ROYAL CHAPEL IN GDAŃSK. STUDY OF FACILITY INVENTORY WITH THE USAGE OF LASER SCANNING WITHIN THE FRAMES OF STUDENT PROJECT

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Abstract

This article presents the photogrammetric works carried out during the architectural inventory of the Royal Chapel in the Main Town of Gdansk (Poland). The facility has the status of a monument of architecture and since decades it is covered by geodetic monitoring, realized with the participation of the Department of Geodesy of Faculty of Civil and Environmental Engineering of Gdansk University of Technology. For several years, the works involve students of “geodesy and cartography” major and supervision over the measurements was taken by Scientific Circle Hevelius from Gdansk University of Technology. Within the complementation of the geodetic measurements made in 2013-2014, the laser scanning of virtually entire facility was performed and the results of studies became the source material for the diploma thesis and student group projects.

The present example shows the positive aspects of cooperation between the monuments conservator and university and student scientific circle. In addition to the possibility to use modern surveying technologies, group project participants learn about the issues of inventory of facilities characterized by significant historical values and they gain additional knowledge concerning the fields related to geodesy (architecture and construction engineering) and substantially different from the engineering industry (history and art). Not without significance is the fact that the works realized within the framework of student tasks served the real protection of the monument and they are a source for further archaeological and architectural analyses.

Keywords: Student project, Royal Chapel in Gdansk, geodesy and cartography.

1 ABOUT THE “HEVELIUS” SCIENTIFIC CIRCLE

Hevelius¹ Geodetic Scientific Circle (SC Hevelius) was founded in 2008 as a student scientific organization. From the beginning of SC Hevelius the goal was to develop students’ skills through practical research and development projects and engineering enterprises, during which it is possible to use the knowledge gained in college, expand it, and also demonstrate own ideas of engineering problems solutions. This approach allows to have confidence that people involved in SC Hevelius operation will be (after graduation) valuable employees for surveying companies, but also will be able to develop interest in science in collaboration with the institution of higher education university.

This can be confirmed by the statistics that clearly show that all the former members of the SC Hevelius, almost immediately after graduation (and even during the study) found a job in their profession, which is not obvious at all on today's job market. These people also confirmed that in most

¹ Johannes Hevelius – astronomer; born: 28 January 1611 (Gdańsk), died: 28 January 1687 (Gdańsk).
cases they do not have any problems with solving tasks set to them by employers, and thus they become employees with a higher potential of knowledge. Some people also decided to continue studying at the higher levels of study and perhaps they will take a scientific career.

The circle operates at the Division of Geodesy of Faculty of Civil Engineering and Environment of Gdańsk University of Technology (DG FCIE GUT) and it uses the equipment, software and most of all the support of FCIE GUT scientific staff.

2 COOPERATION BETWEEN SC HEVELIUS AND SERVICE AGENT OF MONUMENTS

The cooperation between SC Hevelius and services agent of St. Mary's Basilica in Gdansk - Mr. Tomasz Korzeniowski began in 2011. The object of interest of the students became the Royal Chapel - an extremely valuable historical monument in the custody of Korzeniowski. Back in the 90s the employees of Department of Geodesy at Gdańsk University of Technology conducted geodetic monitoring of the facility because of suspicion of its strong subsidence. After a major overhaul of the Chapel it was noticed another crack and man began to wonder about the resumption of subsidence monitoring. Chapel employee who controlled measurements in 1995-1999 - Mariusz Chmielecki MSc. Eng. established a contact between the board of SC Hevelius and Conservator and this resulted in starting the cooperation. Since that time, members of the Circle regularly carry out monitoring of subsidence of Royal Chapel by precise geometric leveling. These works has already resulted in tangible results in the form of obtaining financing actions to prevent the uneven subsidence of the facility.

Due to the commencement of researches related to laser scanning technology, the SC Hevelius became interested in this technology in their operations. Royal Chapel - as a facility threatened by uneven subsidence and at the same time as an extremely valuable one has become the natural choice as the first project related to inventory of 3D building using laser scanning. The students’ concept was supported by Conservator who considers laser scanning as one of the best methods for inventory of historic facilities, allowing for a detailed reconstruction of possibly damaged components.

