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RESEARCH ARTICLE

PHOTOGRAMMETRY AS A TOOL FOR THE PRESERVATION AND DEVELOPMENT OF KAZAKHSTAN'S NATIONAL ARCHITECTURE

A.M. Kussainov[1,2*], M.B. Glaudinova[1,2], O.L. Bantserova[3]

[1]International Educational Corporation, 050043, Almaty, Kazakhstan
[2]Kazakh Leading Academy of Architecture and Civil Engineering, 050043, Almaty, Kazakhstan
[3]National Research Moscow State University of Civil Engineering, 129337, Moscow, Russia

Abstract. *The relevance of this study is determined by the need to preserve and meaningfully develop Kazakhstan's national architecture in the context of the digital transformation of architectural practice. Contemporary methods of documenting and analyzing architectural objects require tools capable of capturing not only geometric accuracy, but also the compositional, spatial, and visual characteristics of the architectural environment. The aim of the article is to substantiate photogrammetry as a tool for the preservation and development of Kazakhstan's national architecture through its application in the compositional analysis of architectural objects, the evaluation of the spatial context of open areas, and the enhancement of the visual and spatial interpretability of interior spaces. The research methodology is based on photographic and video recording of architectural objects and spatial environments using unmanned aerial vehicles and mobile devices, followed by data processing in the 3D Zephyr software environment to generate 3D models and spatial scenes. The results of the study demonstrate that photogrammetry enables architects to analyze proportional and compositional relationships between architectural objects, their interaction with the surrounding landscape and built environment, and to obtain clear visual data for the analysis of both interior and open spaces. The potential of photogrammetry for digital documentation and analytical interpretation of architectural heritage is demonstrated through case studies of the Kozy Korpesh-Bayan Sulu Mausoleum and the Joshy Khan Mausoleum. In the author's architectural project of the Mukagali Makataev Monument, the technology was applied at the compositional design stage to analyze the proportional relationship between the sculptural form and the architectural solution of the pedestal. The obtained results confirm the scientific and practical significance of photogrammetry as a universal tool that contributes to the preservation of architectural heritage, the development of national architectural identity, and the integration of traditional architectural values into contemporary design practice in Kazakhstan.*

Keywords: *photogrammetry, national architecture, architectural heritage, compositional analysis, 3D Zephyr.*

***Corresponding author**
Askar Kussainov, e-mail: ackap89@gmail.com

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ФОТОГРАММЕТРИЯ - ҚАЗАҚСТАННЫҢ ҰЛТТЫҚ СӘУЛЕТІН САҚТАУ ЖӘНЕ ДАМЫТУ ҚҰРАЛЫ РЕТІНДЕ

А.М. Кусаинов[1,2*], М.Б. Глаудинова[1,2], О.Л. Банцерова[3]

[1]Халықаралық білім беру корпорациясы, 050043, Алматы, Қазақстан
[2]Қазақ бас сәулет-құрылыс академиясы, 050043, Алматы, Қазақстан
[3]Ұлттық зерттеу Мәскеу мемлекеттік құрылыс университеті, 129337, Мәскеу, Ресей

