

WOJCIECH CIEPLUCHA

ORCID: 0000-0002-4738-1782

Cracow University of Technology, Poland

JULIA GONET

ORCID: 0009-0009-0309-5483

Cracow University of Technology, Poland

ALICJA PIJEWSKA

ORCID: 0009-0002-8021-2507

Cracow University of Technology, Poland

ANNA STEPANIAK

ORCID: 0009-0002-8199-3659

Cracow University of Technology, Poland

APPLICATION OF PHOTOGRAMMETRY AND BIM TECHNOLOGY IN ARCHITECTURAL HERITAGE DOCUMENTATION

ZASTOSOWANIE FOTOGRAMETRII I TECHNOLOGII BIM W DOKUMENTACJI DZIEDZICTWA ARCHITEKTONICZNEGO

Abstract

The article presents a methodology for integrating photogrammetry with BIM in architectural heritage documentation. The use of drones and mobile devices enables precise digital modeling of historic objects. The technology supports historic building adaptation, conservation documentation generation, and clash analysis, preserving cultural values while modernizing heritage structures.

Keywords: architecture, BIM, conservation, photogrammetry, point cloud

Streszczenie

Artykuł przedstawia metodykę integracji fotogrametrii z BIM w dokumentacji dziedzictwa architektonicznego. Wykorzystanie dronów i urządzeń mobilnych umożliwia precyzyjne odwzorowanie obiektów historycznych w postaci modeli cyfrowych. Technologia wspiera adaptację zabytkowych budynków, generowanie dokumentacji konserwatorskiej oraz analizy kolizji, zachowując wartości kulturowe przy jednoczesnej modernizacji obiektów dziedzictwa.

Słowa kluczowe: architektura, BIM, konserwacja, fotogrametria, chmura punktów

1. INTRODUCTION

1.1. RESEARCH CONTEXT AND SIGNIFICANCE OF EXISTING ARCHITECTURAL OBJECT ADAPTATION

In the face of progressing urbanization and growing requirements for sustainable development, the adaptation of existing architectural objects has become one of the key issues in contemporary design practice. Revitalization, reconstruction, or functional conversion of existing buildings allows not only the preservation of cultural heritage but also the rational management of spatial and material resources. However, this process requires precise analysis of the existing condition and efficient management of technical information regarding the object. Traditional approaches to architectural inventory, based on manual measurements and photographic documentation, although still in use, are increasingly giving way to modern digital solutions. “Digitalization and documentation have been challenging and multidisciplinary topics for cultural heritage (CH) involving new technologies for information capture.”¹ Technological progress today enables spatial data acquisition with unprecedented accuracy and efficiency. Digital photogrammetry, laser scanning, and Building Information Modeling (BIM) are transforming how designers perceive and process data about existing conditions, integrating them directly with the design process.

1.2. AIM AND SCOPE OF THE ARTICLE

The aim of this article is to present a methodology for acquiring photogrammetric data using unmanned aerial vehicles, i.e., drones and mobile devices, and their subsequent implementation in the BIM environment in the context of existing architectural object adaptation. The authors focus on practical aspects of the process – from data acquisition and processing, through point cloud generation, to creating precise digital models and their design applications. The article also includes a case study analysis highlighting the benefits, limitations, and potential for further development of the presented methodology.

1.3. TRADITIONAL METHODS OF ARCHITECTURAL INVENTORY

Architectural inventory, as a preliminary stage of many design processes, has for decades been based on manual measurements taken using measuring tapes, optical rangefinders, or levels. The results of these activities were applied to technical drawings and supplemented with photographic documentation. These methods, despite their accessibility and low cost, were characterized by limited accuracy, high time investment, and significant susceptibility to human error. Moreover, their effectiveness dramatically decreased in the case of objects with complex geometry or construction elements that were difficult to access.

¹ M.M. Vieira et al., *Strategy for HBIM implementation using high-resolution 3D architectural documentation based on laser scanning and photogrammetry of the José de Alencar theatre*, “Digital Applications in Archaeology and Cultural Heritage”, 2023, vol. 30, art. no. e00287, <https://www.sciencedirect.com/science/article/pii/S2212054823000322> (access: 7.10.2025).

