SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 225

DIGITAL TOOLS IN THE PROCESS OF ARCHITECTURAL EDUCATION AS A METHOD OF STUDYING AND PROTECTING ARCHITECTURAL HERITAGE

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Purpose: The article presents the issue of the implementation and popularisation of the use of digital tools in practical classes focusing on the conservation of historic buildings for architecture students.
Design/methodology/approach: The study investigating the role of digital tools and the necessity of their implementation and expanded application in the field of architectural conservation education was conducted at the Faculty of Architecture of the Silesian University of Technology in Gliwice, as well as at selected technical universities in Poland and abroad. The research methodology included questionnaire-based surveys directed at architecture students and interviews with staff from the faculties.
Findings: The research indicates that the implementation of practical classes in the form of workshops is crucial, as it has a number of benefits. The implementation of such workshops provides an opportunity to develop and enrich the curriculum and encourage the student in conservation research and preservation of historical monument.
Research limitations/implications: Research conducted at higher education institutions in the Faculties of Architecture in Poland has shown that relatively few academic units include practical training in the use of digital tools as part of their curricula. Such courses are more commonly found in faculties that are integrated with civil engineering, where greater opportunities for collaboration and knowledge exchange exist. In contrast, the findings from foreign universities are more encouraging. Practical classes involving digital tools are conducted systematically and have yielded remarkable results throughout the didactic process.
Practical implications: The article may serve as a point of reference for the development of didactic strategies in architectural education and for determining the specific competencies and support students require in the course of architectural education.
Social implications: The benefits of young architects' ability to use digital tools influence their future perspectives in the profession. In addition, education in the use of these tools contributes to the preservation of architectural heritage, which is a common cultural good.
Originality/value: The article highlights the critical role of digital tools within architectural education, considering both the student and institutional perspectives. Manuscript fills the gap in the analysis of the use of digital tools in practical classes in the process of architectural education.
Keywords: digital tools, education, thermography, laser scanning, photogrammetry.
Category of the paper: Research paper.

Introduction

In the complex process of architectural education, the study of conservation and research of historic objects, particularly in terms of practical skills in using digital tools, is sometimes marginalised. However, it is worth bearing in mind that, in addition to the traditional methods of examining historic structures, which include the study of bibliography, archival documentation (drawings, cartography, photographs etc.), conservation documentation or surveys, as well as in situ surveys, which should form the basis of the research, methods of surveying buildings using digital tools together with the conducting of thermal analysis are an extremely valuable completion.

Digital methods have become increasingly popular in recent decades, the tools have been improved, the measurements have become more precise and their possible applications continue to expand (Ćosović, Maksimović, 2022). These include among others laser scanning, photogrammetry and thermal imaging measurements. These surveys, for example laser scanning, help to measure an object with much greater accuracy than traditional methods and record more data in less time (Karatzas et al., 2024). Moreover, thanks to the use of drones, it is possible to carry out these surveys in places where access is difficult or impossible. Digital tools provide valuable information about buildings that is impossible to examine without their use - they help determine the structure of a building, the layers that have formed over time, cavities, the technical condition of the building partitions, its humidity, etc. In addition, their remarkable value lies in the fact that they are non-invasive, non-destructive methods - so there is no concern that the research may negatively affect the surveyed heritage site.

Additionally, digital tools can be used to digitise heritage, which is considered one of the effective forms of heritage protection - to create so-called digital twins. The research carried out can be highly valuable for protecting the existing historic fabric, creating conservation guidelines, forecasting how the site will change, depending on external factors, or finally for developing design guidelines and making changes to the site to adapt it to changing user needs, comfort of use or energy efficiency (Bevilacqua et al., 2016). The popularisation of heritage also plays an important role in its conservation - including for example sharing electronic form of the object - digital models of historic buildings. Carrying out heritage surveys using digital methods therefore has not only scientific, documentation and application objectives, but also educational and popularisation purposes.

While it is common during architectural studies for students to be introduced to the theoretical knowledge of the digital tools in question, it is crucial to introduce practical workshops that will allow them to get a thorough understanding of the site and prepare conservation and design guidelines appropriately. The result of these workshops will at a later stage influence the practice and quality of the architectural profession and directly contribute

to the preservation of our heritage. According to research on universities in Poland and selected foreign universities, e.g. in Italy and Slovakia, so far very few faculties of architecture in Poland offer practical workshops in this field, and those are usually combined faculties of civil engineering and architecture. At foreign faculties combining civil engineering and architecture, practical classes have often been implemented as a permanent part of the curriculum, which has a huge impact on the future work of students studying there.