Аңдатпа. *Зерттеудің өзектілігі сәулет практикасының цифрлық трансформациясы жағдайында Қазақстанның ұлттық сәулетін сақтау және оны саналы түрде дамыту қажеттілігімен байланысты. Қазіргі сәулет нысандарын тіркеу және талдау әдістері тек геометриялық параметрлерді ғана емес, сонымен қатар сәулеттік ортаның композициялық, кеңістіктік және көрініс сипаттамаларын қамтитын заманауи цифрлық құралдарды талап етеді. Мақаланың мақсаты - фотограмметрияны Қазақстанның ұлттық сәулетін сақтау мен дамытуға бағытталған тиімді құрал ретінде негіздеу, оны сәулет нысандарының композициялық талдауында, ашық кеңістіктердің кеңістіктік контекстін бағалауда және интерьерлердің көрініс-кеңістіктік ақпараттылығын арттыруда қолдану. Зерттеу әдістемесі ұшқышсыз ұшу аппараттары мен мобильді құрылғылар арқылы жүргізілген фото- және бейнетүсірілімге, алынған деректерді 3D Zephyr бағдарламалық ортасында өңдеу негізінде үшөлшемді модельдер мен кеңістіктік сценалар құруға сүйенеді. Зерттеу нәтижелері фотограмметрияның сәулет нысандарының пропорциялық және композициялық өзара байланыстарын, олардың ландшафтпен және қоршаған сәулеттік ортамен байланысын талдауға мүмкіндік беретінін көрсетті. Қозы Көрпеш-Баян сұлу және Жошы хан кесенелері мысалында сәулет мұрасын цифрлық тіркеу мен аналитикалық зерделеудегі фотограмметрияның әлеуеті айқындалды. Сонымен қатар, Мұқағали Мақатаевқа арналған ескерткіштің авторлық жобасында мүсін мен тұғырдың пропорциялық арақатынасын анықтауда фотограмметрия қолданылды. Алынған нәтижелер фотограмметрияның сәулет мұрасын сақтау, ұлттық сәулеттік бірегейлікті дамыту және дәстүрлерді Қазақстанның заманауи жобалау практикасына интеграциялау тұрғысынан ғылыми және практикалық маңызын растайды.*

Түйін сөздер: *фотограмметрия, ұлттық сәулет, сәулет мұрасы, композициялық талдау, 3D Zephyr.*

***Автор-корреспондент**
Аскар Кусаинов, e-mail: ackap89@gmail.com

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НАУЧНАЯ СТАТЬЯ

ФОТОГРАММЕТРИЯ КАК СРЕДСТВО СОХРАНЕНИЯ И РАЗВИТИЯ НАЦИОНАЛЬНОЙ АРХИТЕКТУРЫ КАЗАХСТАНА

А.М. Кусаинов[1,2*], М.Б. Глаудинова[1,2], О.Л. Банцерова[3]

[1]Международная образовательная корпорация, 050043, Алматы, Казахстан
[2]Казахская головная архитектурно-строительная академия, 050043, Алматы, Казахстан
[3]Национальный исследовательский Московский Государственный строительный университет, 129337, Москва, Россия

Аннотация. *Актуальность исследования определяется необходимостью сохранения и осмысленного развития национальной архитектуры Казахстана в условиях цифровой трансформации архитектурной практики. Современные методы фиксации и анализа архитектурных объектов требуют инструментов, способных передавать не только геометрию, но и композиционные, пространственные и визуальные характеристики архитектурной среды. Целью статьи является обоснование фотограмметрии как инструмента сохранения и развития национальной архитектуры Казахстана за счёт её применения в композиционном анализе архитектурных объектов, оценке пространственного контекста открытых территорий и повышении визуально-пространственной информативности интерьеров. Методология исследования основана на фото- и видеосъёмке архитектурных объектов и пространств с использованием беспилотных летательных аппаратов и мобильных устройств, с последующей обработкой данных в программной среде 3D Zephyr для построения трёхмерных моделей и пространственных сцен. В результате исследования установлено, что фотограмметрия позволяет архитектору анализировать пропорциональные и композиционные взаимосвязи объектов, их взаимодействие с ландшафтом и окружающей застройкой, а также получать наглядную визуальную информацию для работы с интерьерами и открытыми пространствами. На примере мавзолеев Козы Корпеш-Баян Сулу и Жошы хана продемонстрированы возможности фотограмметрии в контексте цифровой фиксации и аналитического осмысления архитектурного наследия. В авторском проекте памятника Мукагали Макатаеву технология применялась для анализа пропорционального соотношения скульптуры и архитектурного решения постамента на стадии разработки композиции. Полученные результаты подтверждают научную и практическую значимость фотограмметрии как универсального инструмента, способствующего сохранению архитектурного наследия, развитию национальной архитектурной идентичности и интеграции традиций в современную проектную практику Казахстана.*

Ключевые слова: *фотограмметрия, национальная архитектура, архитектурное наследие, композиционный анализ, 3D Zephyr.*

***Автор-корреспондент**
Аскар Кусаинов, e-mail: ackap89@gmail.com

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CONFLICT OF INTEREST

The authors state that there is no conflict of interest.

The authors declare that no generative artificial intelligence technologies or AI-based tools were used in the preparation of this article.