1.4. DEVELOPMENT OF BIM TECHNOLOGY IN THE CONTEXT OF EXISTING OBJECT ADAPTATION

“Digital 3D capture and reliable reproduction of architectural features is the first and most difficult step towards defining a heritage BIM.”² The last two decades have witnessed dynamic development of BIM technology, which extends beyond the framework of designing new objects and has found increasingly broad application in adaptations of existing buildings (HBIM). “Working with heritage is complex and projects often include scientific, structural, and documentary studies. Every step requires a systematic approach.”³ BIM enables the creation of digital models containing geometric, material, temporal, and cost data, supporting analytical and decision-making processes. In the context of adaptation, a key function of BIM becomes the integration of actual-condition data with planned design changes, which allows for early collision detection, schedule optimization, and precise construction work planning.

Photogrammetry, understood as a technique for acquiring spatial data from digital photographs, is gaining increasing recognition in the architectural environment. The literature indicates the growing effectiveness of this method in documenting heritage, industrial, and infrastructure objects. Research shows that photogrammetry – both aerial and terrestrial – allows obtaining point clouds of high density and precision, constituting a reliable alternative to laser scanning (LiDAR) in many applications. “The proficiency in tools available in the adopted software is essential to ensure quality models and practical solutions to complex problems.”⁴ Moreover, the development of 3D reconstruction software, such as Reality Capture, has significantly simplified the data processing and integration with BIM tools.



Ill. 1. Drone photograph of the Museum building in Branice, 2025, source: work of Anna Stepaniak

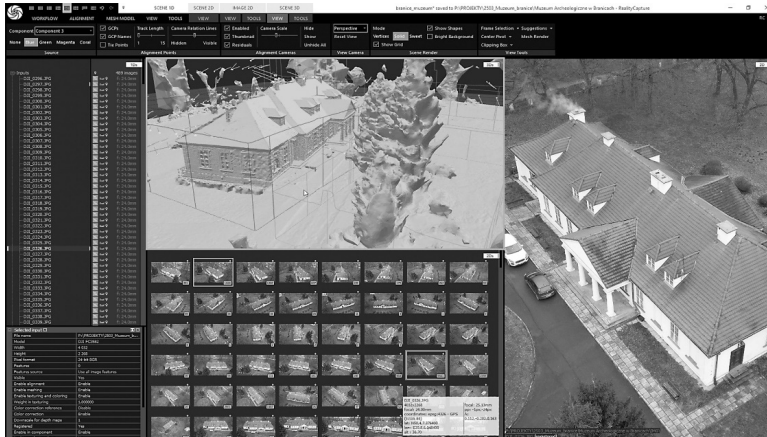
² Y. Alshawabkeh, A. Baik, Y. Miky, *Integration of Laser Scanner and Photogrammetry for Heritage BIM Enhancement*, “ISPRS International Journal of Geo-Information” 2021, no. 5, art. no. 316, p. 1, <https://www.mdpi.com/2220-9964/10/5/316> (access: 7.10.2025).

³ J. Moyano et al., *Systematic approach to generate Historical Building Information Modelling (HBIM) in architectural restoration project*, “Automation in Construction” 2022, vol. 143, art. no. 104551, p. 1, <https://www.sciencedirect.com/science/article/pii/S0926580522004216> (access: 7.10.2025).

⁴ G. Rocha et al., *A Scan-to-BIM Methodology Applied to Heritage Buildings*, “Heritage” 2020, no. 1, p. 62, <https://www.mdpi.com/2571-9408/3/1/4> (access: 7.10.2025).

2. METHODOLOGY OF SPATIAL DATA ACQUISITION

The use of unmanned aerial vehicles (UAVs, commonly known as drones) in the photogrammetric process enables fast and precise data acquisition from great heights, making this method particularly useful for documenting roofs, facades of higher floors, and hard-to-reach fragments of the object. Aerial photogrammetry involves taking a series of photographs in a controlled geometric arrangement (maintaining large transverse and longitudinal overlaps), which are then processed into a point cloud and orthophotomap.



Ill. 2. Processed drone photographs into mesh model and point cloud, 2025, source: work of Anna Stepaniak

Terrestrial photogrammetry complements data obtained from the air, enabling detailed documentation of architectural details, interiors, and places inaccessible to drones. Thanks to the development of mobile recording devices, such as smartphones with high-resolution cameras and image stabilization, it is possible to obtain material of sufficient quality for reconstruction purposes. Many projects involve different technologies, as the authors note in one of them: “The data collection was completed by photogrammetry (with an integrated camera), obtaining high resolution images, and the sample taking of small pieces of surface or matter of each architectural and structural element, for laboratory analysis. These data were essential for the creation of a detailed restoration map.”⁵

Reality Capture is one of the leading tools for 3D reconstruction using photogrammetry techniques. “The HBIM process is started with distant collection of survey data using terrestrial laser scanning or digital photogrammetric modelling.”⁶ This software automatically processes photographs, performing their mutual orientation, geometry reconstruction, and texturing. The end result is a detailed point cloud, mesh model, and textured 3D model.

