

Integrating engineering methods for obtaining three-dimensional data in architectural BIM and HBIM modeling

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Abstract. The engineering survey of buildings is a relevant topic due to the need for analysis and expertise for historical buildings, reconstruction for existing buildings, creation of digital information models and so on. This paper presents the following sequence for a workflow: 1) pre-project analysis; 2) engineering technologies for obtaining a spatial 3D data, such as 3D scanning, photogrammetry, etc.; 3) obtaining a point cloud and import into BIM software, and 4) working with digital information models and digital twins with a focus on Russian software. This analysis is considered based on literature review and on practical studies. Engineering methods are designed to enrich the architect's tools, they have to be introduced and implemented in architectural education, and integrated into architectural projects, especially at master's level.

Keywords: Russian software, BIM, HBIM, LiDar, Terrestrial laser scanning, heritage architecture, education-project.

1 Introduction

The relevance of use of contemporary computer technologies is conditioned by the National program for the development of digital economy and digitalization of the architecture and construction industry in our country [1]. It is also relevant due to a large volume of architectural design documentation that is created in the process of working on new architectural projects, as well as the need for surveys, analysis, expertise, creation of digital 3D information models of historical buildings, and for existing buildings, during the construction of which these methods were not used. Engineering methods for obtaining spatial data are effective when working both with objects of historical and cultural heritage, and for building's reconstruction and monitoring.

To solve these problems, a large number of computer software and engineering technologies have been created, they are constantly improving, and new opportunities are emerging. Different tasks in software can be performed using multiple options, using a

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variety of tools and procedures. Therefore, the competence of an architect to professionally solve the tasks with high quality and efficiency is required here.

The aim of this study is to analyze and outline the process of working on architectural projects that integrate engineering methods and techniques for obtaining a three-dimensional data about an object.

From our perspective, the relevance of this study is also explained by the need to introduce these engineering methods in a research and educational process, for education of architects and specialists in restoration of architectural heritage, especially at the master's level.

2 Methods

This paper uses the following research methods: analysis of existing literature and analysis of practical field studies. Actual surveys of historical heritage complexes and buildings were carried out by the author A.A. Shamarina.

Therefore, this article suggests the following workflow, which integrates engineering methods for obtaining three-dimensional data into architectural projects, adapting practical experience and expertise. The workflow has 4 steps and is presented at Fig. 1.

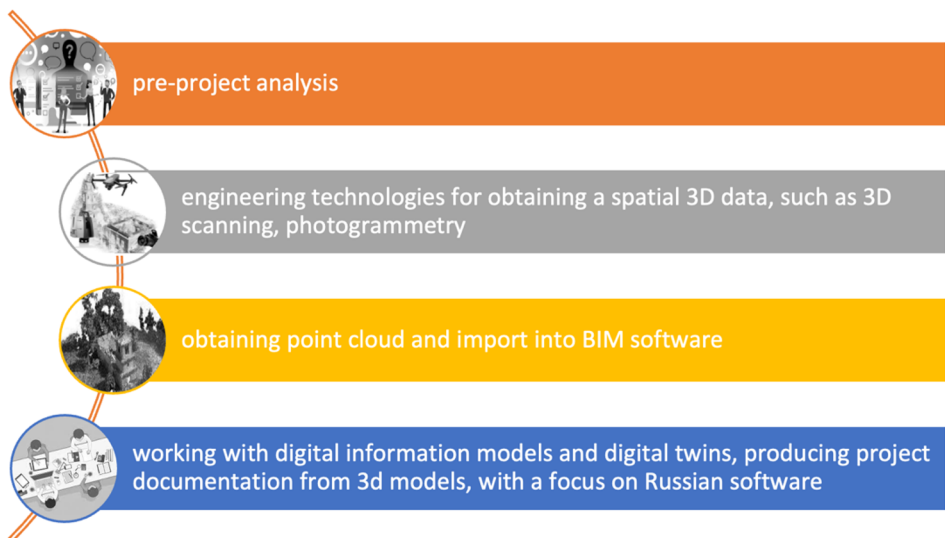


Fig. 1. 4 steps working on education-project.

This section views the workflow step by step: 1) pre-project analysis; 2) engineering technologies for obtaining a spatial 3D data, such as 3D scanning, photogrammetry, etc.; 3) obtaining a point cloud and import into BIM software, and 4) working with digital information models and digital twins with a focus on Russian software.

One of the most important stages in the work of an architect is a pre-project analysis [2]. It is necessary in order to have an idea of the site, the surrounding buildings and context, the features of the terrain and the historical memory of the site. This allows to take into account the local features and, on the basis of them, present the most appropriate and competent architectural solutions.

One of the sources of information is public open data. It helps a researcher to get acquainted with the research object and project site, before visiting the site area. Such collection of information helps to reduce field work, as well as to identify problematic issues in the upcoming work.

The following is the list of online maps and free online open data sources (refer to Table 1).

Table 1. Open data source.