АЛҒЫС / ҚАРЖЫЛАНДЫРУ КӨЗІ

Зерттеу жеке қаржыландыру көздерін пайдалана отырып жүргізілді.

МҮДДЕЛЕР ҚАҚТЫҒЫСЫ

Авторлар мүдделер қақтығысы жоқ деп мәлімдейді.

Авторлар мақаланы дайындау барысында генеративті жасанды интеллект технологиялары мен жасанды интеллектке негізделген технологияларды пайдаланбағанын мәлімдейді.

БЛАГОДАРНОСТИ/ИСТОЧНИК ФИНАНСИРОВАНИЯ

Исследование проводилось с использованием частных источников финансирования.

КОНФЛИКТ ИНТЕРЕСОВ

Авторы заявляют, что конфликта интересов нет.

Авторы заявляют о том, что при подготовке статьи не использовались технологии генеративного искусственного интеллекта и технологии, основанные на искусственном интеллекте.

1 INTRODUCTION

In the context of accelerated urbanization, transformation of historic urban fabric, and the physical deterioration of architectural monuments, the task of preserving and meaningfully developing Kazakhstan's national architecture has become particularly urgent. A significant number of architectural heritage objects are undergoing the loss of their authentic spatial and compositional characteristics as a result of reconstructions, fragmentary restoration interventions, and the absence of comprehensive digital documentation of their original state. Under these conditions, traditional methods of architectural analysis and manual surveying prove insufficient for preserving a holistic perception of architectural form, context, and visual–spatial relationships inherent in heritage objects.

Contemporary digital technologies, and photogrammetry in particular, are shaping new approaches to the study, interpretation, and preservation of architectural heritage. Unlike conventional measurement-based methods, photogrammetry enables the creation of spatially rich 3D models that convey not only geometric accuracy but also compositional, scale-related, and visual characteristics of architectural objects, their surroundings, and interior spaces. International research demonstrates the high effectiveness of photogrammetric methods in the digital documentation of cultural heritage, the development of 3D archives, HBIM models, and visual-analytical platforms for restoration practice and academic research.

In international practice, photogrammetry is widely applied to the analysis of architectural ensembles, open spaces, and historic interiors, providing a comprehensive understanding of spatial context and compositional patterns of the built environment. At the same time, within Kazakhstani architectural research, the potential of photogrammetry is predominantly addressed in a fragmented manner - as an auxiliary documentation tool - without a systematic interpretation of its role in the preservation and development of national architectural identity. This situation defines the scientific problem of the present study, which lies in the insufficient development of methodological approaches to the use of photogrammetry for architectural and compositional analysis and for the digital conservation of Kazakhstan's national architectural heritage.

The aim of this study is to substantiate photogrammetry as a tool for the preservation and development of Kazakhstan's national architecture through its application in the analysis of architectural forms, spatial context, and visual-compositional characteristics of heritage objects and contemporary architectural solutions. To achieve this aim, the following objectives are addressed:

- analysis of contemporary international experience in the application of photogrammetry and digital documentation of architectural heritage;
- identification of the potential of photogrammetry for the compositional analysis of architectural objects, open spaces, and interior environments;
- testing of photogrammetric methods using case studies of architectural heritage objects and the author's architectural projects;
- evaluation of the practical significance of photogrammetry for integrating national architectural forms into contemporary design practice.

The scientific novelty of the research lies in reinterpreting photogrammetry not merely as a measurement-based tool, but as a method of visual-spatial and compositional analysis that contributes to the preservation of architectural identity and the development of national architecture in the context of digitalization. The practical significance of the study is determined by the applicability of the obtained results in architectural design, restoration, reconstruction, and the formation of digital archives of cultural heritage objects in Kazakhstan, in accordance with contemporary international approaches to sustainable development and heritage conservation.

2 LITERATURE REVIEW

Over the past decade, the digitalisation of architectural and construction processes has become one of the key directions in the development of global architectural practice. A central role in this

transformation is played by Building Information Modelling (BIM), which integrates design, engineering, and management data into a unified digital environment and is widely applied at the design and construction stages. At the same time, academic literature indicates that the dominance of the BIM-based approach in architectural design is accompanied by a number of methodological limitations. The extensive use of parametric templates and standardised component libraries often reduces the role of empirical analysis of the real architectural environment, leading to the formalisation of architectural solutions and a weakening of the project's connection with the historical, cultural, and spatial context of the site (**Aitbayeva, 2020**). This issue becomes particularly significant when working with architectural heritage and national architecture, where compositional and contextual characteristics play a decisive role.