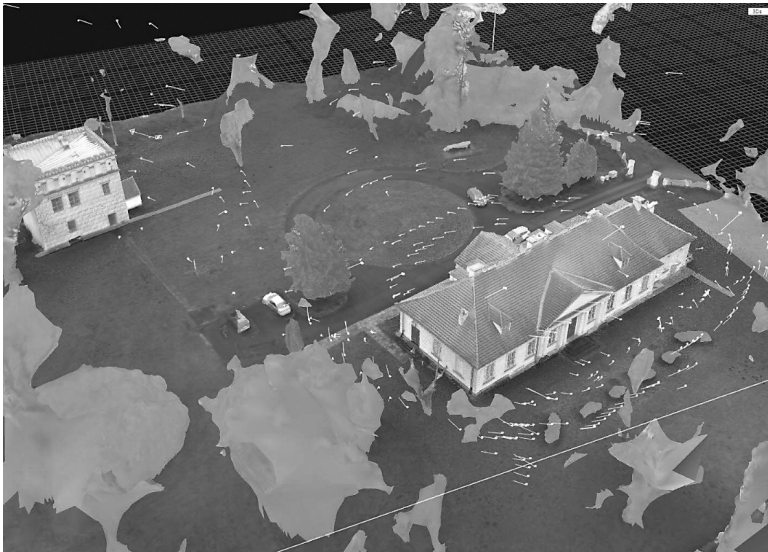
⁵ C. Biagini et al., *Towards the BIM implementation for historical building restoration sites*, “Automation in Construction” 2016, vol. 71, part 1, p. 81, <https://www.sciencedirect.com/science/article/pii/S0926580516300425> (access: 7.10.2025).

⁶ S. Logothetis, A. Delinasios, E. Stylianidis, *Building Information Modelling for Cultural Heritage: A review*, “ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences” 2015, vol. II-5/W3, p. 181, <https://isprs-annals.copernicus.org/articles/II-5-W3/177/2015/isprsanals-II-5-W3-177-2015.pdf> (access: 7.10.2025).

In practice, the quality of photographic material and the number and resolution of photographs are of key importance. The process includes several key stages:

- Data import – loading drone-captured photographs into the program, preserving meta-data containing GPS position and camera orientation information.
- Image alignment – the program automatically identifies characteristic points on overlapping photographs and calculates precise positions of each photograph in 3D space, creating a sparse point cloud.
- Dense point cloud generation – based on aligned photographs, photogrammetric algorithms create a detailed representation of the object consisting of millions of points with precise XYZ coordinates and color information.
- Mesh creation – transformation of the point cloud into a three-dimensional polygon mesh representing the object's surface, with the possibility of decimation (polygon count reduction) for model optimization.
- Texturing – applying textures from original photographs to the mesh model for a realistic representation of the object's appearance.
- Data export – saving
- the point cloud in .e57 format enabling import into BIM software or exporting the mesh model to a format, suitable for further processing.
- Reality Capture stands out for its processing speed and high reconstruction precision, making it an ideal solution for low-budget architectural documentation.

After obtaining the raw point cloud, it is necessary to clean it (e.g., from noise and unwanted background data), unify density, and convert it to a format compatible with BIM software. At this stage, additional algorithms are often used for automatic detection of flat surfaces and edges. Point cloud optimization is crucial for smooth operation in the parametric modeling environment.



III. 3. *Point cloud from drone photographs*, 2025, source: work of Alicja Pijewska



Ill. 4. Mesh model generated from drone photographs, 2025, source: work of Alicja Pijewska

3. BIM MODELING BASED ON PHOTOGRAMMETRIC DATA

The process of BIM modeling based on photogrammetric data constitutes a key stage in the digital transformation of the existing architecture. The previously acquired point cloud, generated using photogrammetric technologies, becomes the basis for creating a digital model that reflects the actual condition of the object. “A photo-matching survey was undertaken with the intention of checking the accuracy of the provided set of drawings and highlight differences between the design and as-built project. The requirement was for a single rectified image with a clear, visible reference point against which we could align the digital model.”⁷