The article is aimed at presenting the possibilities and benefits of using digital tools in architectural education by introducing practical classes in the form of workshops. The article presents a methodology for surveying historic buildings using selected digital tools. Example results of the survey are presented and the possibilities of their application in design and conservation are highlighted. Additionally, the results of a survey are discussed, which shows how architecture students perceive the use of digital tools in architectural studies in the context of education and their motivation to use these tools in their design work.

Methodology of surveying historic buildings using selected digital tools and examples of results

New survey techniques are being successfully used in the study of historic buildings (Więcek, Poksińska, 2006). By digitisation activities in the area of monuments, we understand non-invasive measurement methods that are used for, among other things, inventory purposes (Czajkowski 2023) and thermal and humidity analysis. Performing a digital survey makes it possible to create a digital copy of an object and to analyse its historical-architectural features by cataloguing its losses, deformations, geometry and state of preservation. Precise dimensioning gives us the shape, structure of the three-dimensional surface, and colour not only of the external form, but also of the building's furnishings. Familiarising students with non-invasive digital methods, together with practical instruction on how to carry out research using the tools, will enable them to understand the whole process of conservation and conservation design of an existing monument. The aim of such classes would additionally be to create a copy of the monument reflecting and evaluating its technical condition with further knowledge of how to create as-built documentation. The materials created as a result of the activities will contribute to the creation of a database of information about the heritage site for research and educational purposes, as well as for the promotion of cultural heritage.

Photogrametry and laser scaning

The photogrammetric method is an essential tool for the development and execution of architectural and building inventories. It is a branch of technical science that aims to characterise an object by taking photographs using ground-based as well as aerial techniques.

Through the use of digital cameras and survey cameras, photogrammetric images are taken, which make it possible to reconstruct the shapes, sizes and relative positions of objects in the site. The registration of images can take place in sites that are difficult to access and the fast registration of images with a large number of points makes it possible to collect a lot of important and reliable data about the site. A photogrammetric image is a true reflection of the object (Figure 1). However, there may be radial deviations due to the tilt of the image (Orłowski, Tunkiel, 2022).

Laser scanning is a technology that uses a laser to obtain an accurate measurement of distance. The point cloud that is obtained as a result of the inventory is an image of reality represented by a dataset of millions of measurement points (Figure 2). The process of laser scanning begins by setting up the scanner and emitting light rays which, after reflecting off the object, return to the scanner. By measuring the interval from when the ray is emitted to when it returns, the scanner calculates the distance to each point of the object. By repeating the process millions of times, a so-called point cloud is created, which is an accurate representation of the scanned object, making it possible to create a three-dimensional model of the monument being measured. "Laser scanning, in correlation with terrestrial digital photogrammetry, in a way that is above all extremely fast and non-interfering with the object, allows a very large amount of spatial data to be collected, with which a precise simulation of the object or part of it can be made" (Orłowski, Tunkiel, 2022).

Figure 1. Photogrametry of historic Pavilion Wrzos in Goczałkowice Zdrój.
Source: Wałek, Krause- Świerczyńska.

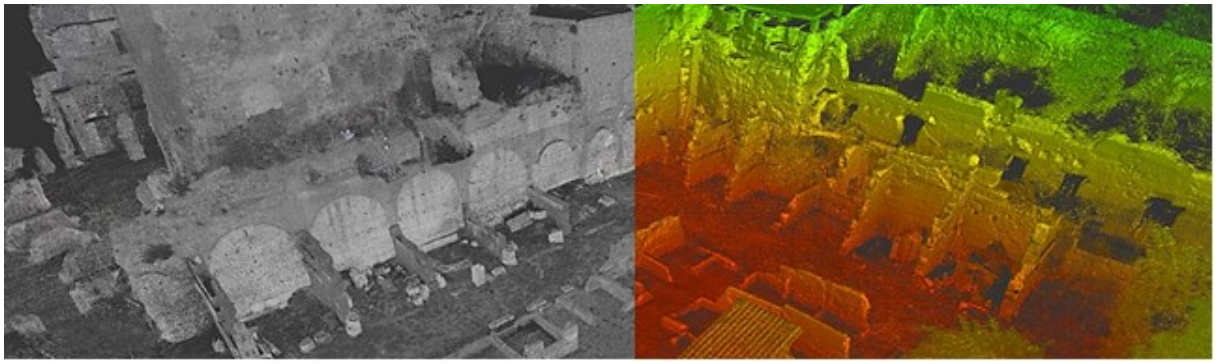

Figure 2. Laser scanning of Horrea Agripiana Rome.
Source: Wałek.