Domestic studies emphasise that digital technologies in architecture should be regarded not only as tools for optimising design processes, but also as instruments for sustainable development, heritage preservation, and the interpretation of cultural identity (**Nabiyev et al., 2024; Baitenov, 2023**). In this context, there is a growing interest in digital documentation methods oriented towards the analysis of the actual physical condition of architectural objects and their environments.

In international research, photogrammetry is considered one of the most accessible and mobile methods for 3D documentation of architectural objects. It has been demonstrated that the processing of overlapping photographic datasets using Structure from Motion and Multi-View Stereo algorithms enables the generation of spatial models that preserve both geometric accuracy and visual characteristics of objects while requiring minimal specialised equipment (**Dabove et al., 2019; Shan et al., 2023**). These properties justify the application of photogrammetry at the pre-design and conceptual design stages, which directly corresponds to the methodological framework adopted in the present study.

A number of studies confirm that data acquired using cameras embedded in mobile devices are comparable in quality to results obtained with specialised photographic equipment, thereby expanding the possibilities for the application of photogrammetry in architectural practice and educational processes (**Saif et al., 2022; Paukkonen et al., 2023**). This aspect substantiates the use of photographic data collected without specialised surveying equipment or unmanned aerial vehicles in the present research, reflecting the practical conditions of everyday architectural practice.

In the field of architectural heritage preservation, photogrammetry has developed primarily as a method of digital documentation and the creation of 3D archives of heritage objects. In international practice, photogrammetric data are frequently integrated into Historic Building Information Modelling (HBIM) environments, which enable structured information management for conservation and restoration purposes (**Murphy et al., 2009**). At the same time, it is noted that HBIM models based on parametric generalisations of geometry provide a limited representation of the actual condition of heritage objects, including deformations and surface-level visual features.

Within this context, photogrammetry is increasingly regarded as a more appropriate tool for primary documentation of architectural heritage, as it is based on existing geometry and visual data without prior parametric abstraction. This allows the resulting models to be used not only for documentation purposes, but also for architectural and compositional analysis, including the study of proportions, visual relationships, and the interaction of architectural objects with their spatial context (**Kesik et al., 2022; Miłosz et al., 2020**). This approach is directly implemented in the methodology of the present study in both the analysis of architectural heritage objects and the author's architectural project of a monument.

Regional studies of Kazakhstan's architectural environment highlight the necessity of documenting and analysing the actual condition of historic buildings in the context of rapid urbanisation and the loss of authentic architectural appearance (**Abdrassilova et al., 2021; Aukhadiyeva et al., 2021; Abdrassilova et al., 2024; Baitenov et al., 2024**). These findings correlate with the objectives of the present research, which focuses on the use of photogrammetry for the documentation and interpretation of architectural forms within the framework of national architecture.

The relevance of applying digital methods in work with architectural heritage objects is also established at the regulatory and legal level. The Law of the Republic of Kazakhstan "On the Protection and Use of Historical and Cultural Heritage Objects" provides for the documentation, registration, and preservation of sites of historical and cultural significance, as well as for the implementation of modern technologies for their study and public dissemination. These provisions form the legal framework for the use of photogrammetry as a tool for digital documentation, analysis, and preservation of architectural heritage within architectural practice in Kazakhstan.

Despite the substantial body of existing research, photogrammetry in most studies is predominantly treated as a tool for measurement and documentation. Its potential as a method of architectural and compositional analysis and as a means of supporting creative design processes remains insufficiently explored, particularly in the context of Kazakhstan's national architecture. This identified research gap determines the methodological focus of the present study, which is oriented towards the use of photogrammetric models for analysing proportions, visual relationships, and design decisions at the conceptual design stage.