Importing the point cloud into a BIM environment, such as Revit or Archicad, constitutes the first step in the digital reconstruction process. Files in .e57, .rcp, or .las formats are loaded into the program as a spatial reference, based on which the designer can manually or semi-automatically create model geometry. In practice, it is important to perform appropriate data optimization to maintain a balance between detail and work efficiency in the design environment. The point cloud also requires adjustment to design coordinate systems and verification of scale and orientation, which is often accomplished using georeferencing

⁷ D. Craggs, M. Crilly, N. Dawood, *REALITY CAPTURE for BIM – Application, evaluation and integration within an architectural plan of works* [in:] “16th International Conference on Construction Applications of Virtual Reality”, Hong-Kong 2016, https://www.researchgate.net/publication/315489085_REALITY_CAPTURE_for_BIM_-_Application_evaluation_and_integration_within_an_architectural_plan_of_works (access: 7.10.2025).

markers (so-called ground control points). Only properly integrated point cloud constitutes a reliable foundation for further modeling stages.

Based on point cloud data, it is possible to create models in which each architectural element (wall, floor, window) is a separate object possessing a set of geometric and material attributes. This process is sometimes referred to as “Scan-to-BIM” and requires not only technical knowledge but also design interpretation. Depending on the Level of Detail (LOD) of the model, the designer may decide on a simplified representation or a detailed reconstruction of complex details.

High accuracy of the representation of real-object geometry is one of the main advantages of BIM modeling based on photogrammetric data. A properly generated point cloud achieves precision on the order of several millimeters, which translates into the possibility of conducting accurate technical and design analyses. Model accuracy can be verified by comparing geometric elements with source data (e.g., point cloud cross-sections). This makes it possible to maintain high reliability of design documentation, which is important, for example, in the case of heritage building renovation.

Tab. 1. *Measurement inaccuracies, 2025*, source: work of Julia Gonet, Alicja Pijewska, and Anna Stepaniak

Measured element	Tape measurement	Rangefinder measurement	Point cloud measurement	Revit measurement
Southern elevation				
Extension wall	7,65 m	7,65 m	7,50 m	7,55 m
Window (6th axis)	1,47 m	1,48 m	1,47 m	1,42 m
Window recess (12th axis)	1,32 m	1,31 m	1,30 m	1,42 m
Rustication width	0,47 m	0,47 m	0,49 m	0,58 m
Rustication height	0,28 m	0,32 m	0,28 m	0,34 m
Northern elevation				
Rustication width	0,51 m	0,50 m	0,54 m	0,63 m
Door (5th axis)	1,45 m	1,45 m	1,45 m	1,35 m
Rounded recess (left)	0,99 m	0,99 m	0,99 m	1,02 m
Western elevation				
Elevation width	10,96 m	10,97 m	10,88 m	10,87 m

Despite numerous advantages, BIM modeling based on photogrammetry carries a series of challenges. The most important include the necessity of data interpretation in places that are illegible, obscured, or distorted (e.g., due to light reflections or geometric deformations). Additionally, processing large datasets requires high-performance workstations and advanced software, which raises the technological entry threshold. “Following a phase of a detail data acquisition procedure, Building Information Modelling (BIM) is used for design and management of projects in the built environment industry. BIM provides a multi layered, multi-dimensional, multi-disciplinary, parametric, smart and informative digital model of a project.”⁸

⁸ K. Themistocleous et al., *The use of UAVs and photogrammetry for the documentation of cultural heritage monuments: the case study of the churches in Cyprus*, “Proceedings of SPIE” 2019, art. no.

It is also worth mentioning the issue of standardization – the lack of uniform procedures regarding the level of detail, component names, and BIM data structures hinders interdisciplinary cooperation and long-term model management. Moreover, not all structural elements can be easily parameterized – this particularly concerns atypical historical details.