Within the frames of cooperation, also the project of constant monitoring of subsidence was realized with the use of hydrostatic levelling, feeler gauges and automatic piezometers of the extremely valuable facility located next to the Royal Chapel – the biggest brick temple in Europe - St. Mary's Basilica in Gdansk. Perhaps in the future it will be possible to gain funds and install such a system. This action would allow to monitor the status of both facilities, potentially threatened by unstable water and soil conditions.

More recently, within the framework of this cooperation, the students supported also the creation of a database on sacred historic facilities from across the Poland.

3 ABOUT THE ROYAL CHAPEL IN GDAŃSK

The Royal Chapel (full name: Rector's Chapel Church of the Holy Spirit) is a historic religious building located at 42 Św. Ducha street at the Main Town of Gdańsk. It is located in the Polish state register of monuments (item. of reg. 292 dated on the 24th of February 1967.).
The chapel was built in Baroque style for Gdansk Catholics in the years of 1678-1681, when located next to St. Mary's Church passed entirely in the hands of Protestants, and there was a need to have a smaller but own place for pray (since 1558 there was a consent of King Sigismund II Augustus of the Jagiellonian dynasty on celebration of Protestant worship at the altar of St. Nicholas in the catholic (in these days) St. Mary's Church). The construction of Chapel was financed from the legacy (record of inheritance) of Archbishop of Gniezno and primate of Poland - Andrzej Olszowski (1621-1677) with the support of the Polish king - Jan III Sobieski. The foundation stone of the Chapel was laid on the 21st of July 1678. It was equipped with a silver plate, which Latin inscription mentions Pope Innocent XI, the Emperor Leopold I, the Polish King John III, Kujavian and Pomeranian Bishop – Stanisław Sarnowski and voivode - Ladislaus Dönhoff. Address of the chapel was defined as "in honor of the Holy Spirit, and the memory of Saints John the Baptist and the Apostle Andrew". The foundation stone was blessed by Joachim de Hirtemberg Pastorius, Apostolic Protonotary, Chełmiński Canon, Dean, Pastor and Gdansk and Pomerania Official, His Majesty King The Splendid Polish Secretary, Commissioner and Historian of Poland [1].

The construction works were conducted by Bartel Ranisch in accordance with the design of Tielman van Gameren, but sometimes the authorship is attributed to Isidore Affaita [2-4].

In 1838 and in 1877 the renovation works were carried out and in the years of 1934-1937 arch. Friedrich Fischer carried out restoration work.

In March 1945 the following were destroyed: the roof, part of vaults and additions and interior equipment. Materials concerning this period can be seen in [5, 6] and [7]. In 1946 the restoration and maintenance of buildings was started and it lasted intermittently until 2005.

During renovation works in the 90s of XX century there were suspicions of strong subsidence of the facility and therefore the Department of Geodesy of Gdansk University of Technology was asked for the monitoring of vertical foundations displacements. Measurements were carried out until 1999 and in 2011, after a 12-year break, they were resumed by SC Hevelius.

4 ABOUT THE MEASUREMENTS OF SUBSIDENCE IN ROYAL CHAPEL IN GDAŃSK

SC Hevelius realizes the research of vertical facility foundations displacements using precision optical and digital levelling instruments since 2011. For this purpose a method of precise geometric levelling of controlled points (benchmarks) installed on site is used.