Title and description	Link
Cadastral map of Russia	https://pkk.rosreestr.ru
OpenStreetMap	https://www.openstreetmap.org/
Yandex maps	https://n.maps.yandex.ru/
Retromap – historical maps	http://retromap.ru/
PastVu – historical photos	https://pastvu.com/
ASTER	https://srtm.csi.cgiar.org/srtmdata/
Free GIS Data	http://freegisdata.rtwilson.com/
Cadmapper	https://cadmapper.com/

Open source data analysis is an important part of pre-project phase, and it is necessary in a research work of students in all types of architectural projects.

After the pre-project analysis has been completed, the researcher proceeds to a field work. Various sketches, measurements, and collection of spatial data are performed during a field work.

One of the technologies for collecting spatial data is *LiDar*. Scanning *LiDAR* devices in a machine vision system form a three-dimensional picture of the environment. When using this technology, an architect receives complete three-dimensional information about the spatial environment, which allows to draw conclusions about the appropriateness of decisions made when designing new buildings, or modeling and monitoring historical architectural buildings in a dense historical built environment [3]. And also, this technology allows to monitor the life cycle of buildings from conception phase to building remodeling or disposal.

Different types of scanning devices are available on the market, from hand-held to aerial scanning devices. The choice of instrument depends on the tasks assigned to the researcher [4].

The two technologies are most often combined - there are terrestrial laser scanning and photogrammetry. Terrestrial laser scanning in architecture is used for documenting historical and cultural heritage objects, monitoring, and, as mentioned earlier, for adding a new object into the dense core of an existing built environment.

According to the principle of operation of a scanner, they are divided into pulse and phase scanners. Nowadays, phase ones have gained great popularity due to their lightness and simplicity in work in the field. When working with a scanning installation, they often encounter "black holes" - these are places where the laser beam cannot reach. In such cases, aerial photogrammetry from a drone and terrestrial laser scanning can be combined together.

The principle of *photogrammetry* or *aerial photogrammetry* is to analyze several photographs of a static object taken from different viewpoints and automatically detect pixels corresponding to the same physical point. The input data required from the user is camera parameters, such as focal length and lens distortion. Photogrammetric technology is also capable in terms of reconstructing objects of various scales photographed from the ground or from the air. The key advantages of 3D photogrammetry scanning technology are its accuracy and speed of data collection [7,13].

One of the main applications of photogrammetry in architecture is the performance of architectural and construction measurements for the purpose of reconstruction and restoration of buildings, as well as for research purposes. Depending on the purpose, architectural and construction measurements of buildings are divided into schematic, architectural and archaeological types.

Different software is used to solve the tasks, for instance, RealityCapture, Agisoft Metashape, COLMAP, Meshroom, and MicMac.

Fig. 2 illustrates the use of photogrammetry, with a combination of photographs received with aerial drone camera and terrestrial camera [7].

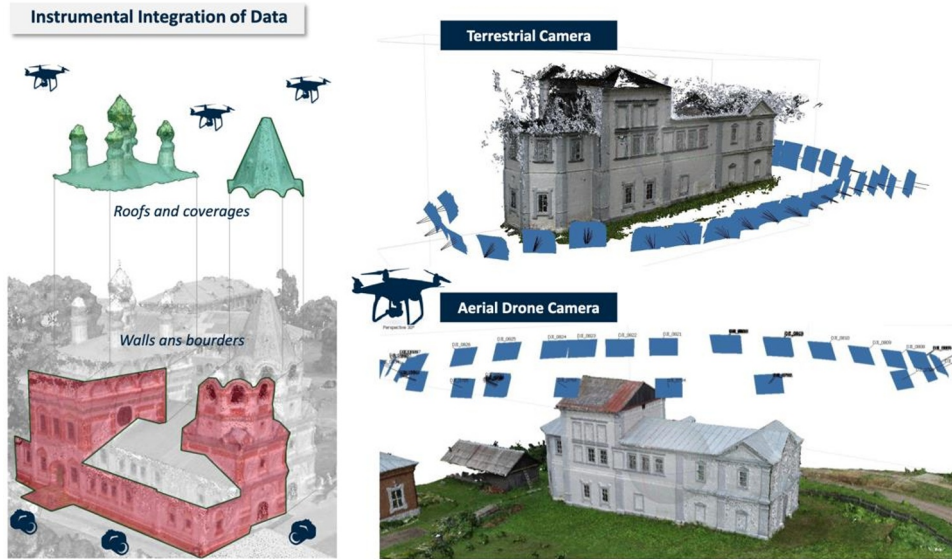


Fig. 2. Example of the use of photogrammetry, with a combination of photographs with aerial drone camera and terrestrial camera. Project PROMETEUS.

As part of the research and educational project with participation of A.A. Shamarina, an enormous amount of work has been done to create a BIM cataloging of objects of the Upper Kama Sites of the Perm region.

This project showed the possibility of introducing HeritageBIM into the educational environment and promoting the historical and cultural heritage of Russia. Both PhD and Masters students from different participating countries worked on the project.