3 MATERIALS AND METHODS

The methodological framework of the study is based on a photogrammetric approach to the digital documentation and analysis of architectural objects, aimed at identifying their spatial, compositional, and proportional characteristics. The application of this method is determined by the objectives of the research, which focus on the preservation and development of Kazakhstan's national architecture, where working with the actual physical condition of an object, its visual perception, and its spatial context is of fundamental importance, rather than relying solely on abstract parametric geometry.

Within the author's research, the 3D Zephyr software was used as the primary tool for photogrammetric modelling. The selection of this software was обусловлена the practical conditions under which the applied part of the study was conducted, specifically during the development of the Mukagali Makataev Monument project in 2020. At that time, 3D Zephyr was one of the few accessible and functionally comprehensive solutions that provided the possibility of free 3D model generation based on the processing of up to 50 photographs, including point cloud generation, mesh construction, and texture mapping.

Table 1
Comparative Analysis of Photogrammetry Software (2020)

Feature	RealityCapture (2020)	Agisoft Metashape (2020)	3DF Zephyr (2020)
Pricing Model	PPI (Pay-Per-Input) credits or high-cost license	Perpetual License (one-time payment)	Perpetual License (one-time payment)
Cost (approx.)	~$19 for credits or €15,000 (Full Enterprise)	$179 (Standard) / $3,499 (Professional)	Free (50 photo limit) / €149 (Lite) / €3,900 (Pro)
Processing Speed	Extremely Fast (Market Leader)	Moderate	Slow (compared to others)
GPU Requirements	NVIDIA ONLY (CUDA)	NVIDIA / AMD (OpenCL support)	Any GPU (NVIDIA preferred)
User Interface	Complex / Professional	Clean / Standard Windows-style	Most User-Friendly (Wizard-based)
Best For	High-end VFX and Game Dev	Geodesy, Mapping, and General Use	Hobbyists and Small Objects

Alternative solutions, such as RealityCapture and Agisoft Metashape, were predominantly distributed on a commercial basis during the specified period and were characterised by high licensing costs and a more complex user interface. These factors significantly limited their application in individual architectural practice and author-driven design research. The choice of 3D Zephyr corresponded both to the technical capabilities available at the time and to the research

objectives, which were oriented towards the practical implementation of photogrammetry in architectural design. It should be noted that as of 2025, the RealityCapture software has become available for non-commercial use, creating a basis for the further expansion and comparative analysis of photogrammetric methodologies in future studies (**Table 1**).

The acquisition of source data for the author's project of the Mukagali Makataev Monument was carried out through terrestrial photographic survey using a mobile device camera. Image capture was performed along a circular trajectory with a uniform step, ensuring sufficient image overlap and reliable spatial reconstruction. Unmanned aerial vehicles were not employed in this project. References to aerial photography and UAV-based data acquisition in this article relate to general photogrammetric practice and are presented through case studies of the Kozy Korpesh-Bayan Sulu Mausoleum and the Jochi Khan Mausoleum, without direct association with a specific software environment.

Photographic data processing in the 3D Zephyr environment included automatic camera calibration, estimation of camera positions, and the generation of sparse and dense point clouds based on Structure from Motion algorithms. This was followed by the construction of a polygonal mesh and texture mapping, resulting in a visually reliable 3D representation of the object that preserves its actual proportions and surface characteristics.

The resulting photogrammetric model was exported in a universal file format (OBJ) and integrated into the SketchUp software environment, which was used at the conceptual and compositional design stages. The 3D model served as a spatial reference for analysing the proportional relationship between the sculptural form and the architectural design of the pedestal, as well as for evaluating visual balance and scale characteristics of the composition within a virtual environment. Within the scope of the study, SketchUp was employed as a conceptual 3D modelling tool that provides flexibility in working with form and clarity in spatial analysis, without adopting an object-based BIM paradigm.

The applied methodology reflects the practice-oriented nature of the research and demonstrates the potential of photogrammetry as an accessible tool for architectural analysis, applicable both in author-driven design practice and in research aimed at the preservation and development of Kazakhstan's national architecture.

4 RESULTS AND DISCUSSION

The obtained results demonstrate that photogrammetry in architectural practice can be regarded not only as an auxiliary tool for visualization or measurement, but also as an effective means of spatial and compositional analysis, which is particularly relevant when working with cultural heritage objects and national architecture. The use of 3D photogrammetric models at the conceptual and pre-design stages enables architects to operate with the actual visual-spatial condition of an object and its surroundings, rather than with abstract geometric representations.