4. BIM MODEL APPLICATIONS IN THE OBJECT ADAPTATION PROCESS

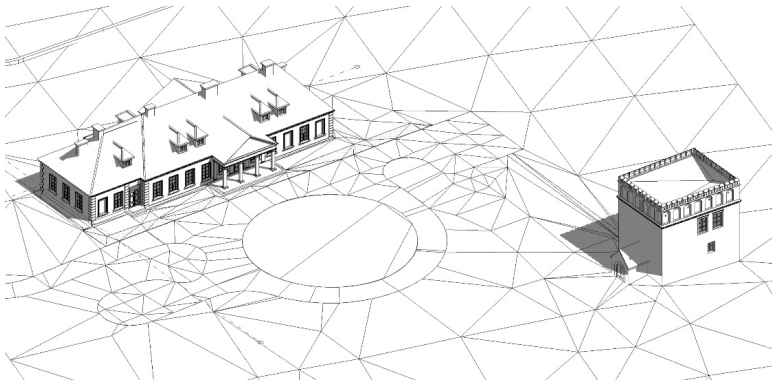
The implementation of a BIM model in the architectural object adaptation process enables the use of advanced analytical and design functionalities that significantly exceed the capabilities of traditional documentation methods. The digital model developed based on photogrammetric data constitutes an integrated information base, supporting design decision-making based on comprehensive data about the actual condition of the object.

4.1. TECHNICAL DOCUMENTATION GENERATION

The parametric nature of the BIM model enables automatic generation of complete technical documentation while maintaining consistency and synchronization between individual elements. The model constitutes a unified source of geometric data from which plans, sections, elevations, and material schedules are generated, thereby eliminating the risk of inconsistencies characteristic of traditional design methods.

The high accuracy of real object geometry representation, achieved through the use of point clouds with precision on the order of several millimeters, translates into the reliability of design documentation. Automation of the documentation generation process reduces time investment and minimizes the probability of errors related to human factors.

The model also enables efficient generation of alternative design variants and their visualization in the context of existing building fabric, supporting the communication process with project stakeholders and optimization of design solutions.



Ill. 5. BIM model in Revit, created based on point cloud, 2025, source: work of Julia Gonet

111560I, p. 5, https://www.researchgate.net/publication/336247352_The_use_of_UAVs_and_photogrammetry_for_the_documentation_of_cultural_heritage_monuments_the_case_study_of_the_churches_in_Cyprus (access: 7.10.2025).



III. 6. *Generated inventory from model in Revit, 2025, source: work of Julia Gonet*

4.2. CALCULATION OF DEBRIS QUANTITIES AND MATERIALS FOR REMOVAL

The use of a BIM model in the adaptation process enables precise calculation of the volume and mass of materials intended for demolition. Computational algorithms use geometric data contained in the model to automatically determine the volume of individual structural elements subject to the deconstruction process. The system enables differentiation of material types (brick, concrete, wood, steel) and assignment of appropriate physical parameters, which allows accurate estimation of debris mass for removal. This functionality supports logistical planning processes, cost estimation, and construction waste management. The ability to predict quantities of materials for removal at the design stage contributes to optimization of construction processes in economic and environmental terms, while simultaneously supporting the implementation of circular-economy assumptions through identification of materials suitable for recycling.

4.3. SPATIAL COLLISION ANALYSIS BETWEEN EXISTING AND DESIGNED CONDITIONS

A BIM model based on photogrammetric data enables the conduct of advanced collision analysis between existing building fabric and designed elements. Precise representation of real object geometry allows for the early detection of potential spatial conflicts before implementation begins. Collision-detection algorithms automatically identify places where new structural, installation, or equipment elements may interfere with existing structures. The analysis includes both “hard” collisions (physical element interpenetration) and “soft” collisions (violation of required technological distances). Early identification of spatial collisions enables optimization of design solutions, reduces the risk of execution problems, and minimizes costs associated with the necessity of introducing changes during implementation. This functionality is of particular importance in the case of objects with complex geometry or high degree of installation complexity.

4.4. DYNAMIC COST ANALYSIS

The integration of the BIM model with cost databases enables the conduct of dynamic economic analysis of the adaptation project. The system automatically recalculates implementation costs in response to modifications introduced by the designer, ensuring real-time budget control.

The parametric nature of the model allows for the automatic generation of material and labor schedules based on geometric data and technical specifications. Cost estimate updates occur synchronously with design modifications, enabling current monitoring of the impact of design decisions on the investment budget. This functionality supports the process of economic optimization of design solutions, enabling comparison of costs of alternative variants and identification of areas with the greatest savings potential. Dynamic cost analysis thus contributes to effective financial resource management of the adaptation project.

5. CASE STUDY – MUSEUM IN BRANICE

The Museum in Branice, located in a historic palace-park complex, constitutes an example of successful implementation of the presented photogrammetric and BIM methodology in the documentation of cultural heritage objects. The museum complex, consisting of the main exhibition building and adjacent utility buildings, is characterized by complex architectural geometry, rich historical detail, and varied technical condition of individual structural elements. The museum object, erected in the 18th century and repeatedly reconstructed in subsequent centuries, presents particular documentation challenges due to the irregularity of architectural forms, complicated structural arrangement, and richness of stucco and stone details. An additional difficulty was the necessity of conducting an inventory without disrupting the normal functioning of the museum institution and permanent exhibitions.