Thermal imaging surveys

Thermal imaging is a field of technology that deals with the detection, registration and imaging of infrared radiation emitted from the surface of the object under examination (Szmolke, 2015). It is an effective research tool that assists in evaluating the technical condition in terms of the thermal insulation of the building under examination. During thermal imaging surveys, the instantaneous temperature distribution on the surface of the building structure is recorded (Figure 3). A complete analysis of the thermal and humidity condition reveals the extent to which any defects exist and the regularity of the temperature distribution (Steidl, Krause, 2009). This analysis is carried out by comparing the measured temperature (thermogram) with the temperature calculated by numerical methods using appropriate computer programmes. Elements of a building diagnosed with a thermal imaging camera make it possible to determine the occurrence of humidity in external walls, infiltration of external air through partitions, the difference in thermal insulation of materials in a building partitions, as well as to check the thermal and humidity condition of selected fragments in terms of surface condensation using the fRsi index (Figure 4).

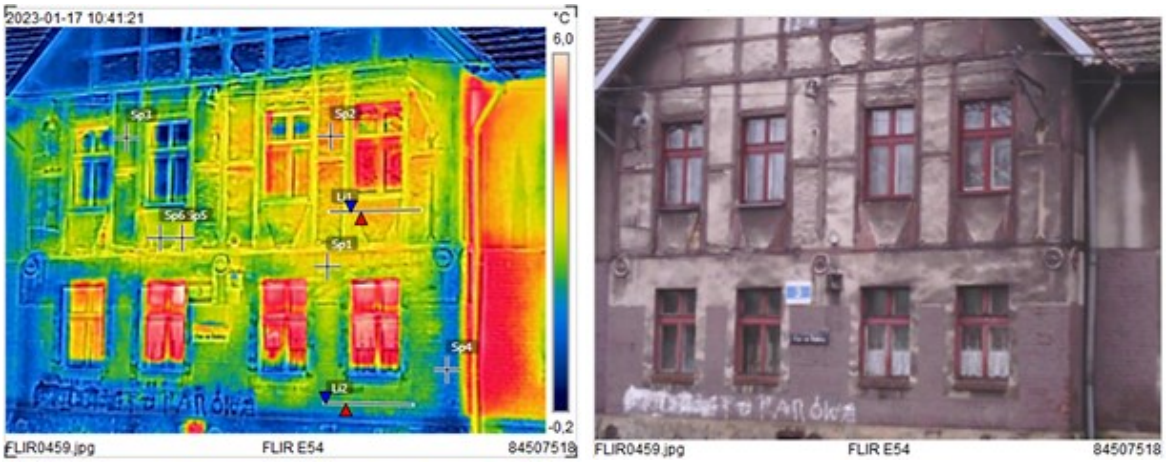

Figure 3. Thermal imaging surveys of building facades, Bytom, Osiedle Bobrek.
Source: Krause-Świerczyńska.