The visualization of an architectural scene based on photogrammetric data combined with design calculations and dimensional parameters provides a holistic perception of the composition and allows for the identification of visual and aesthetic inconsistencies in relation to the territorial context. Unlike conventional two-dimensional drawings and schematic 3D models, this approach makes it possible to analyze scale relationships, dominant elements, and the nature of interaction between an architectural object and its environment prior to construction. This is especially important for projects located in complex historical, cultural, or landscape contexts, where visual misjudgments may lead to the loss of artistic expressiveness and contextual integrity.

The results of the analysis indicate that photogrammetry significantly reduces the time and labor required for primary site surveys in comparison with traditional measurement methods. The photogrammetric approach enables the rapid generation of façade drawings and spatial models without direct physical contact with the object, which is of particular importance when working with architectural monuments and cultural heritage sites. Contemporary image-processing

algorithms make it possible to achieve a high level of detail in 3D models while maintaining visual reliability, a finding that is consistent with evidence reported in international studies.

In a broader scientific context, architectural photogrammetry is understood as a set of methods aimed at determining the geometric and spatial characteristics of buildings and structures, performing architectural surveys, and generating digital models for restoration, reconstruction, and conservation purposes. Unlike parametric models, photogrammetric data record the actual condition of an object, including deformations, material losses, and surface irregularities, which makes this approach especially valuable for scientific analysis and heritage preservation.

The practical relevance of photogrammetry is confirmed by examples of digital documentation of the Kozy Korpesh-Bayan Sulu Mausoleum and the Joshy Khan Mausoleum, whose 3D models are available in open-access formats and enable remote visual investigation of architectural forms (**Figure 1**). The analysis of such models provides a basis for an in-depth study of form-making principles, proportional relationships, and structural characteristics of monuments without the need for continuous on-site presence. In the long term, these digital representations may serve as a foundation for academic research, restoration concepts, and educational programs, in line with contemporary international approaches to the digital conservation of cultural heritage.

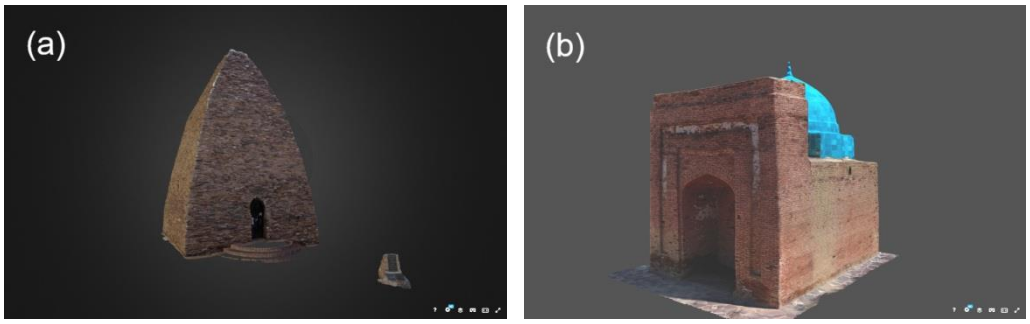

Figure 1 - Virtual models of Kazakhstan's architectural monuments(author's material):
a) Kozy Korpesh-Bayan Sulu Mazar;
b) Joshy Khan Mausoleum.

An additional area of application for photogrammetry involves the digital documentation of archaeological and urban heritage sites threatened by natural processes and anthropogenic impacts. (**Figure 2**) Case studies of photogrammetric surveys of ancient settlements and fortified sites demonstrate that 3D models can function as evidentiary visual records for reconstructing historical processes and for promoting cultural heritage in both academic and public domains. For regions of Central Asia, where archaeological sites are particularly vulnerable to climatic and geomorphological factors, this approach is of heightened relevance.