The documentation of the Museum in Branice was conducted using an integrated approach combining UAV aerial photogrammetry and terrestrial mobile photogrammetry. For external documentation, a DJI Air 3S drone was used, taking a total of over 250 photographs at 20-megapixel resolution. Flights were planned to ensure 80% longitudinal coverage and 70% transverse coverage, which guaranteed high-quality 3D reconstruction. Data processing in Reality Capture software took approximately 2 hours of computational time, generating a point cloud with an average density of 3 mm. The absolute accuracy of the model, verified through control measurements, was ± 50 mm for elevations.

The BIM model of the Museum in Branice was developed in the Autodesk Revit environment based on an optimized point cloud. Particular attention was paid to representing historical external walls and architectural details.

6. SUMMARY

The methodology presented in the article for integrating photogrammetric technologies with BIM systems constitutes a significant step toward the digitization of architectural object adaptation processes. The use of unmanned aerial vehicles and mobile devices for spatial data acquisition, combined with advanced 3D reconstruction software, enables the obtaining of precise digital models of existing objects at relatively low implementation costs. “The work here presented shows that it is possible to develop a high-quality 3D model semantic-aware, able to connect geometrical-historical survey with descriptive thematic databases.”⁹

⁹ R. Quattrini et al., *From TLS to HBIM. High quality semantically-aware 3D modeling of complex*

The key value of the presented methodology is the transformation of the traditional architectural inventory process from a method based on manual measurements and photographic documentation into an automated system for spatial data acquisition and processing. The accuracy of geometry representation on the order of several millimeters, achieved through the use of point clouds, translates into high reliability of design documentation and the ability to conduct precise technical analyses.

The implementation of BIM solutions based on photogrammetric data brings multidimensional operational benefits. Automation of technical documentation generation, precise calculation of material quantities for removal, advanced spatial collision analysis, and dynamic cost analysis constitute functionalities that significantly enhance the efficiency of adaptation processes. A holistic approach to building information modeling enables integration of spatial, material, and temporal data, supporting the design decision-making process based on a comprehensive information base.

The presented methodology contributes to optimization of construction processes in economic and environmental terms, reducing the risk of spatial collisions and enabling rational management of material resources. The ability to detect potential execution problems early is of particular importance, as it minimizes costs associated with the necessity of introducing changes during implementation.

Despite numerous advantages, the methodology encounters several technological and cultural challenges. The necessity of data interpretation in illegible places, computer hardware performance requirements, and the lack of standardized procedures constitute main barriers to widespread implementation. Additionally, the complexity of historical details and atypical structural solutions may hinder the model parameterization process.

The presented methodology constitutes a solid foundation for further development of digital tools supporting architectural object adaptation. The potential of photogrammetric technologies combined with BIM systems indicates the possibility of significant transformation of design practice toward more efficient, precise, and sustainable solutions. The development of artificial intelligence and automation of the modeling process may in the future further simplify the implementation of the presented methodology, making it accessible to a broader group of specialists.

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Author's Note

Wojciech Cieplucha, BEng, PhD, Architect

Research and teaching assistant at the Faculty of Architecture of Cracow University of Technology in the Chair of Architectural Design (<https://kpa.arch.pk.edu.pl>). Author of publications in the field of design theory, housing, and decision-making in design. Specializes in modern technologies in architecture and construction – Building Information Modeling (BIM).

wojciech.cieplucha@pk.edu.pl

Julia Gonet, BEng, Architect

Student at the Faculty of Architecture of Cracow University of Technology. Internship at an architectural office. Specializes in BIM technology, actively participating in the work of the BIM Scientific Club.

juliagonet6@gmail.com

Alicja Pijewska, BEng, Architect

Student at the Faculty of Architecture of Cracow University of Technology. Internship at an architectural office. Specializes in BIM technology, vice-chairman of the BIM Scientific Club, based in the Department of Architectural Design.

alicjapijewska@gmail.com

Anna Stepaniak

Student at the Faculty of Architecture of Cracow University of Technology. Member of the BIM Scientific Club. Develops competencies in modern design methods and in modeling in the digital BIM environment.

step.ania.k18.25@gmail.com