-01]. URL: <https://www.capturingreality.com/>
- [32] NATIONAL HERITAGE INSTITUTE. *Jindřichův Hradec: Official web presentation* [online]. 2020 [2020-10-02]. URL: <https://www.zamek-jindrichuvhradec.cz/en>
- [33] 3D SYSTEMS. *Geomagic Wrap 3D Scanning Software* [online]. 2020 [2016-02-22]. URL: <http://www.geomagic.com/en/products/wrap/overview>
- [34] DURDÍK, Tomáš. *Ilustrovaná encyklopedie českých hradů*. Praha: Nakladatelství Libri, 2009. ISBN 978-80-7277-402-9.
- [35] LÍBAL, Dobroslav a A. LIŠKOVÁ. *Státní hrad Křivoklát. Stavebně historický průzkum. Dům čp. 132, 133*. Strojopis. 1985

- [36] ÚSTAV GEODÉZIE A KARTOGRAFIE PRO KRAJ STŘEDOČESKÝ A HL. M. PRAHY. STŘEDISKO MAPOVACÍ. *Křivoklát hrad. Zaměření. 1:50.* 1967
- [37] PLAČEK, Miroslav. *Hrady a zámky na Moravě a ve Slezsku.* Praha: Libri, 1996. ISBN 978-80-85983-08-1.
- [38] MĚŘÍNSKÝ, Zdeněk, Daniela NOVOTNÁ a Martina STRAKOVÁ. *Brtnice: rodiště Josefa Hoffmanna.* Brtnice: Město Brtnice, 2006. ISBN 978-80-254-1426-2.
- [39] VILÍMKOVÁ, Milada, Jan MUK a Jiřina MUKOVÁ. *Jindřichův Hradec, zámek. Stavebně historický průzkum.* Strojopis. 1976