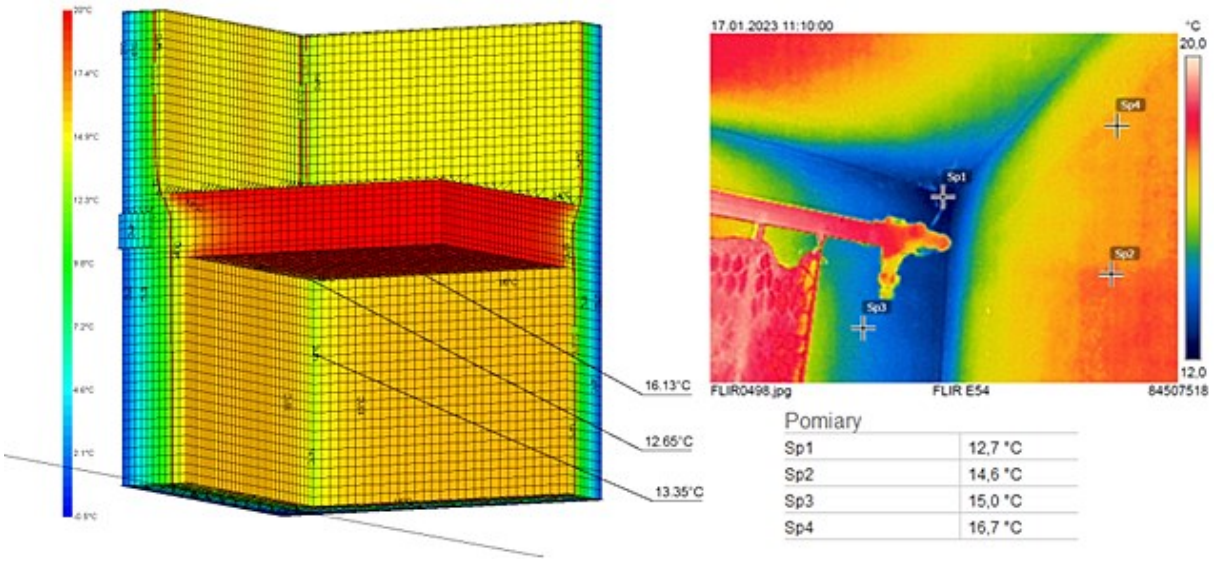

Figure 4. Thermal analysis of a selected detail in a 3D analysis program, Bytom, Osiedle Bobrek. Source: Steidl.

Methodology Experience with practical classes on the use of digital tools in architectural education in Poland and abroad

The research shows that in Poland very few Faculties of Architecture introduce practical classes in the use of digital tools into the study programme. Much more often such classes take place at faculties that are combined with civic engeneerning. For the purposes of this article, the curriculum of the most important faculties of architecture in Poland and a few selected ones in Europe was analysed. Among those surveyed in Poland, only a few faculties offer practical classes in digital tools - usually in photogrammetry, less often in laser scanning. The surveyed universities do not offer thermal imaging studies at the faculties of architecture. At the Faculty of Architecture of the Silesian University of Technology, practical classes in photogrammetry, amounting to approximately 15 hours in the course Computer-aided Design, were piloted by PhD Eng Arch. Magdalena Wałek, for part of the 2nd year of the 1st degree programme. In a similar number of hours at the Faculty of Architecture at the West Pomeranian University of Technology in Szczecin, students in the course Computer CAD Design have the opportunity to learn how to use laser scanners, on the example of scanning large spaces and small forms. An interesting form of conducting such classes is the introduction of digital tools within the scope of inventory practice - the examples of the Faculty of Architecture at Poznan University of Technology, the Faculty of Architecture of the Opole University of Technology, as well as the Faculty of Civil Engineering and Architecture of Kielce University of Technology, where within the scope of a two-week inventory practice, students learn surveying practices involving measurements of the object by digital photogrammetry and laser scanning. The case is different

abroad, where such classes are more common. For example, architecture students at the Department of Civil and Mechanical Engineering at the University of Cassino and Southern Lazio (UNICAS) and the Department of Humanities and Philosophy at UNICAS, have practical classes in laser scanning as well as photogrammetry with 10 hours of practise alone. According to the course instructors, Cassino students emphasise the extraordinary value of the practical classes and the fact that, thanks to their integration into the study programme, they can be recruited for important positions where the use of digital technologies is fundamental to their work. However, conducting workshops can be challenging. Course instructors emphasise the very small number of hours allocated to practical training, which means that the matters taught have to be reduced to the basics. Far more often than in practical workshops, students are confronted only theoretically with the topic of digital tools and their possibilities. However, of the largest faculties or institutes at technical universities offering a degree in architecture that have not yet introduced practical classes on the use of discussed digital tools, many units are planning to introduce more practical classes into the curriculum in the coming years.