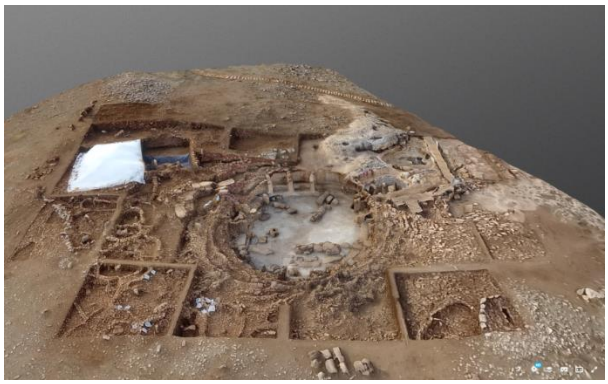

Figure 2 - Photogrammetric 3D model of the Karahan tepe archaeological excavation, Turkey (author's material)

The results of photogrammetric surveys of interior spaces demonstrate the effectiveness of the method for collecting spatial data under constrained conditions (**Figure 3**). The use of mobile

devices makes it possible to generate 3D models of interior environments with deviations not exceeding several millimeters, which is acceptable for pre-design analysis, area calculations, and the assessment of volumetric and spatial parameters. At the same time, photogrammetric models allow for repeated analysis in a virtual environment, reducing the need for multiple site visits. The limitations of the method become apparent when high-precision construction measurements are required, in which case photogrammetric data must be supplemented by traditional surveying techniques, a conclusion consistent with findings reported by other researchers.

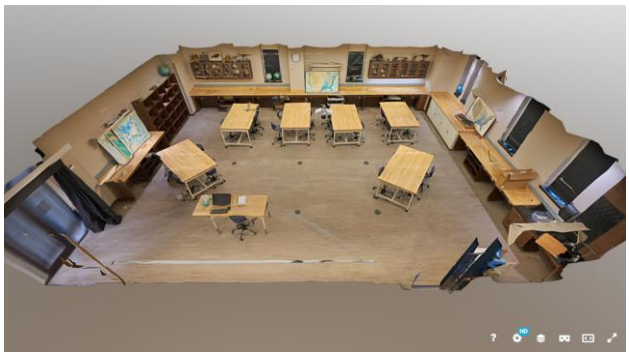

Figure 3 - Photogrammetric 3D model of the scanned interior (author's material)

A central component of the study is the author's case study related to the design of the Mukagali Makataev Monument in the village of Narynkol, Raimbek District, Almaty Region, Republic of Kazakhstan. During the design process, a miniature sculptural model of the poet was created and subsequently digitized using photogrammetry. The resulting 3D model served as the basis for compositional analysis and for the architectural design of the pedestal (**Figure 4**).

The photogrammetric model enabled the analysis of proportional relationships between the sculptural form and the pedestal within a virtual environment, ensuring precise adjustment of the visual balance of the composition. The monument was conceived as a composition consisting of two interrelated elements - the statue and the pedestal. The height of the bronze statue is 3.75 m; the image of the poet is rendered in restrained plastic form with a slight inclination of the figure, emphasizing the lyrical and romantic character of the representation.

The pedestal is made of granite and takes the form of a square prism in plan, with pointed recesses along its four edges, representing an interpretation of contemporary national architectural motifs. Two types of granite - polished and unpolished - were used in the finishing, creating a contrast in tone and texture. An engraved inscription indicating the name and lifespan of Mukagali Makataev is placed on the front face of the pedestal. The lower part of the pedestal is framed by perimeter inserts that visually separate it from the stylobate base.

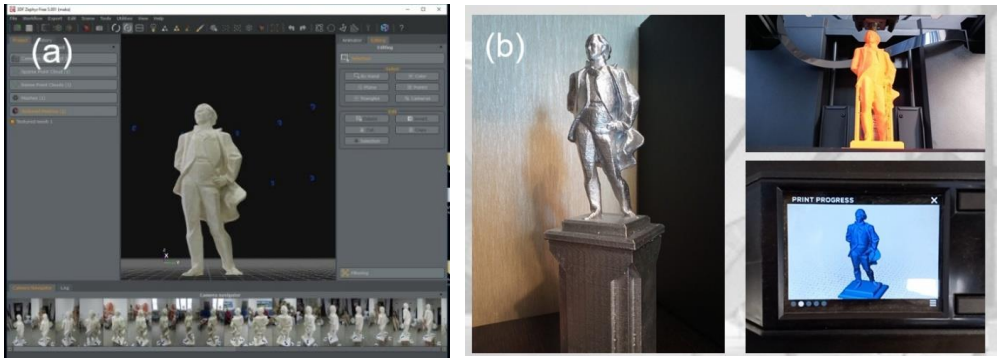

Figure 4 – Workflow of the design and fabrication process (author's material):
a) photogrammetric digitization of the Mukagali Makataev sculpture;
b) 3D printing of the sculptural model together with a preliminary version of the pedestal.