The facility was founded on the ground, where due to the nearby presence of watercourses and unfavourable arrangement of the ground layers, the groundwater level subjects to large fluctuations, which in turn has an adverse effect on the objects located in the area. For the stability of the foundations of the facility, the deep trench located close to them had also unfavourable effect. Researches performed using methods of satellite levelling and hydrotechnical and geological measurements confirmed the instability of land on the area of the Gdańsk Main Town [8-14].
The measurements confirmed the trend to larger subsidence of the northern part of the building, which was already observed during measurements in the 90s of the twentieth century. This time, however, the subsidence of the north wall and supports was very clear (Fig. 4). Also, thanks to these researches it was possible to accelerate the removal of the so-called "hole of shame" which is a large archaeological excavation in the immediate vicinity of the north wall of the Chapel. In connection with not favourable water and ground conditions, the excavation posed a threat to the foundations of buildings. Another series of measurements in the near future will show whether the subsidence of the northern part of the facility was slowed. When carrying out their research, students refer to the control benchmarks installed on the tower of the nearby St Mary's Basilica, which is considered as the most stable facility in the vicinity. More important than the size of Chapel foundations subsidence is the possibility to control their uniformity and this is the primary objective of the measurements.

Levelling measurements in the Royal Chapel are bound to the geodetic altitude matrix (Fig. 5). At the link the precise levelling instrument of Leica DNA03 is used, but this levelling has no strict features of precise levelling due to the use of GKNL4M patch-type and stand with sliding legs - GST120-9 PRO. The resulting accuracy, however, allow you to check the obtained results and control in respect of previous years.
5 ABOUT THE INVENTORY MADE BY TLS METHOD

Inventory with the use of the terrestrial laser scanner (TLS) was performed in May 2013 (Fig. 6). It was an another stage of cooperation between SC Hevelius and Conservator, and simultaneously students performed the second project concerning the laser scanning. The first was a comparative scan of the waterfront cliff before and after the demolition of bunker located on this waterfront [15, 16]. Members of the SC Hevelius also gained experience in scanning the historic forge in Gdansk Orunia [17]. This time, however, the first time the members of the SC Hevelius had an opportunity to perform a complete scan of the facility. Number of Scanner stations was incomparably greater than in case of the first project, and the design of their location and the subsequent combination into the model was more difficult than in the first case.

Fig. 6. Co-author during the performance of scanning at the entrance to the Royal Chapel.

Leica C10 scanner was used to carry out scanning in two stages. At first, 8 stations were arranged around the facility. „Black/White” tags were used to merge them further into the 3D model (Fig. 12) and they were arranged on the scanned object and the surrounding buildings. Their position is designed as to make it possible to see 3 symbols on the previous and next station from each station. Thanks to this, combination of scans is realized in an automated manner by indicating the corresponding symbols and granting them appropriate identifiers.

Much more difficult to perform was the second phase of scanning which covered scans of the roof, dome and interior of the Chapel – in total – 13 stations. Due to the historical and sacred nature of the facility, many limitations were encountered. It was not possible to deploy stamps inside (possibly only stamps on tripods). It was decided, however, that it may be an advantageous situation for the realization of tests and combination of scans using the “cloud to cloud” method with the use of geometric formulas inside the facility (Fig. 13). It is a method much more labour intensive than the use of identification stamps and in addition, obtaining the adequate accuracy of relationship requires the creation of large quantities of them; however, it allows to combine the scans with areas of mutual coverage without any additional supporting elements.

Fig. 7. Scan view: Royal Chapel on the background of St. Mary’s Basilica – an effect obtained after combining clouds with TLS inside the facility.
Fig. 8. Scan view: Royal Chapel interior – an effect obtained after combining clouds with TLS inside the facility.

Fig. 9. Scan view: Royal Chapel from the outsider – an effect obtained after filtering needless elements beside the complex of facilities.
Fig. 10. Scan view: Inside shell of the facility – an effect obtained after filtering and limiting the surface to the inside surface of the Royal Chapel.

Fig. 11. Scan view: Interior of the Royal Chapel with the polychrome elements in the dome.
In case of roof scans it was impossible to use a tripod for the instrument because of the fact that the roofing is covered with very sensitive copper plates. The roof structure did not allow for a free and stable setting of any instrument base. And due to this fact, the instrument was set directly on copper plates of the roof. This gave problems with its stability and required additional checks of the measured data. Ultimately, however, due to an additional splitting of scans from every station and their separate orientation in relation to the rest, it was possible to create a 3D model (Fig. 7-11).