Student's perspective on the issue of application of research results in the conservation and design process – results of survey

In order to study students' understanding of the use of digital tools in the conservation process, such as photogrammetry, scanning or thermal imaging research in the study of historic buildings, a survey was conducted among 56 master's students of the Faculty of Architecture at the Silesian University of Technology. The students taking part in the survey were enrolled in a course on conservation design in the academic year 2024/2025. As part of the course, students have lectures on conservation design, during which the theoretical aspects of researching historic buildings, including using modern digital tools, are covered. However, there are no workshops on the practical use of these tools, which in the opinion of the authors of the article and the students interviewed would be a valuable addition to architectural education.

Respondents were asked nine questions about the use of digital tools in architecture education. The first question concerned familiarity with research using digital tools in general. The question of whether the surveyee have had the opportunity to survey historic buildings using digital tools in your architectural education process was answered in the affirmative by only 17.9% of the respondents. The next questions focused on the specific digital tools discussed in the article - thermal imaging, photogrammetry and laser scanning. The largest percentage of respondents have had experience with laser scanning during their architectural education or design practice, with 35.7 % answering the question in the affirmative. 21.4 % of respondents had experience with thermal imaging, while the fewest (8.9 %) had used or made use of photogrammetry. The vast majority of second-level students surveyed had never had any

experience with building surveys using digital tools. Furthermore, the research showed that the vast majority of the students surveyed would like to have knowledge in this area. More than 96% indicated that incorporating digital tools into architectural education, in their opinion, would be useful, and more than 98% of respondents believe that having the knowledge and skills to use digital tools in the survey of historic buildings could positively impact their future employability. Interestingly, just less than 52% felt that this skill was necessary when working with a building structure. Respondents were also asked if they would be interested in learning how to use digital tools - over 98% answered in the affirmative.

Table 1 shows results of a survey on digital tools in architectural education.

Table 1.
Results of a survey on digital tools in architectural education

Survey question	Yes	No	No opinion
In your architectural education process, have you had the opportunity to study historic buildings using digital tools?	17,9%	82,1%	-
Have you had any experience with thermal imaging in your studies or work?	21,4%	78,6%	-
Have you had any experience with photogrammetry in your studies or work?	8,9%	91,1%	-
Have you had any experience with laser scanning in your studies or work?	35,7%	64,3%	-
In your opinion, would the introduction of digital tools into the architectural education process be useful?	96,4%	3,6%	-
In your opinion, could having the knowledge and skills to use digital tools in the survey of historic buildings have a positive impact on employment opportunities?	98,2%	1,8%	-
Is the ability to use digital tools necessary when working with a building structure?	51,8%	48,2%	-
Would you be interested in learning to use digital tools?	98,2%	1,8%	-
Do you find digital tools helpful in the design process?	92,8%	1,8%	5,4 %

Source: own study.

The analysis of the last open-ended question, concerning the usefulness of digital tools in the design process, resulted in interesting findings. Students most frequently indicated that digital tools:

- improve the surveying process, obtain more accurate information, improve the pre-design process,
- significantly reduce the margin for error, making the documentation of the building more reliable,
- allow for quick and precise building surveys,
- speed up work and simplify the design process,
- gives a better understanding of the subject matter - site, building, etc.,
- improve studying and modelling of buildings, especially those with little or no documentation,
- allows the collection of data that would be difficult or impossible to investigate without digital tools,
- help with digitalisation and documentation.

The results of the survey highlight both the students' awareness of the importance of using digital tools in the architectural profession and the need to introduce practical exercises in the use of digital tools into the process of architectural education.

Conclusion

The use of digital tools is an integral part of the conservation process. Thanks to the available advanced technologies, it is possible to support conservation efforts by creating detailed documentation. The ability to use digital tools and read the obtained results contributes to the preservation of cultural heritage, which is so important for future generations.

The use of thermal imaging in the examination of historic buildings, as a non-destructive diagnostic tool in conservation issues (Więcek et al., 2010), allows the identification and adoption of appropriate design solutions, such as the determination of the physical and chemical properties of the materials used, identification of brick threads under plaster, detection of brickworks, and, thanks to scanning technology and photogrammetry, it is possible to create precise digital models of the original buildings. Digital tools such as laser scanning, photogrammetry, thermal imaging or humidity measurements are non-destructive methods of surveying historical building. They are an excellent source of information for the precise identification of a building, its structure and its technical condition.