The total height of the pedestal together with the stereobate platform is 4.5 m. The platform has a square plan and is complemented by steps; triangular planters are placed at the corners, enhancing compositional stability and visual legibility of the monument within a wide field of view. The proportional relationships between the sculpture, the pedestal, and the stylobate were repeatedly refined during the process of virtual modelling based on photogrammetric data (**Figure 5**).

The digitized composition of the monument was also used for the fabrication of a physical scale model using additive manufacturing technologies, which increased the clarity of the design solutions and facilitated the approval process with local executive authorities. The authorship of the installed monument is confirmed by Copyright Certificate No. 10308 dated 27 May 2020, issued by the Ministry of Justice of the Republic of Kazakhstan.

Figure 5 - Monument to Mukagali Makataev in Narynkol village (author's material):
a) conceptual sketch;
b) realised monument.

The experience of designing the Mukagali Makataev Monument demonstrates that photogrammetry can be effectively employed as a tool for creative architectural exploration, ensuring continuity between the author's conceptual intent and the realized object. The use of a digital model minimized discrepancies between the conceptual design and the final implementation and increased the accuracy and justification of architectural decisions at the stage of developing working documentation.

5 CONCLUSIONS

1. The study confirms the applicability of photogrammetry as a method for the digital documentation of the actual condition of architectural objects, including their geometry, proportional relationships, and surface visual characteristics. The resulting 3D models of architectural heritage monuments and memorial objects demonstrate their suitability as digital representations for analytical use, visual examination, and subsequent application in restoration and design tasks.

2. The results of the case study of the Mukagali Makataev Monument demonstrate that photogrammetry can be effectively applied at the conceptual and compositional design stages as a tool for analyzing the proportional relationship between the sculptural form and the architectural solution of the pedestal. The use of the digitized model made it possible to refine scale and visual parameters prior to implementation, ensuring a high degree of correspondence between the author's conceptual intent and the realized object.

3. The conducted analysis shows that the photogrammetric method reduces the time required for surveying and pre-design activities compared to traditional manual measurements, owing to the possibility of repeated analysis of the object in a virtual environment without additional site visits.

During the survey of interiors and façades, deviations within several millimeters were achieved, which is acceptable for architectural analysis, area calculations, and pre-design decision-making. However, for construction and installation works, photogrammetric data require refinement using conventional measurement methods, a conclusion consistent with findings reported in contemporary studies.

4. From a scientific perspective, photogrammetry in the present research is reinterpreted not only as a measurement technology, but also as a method of architectural and compositional analysis oriented towards working with actual architectural form and visual context. This expands the methodological toolkit of architectural research and enables the use of photogrammetric data for interpreting national architectural techniques and form-making principles.

5. The contribution of the study to the development of applied scientific methods for the preservation and advancement of Kazakhstan's national architecture lies in substantiating photogrammetry as an accessible and reproducible tool suitable for the digital conservation of architectural heritage, the analysis of memorial architecture, and the support of author-driven design practice. The proposed approach demonstrates the possibility of combining digital documentation with creative architectural exploration without compromising national architectural identity.

6. The limitations of the study include the dependence of photogrammetric model quality on shooting conditions, lighting, and camera characteristics, as well as the absence of direct comparison with laser scanning results and alternative photogrammetric software solutions applied to the same object. These factors limit the generalization of the findings across all types of architectural objects and survey conditions.

7. Prospects for further research are associated with conducting comparative analyses of different photogrammetric software solutions, including contemporary free versions of RealityCapture, as well as with expanding the methodology for applying photogrammetry to digital conservation tasks, the analysis of the national architectural code, and the integration of photogrammetric models into architectural education and research practices in Kazakhstan.

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