![Fig. 12. View of the field image (left) and scan view (right): typical measuring stamp for connecting scans. Element on the roof. Strips (breaks) in the scanned stamp indicate vibration of the measuring instrument because of wind gusts and light roof structure.](image)

![Fig. 13. Scan view: measurement stamps identified on the edges of patterns inside the flooring of Royal Chapel.](image)

Model of the object provides a good basis for creating inventory documents (plans, projects of repairs, verification of object condition). In conjunction with a descriptive and photographic documentation it is possible to reproduce each scanned item. The possibility of three-dimensional objects view, such as reliefs or decorations gives many more possibilities than only sketches. It will also be possible to e.g. create a model for blind people.

The project of scanning correlates also well with project of subsidence measurement. When performing scans outside the object, also the excavation located next to the wall of the Chapel was scanned. Subsequent scans at this point will enable a comparative analysis of changes in the field and they are a complementation of levelling data.
6 PROBLEMS, RESULTS AND BENEFITS

Working in a historic sacred building is an interesting variation in the context of standard studies conducted at the university. It also lets you know the problems associated with the work in the immediate vicinity of the historic and historically valuable buildings. Due to the character of the building, there are also some limitations. Measurements can be made only upon consent granted by the conservator and in the time determined by him. Time pressure does not facilitate the task, however, it is a valuable lesson of practical and quick solution of problems by students. It also requires far-reaching self-organization and realization of team projects. Preparation of the measurement equipment and documentation of insurance, transportation, contact with the conservator, measurements and their development are entirely at the discretion of SC Hevelius members. They can of course count on substantial support from their caregivers, but in order to efficiently carry out measurements and develop results in the determined period of time they must strongly cooperate within a team and share the tasks responsibly. “Task manager” who is appointed by the President of SC Hevelius who has required experience and obedience of camaraderie supervises the measurements realized inside the Chapel as well as every single project. Beyond the strict measuring team, works also involve members of the SC Hevelius and candidates for membership in order to familiarize with the situation and in order to prepare to taking over the tasks in the following years. Such a system enables the organization to seamlessly take over the tasks by following vintages of students and it allows for the assessment of work within the discussions held at the meetings of the SC Hevelius.

Another major difficulty is the touristic character of the place. Crowds of tourists in Gdansk significantly complicate the task, and sometimes may lead to the total destruction of the effects of work even by the accidental displacement of geodetic mark, which makes it impossible to develop the results. Such a situation is likely to be encountered in 2013 while making a levelling measurements, so their development gave erroneous results and repeating the measurement within that year was no longer possible. The pressure increases so the more that the object conservator expects to receive test results after making the facility available. For students from SC Hevelius this is a very important experience which learns them how to deal with similar situations in their professional future.

A large number of people in the vicinity of the object also disrupted the works related to its scanning. Unfortunately, it is impossible to exclude the area of use for the purposes of works carried out by SC Hevelius. Therefore, in a later results study it was necessary to deal with a lot of accidentally recorded data and their "cleaning" from the scans.

The current problem solving under pressure is very beneficial for the development of students and this constitutes the base of Circle activity. Data developed on the basis of performed works constitute a valuable source of information for the object conservator.

7 SUMMARY

Cooperation with an institution such as the conservator of monuments provides advantages for both parties. Conservator receives valuable results of the research, while students can demonstrate their commitment and knowledge when developing their practical skills. Circle’s works are carried out under the supervision of university tutors, allowing you to develop reliable results, but it also gives you the possibility to implement appropriate didactic changes for rest of students thanks to sample problems encountered by colleagues carrying out work under the activity of Scientific Circle. Such activities are also beneficial for the university. It provides (for the purpose of Circle’s activity) the necessary budget, tutoring and equipment, because students affiliated within the similar organizations devote their own time striving to develop themselves, and by sharing the results of research and by cooperating with other institutions they positively affect the prestige of the university. They are also valuable employees on the labor market which also has a beneficial effect on the image of the university.

REFERENCES