To support the effective integration of digital tools such as photogrammetry, laser scanning, and thermal imaging into curricula of architectural faculties, we propose a multi-layered approach. First, these technologies should be introduced gradually, beginning with theoretical modules that explain their principles and relevance to architectural practice. This foundation can be followed by practical workshops, ideally in the form of multiple in-situ research trips to heritage sites. In addition to subjects dedicated to digital tools we also recommend embedding using digital tool competencies into existing design studios and technical courses.

A meaningful integration of digital tools such as photogrammetry, laser scanning, and thermal imaging in architectural education faces several practical challenges. Among the most important are limited funding opportunities, which limit the ability of universities to invest not only in the necessary equipment and software, but also for in situ research trips for the groups of students that classes in heritage areas would entail. Additionally, there is often a shortage of adequately trained instructors who can confidently teach these technologies, as professional development in this area is still not widely prioritized among architects - It would therefore be advisable to provide staff with training or to have external experts teach such subjects. Addressing these barriers is essential to provide students with a practical experience with technologies that are increasingly relevant to contemporary architectural practice.

While digital tools such as photogrammetry, laser scanning, and thermal imaging offer immense value for heritage preservation, the discussion should also address the ethical and legal dimensions of their use. Questions of data ownership are particularly pressing—clarifying who holds the rights to 3D scans or other digital data about monument or heritage site is essential. Moreover, the lack of standardized protocols for digital archiving poses risks to long-term accessibility and reliability. Expanding the discourse to include these issues is vital to ensure that digital heritage practices remain responsible.

In conclusion – the research indicates that the implementation of practical classes in the form of workshops on the use of digital tools in the architectural education process is needed, as it has a number of benefits. Practical classes on the use of digital tools are extremely valuable and the implementation of such workshops provides an opportunity to develop and enrich the curriculum and encourage the student in conservation research and preservation of historical monument.

References

1. Bevilacqua, M.G., Caroti, G., Zaragoza, I.M.-E., Piemonte, A. (2016), Frescoed vaults: Accuracy controlled simplified methodology for planar development of three-dimensional textured models. *Remote Sensing, 8(3),* 239, DOI: 10.3390/rs8030239.
2. Ćosović, M., Maksimović, M. (2022). *Application of the digital twin concept in cultural heritage.* VIPERC 2022: 1st International Virtual Conference on Visual Pattern Extraction and Recognition for Cultural Heritage Understanding.
3. Czajkowski, K. (2023). *Nowoczesne technologie w dokumentacji zabytków, Spójny system zbierania, opracowania i prezentacji danych jako podstawa działań konserwatorskich*. Warszawa: Narodowy Instytut Dziedzictwa.
4. Karatzas, S., Lazari, V., Fouseki, K., Pracchi, V.N., Balaskas, E. (2024). Digital twins-enabled heritage buildings management through social dynamics. *Journal of Cultural Heritage Management and Sustainable Development*, DOI: 10.1108/JCHMSD-08-2023-0136.
5. Orłowski, T., Tunkiel, M. (2022). Skanowanie obiektów zabytkowych metodą fotogrametryczną na przykładzie drewnianego kościoła pw. Św. Brykcjusza w Gościecinie. *Zeszyty Naukowe Wyższej Szkoły Technicznej w Katowicach, 14,* 45-56. ISSN 2082-7016; eISSN 2450-5552.
6. Steidl, T., Krause, P. (2009). Termowizja w ocenie jakości przegród budowlanych. *PAK, vol. 55, no. 11,* 942-945.

7. Szmolke, N. (2015). Diagnostyka obiektów z wykorzystaniem kamery termowizyjnej. *Czasopismo Inżynierii Lądowej, Środowiska i Architektury [Journal of Civil Engineering, Enviroment and Architecture], JCEEA, XXXII, 62(2/15),* 469-476.
8. Więcek, B., Perkowski, J., Wysocki, M. (2010). Zastosowanie termowizji do badań architektonicznych obiektów zabytkowych. Instytut Elektroniki Politechniki Łódzkiej Międzyresortowy Instytut Techniki Radiacyjnej Politechniki Łódzkiej. *Prace Instytutu Elektrotechniki, 245*, 31-40.
9. Więcek, B., Poksińska, M. (2006). Zastosowanie termografii w konserwacji zabytków. *PAK, no. 3*, 7-10.