Next, the workflow and research phases for working on such a project and software that is used to implement the tasks is viewed (Fig. 3).

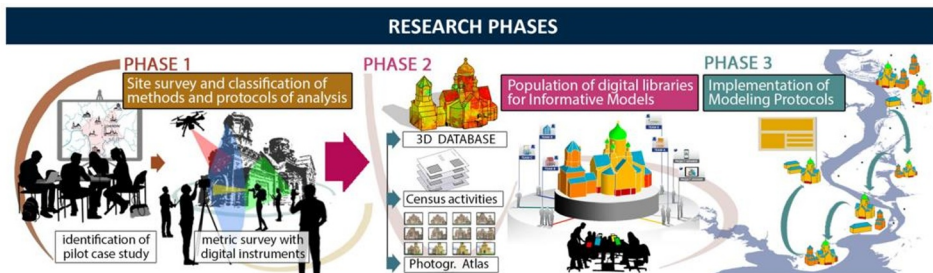


Fig. 3. Workflow for PROMETEUS project. EU Horizon 2020 – R&I – RISE – Research & Innovation Staff Exchange Marie Skłodowska-Curie, PROMETEUS- PROtocols for information Models librariEs Tested on HEritage of Upper Kama Site.

The first phase included pre-project analysis and field work, the second phase included work on the received spatial data, and the third phases consisted on protocol itself.

The following equipment was used: Static Laser Scanner, Terrestrial Camera, Aerial Drone Camera, Mobile Stencil Scanner. Each tool was responsible for its own amount of information.

Static Laser Scanner - structural deformation, (architectural geometry, morphological relations)[4,5].

Terrestrial Camera- constructive detail, decay information, materials textures.

Aerial Drone Camera- general context, landscape conformation, Boundary definition materials textures [7].

Mobile Stencil Scanner - boundary definition, Landscape Relations, main plan, relation with Urban Fabric, territorial context.

Behind each instrument was a team of researchers who subsequently converted the data into point clouds and then into a BIM model [14,17,18].

A point cloud is spatially organized data in the form of a set of points, where each point has its own XYZ coordinates. This data is obtained from a Lidar or photogrammetric survey that provides a 3D representation of existing buildings. Point clouds can provide an existing surroundings and context, as well as speed up the design process when working with existing buildings. This data can be imported into the BIM file to continue working with it[13,].

Before a further work, it was necessary to combine individual clouds into a single data array. For this the following software was used: Agisoft Metashape, Leica Geosystem Cyclone 9.0, FARO SCENE & etc.

Next, the data was imported into the BIM information model in order to continue working with them [10,12,14,15].

The process of importing point clouds with different software is shown below (Table 2):

Table 2. Import a point cloud into BIM-software.

Software	Import a point cloud into BIM-software
Import point cloud to Archicad (foreign software) [6,12,14]	Import of a point cloud is carried out through the tab «File» > «Interoperability» > «Insert Point Clouds». Point cloud has to be saved in E57 or XYZ file formats
Import point cloud to Revit (foreign software)	Import of a point cloud is carried out through the tab « Insert » > «Pointcloud». Point cloud has to be saved in RCP or RCS file formats
Import point cloud to Autocad (foreign software [5])	To create point clouds from object scan data there is a program Autodesk ReCap. It converts raw data into scan files (RCS file) and project files (RCP file). File of both file formats can be inserted in AutoCAD by inserting an external link
Import point cloud to NanoCAD (Russian software)	Import of a point cloud is carried out through: Point clouds > Import. In the point import dialog choose which data should be imported. It is possible to import point clouds into drawing model space from files of LAS, LAZ, BIN, PTX, PTS, PCD, TXT, XYZ, XYB, PLY, E57, RCS, RCP, NPC file formats
Import point cloud to Renga (Russian software)	Importing a point cloud is now possible only through another open source software, for example, MeshLab or FreeCad. It is necessary to convert the point cloud to 3D format and then import to Renga

As can be seen from Table 2, the software is diverse and researchers from different countries may use different programs. The general data format allows this joint work.

The use of Russian software products that allow to perform architectural projects, create information models of buildings and structures and carry out other related work, as well as allow the possibility of importing 3D scanning data into BIM models is viewed next [8,9,11,12].

In Russia information modeling technologies are actively used in architecture projects and construction due to the perspectives of digitalization of the construction industry and the development of the digital economy. The attention has been focused on to the use of Russian software.

Therefore, Russian software in the field of digital information modeling and making digital twins - nanoCAD and Renga software is considered. These programs can be used for developing architectural projects, project management, making digital information models, and to import point clouds into models for further work with them.

2.1 NanoCAD

NanoCAD allows to create and develop architectural drawings based on Russian national drawing standards and norms. It allows to use Russian system of project documents for construction. The advantage of this software is the possibility to use drawing standards and verification for compliance with standards.

NanoCAD allows to work on architectural project documentation (fig.4), develop building construction drawings (for example, using NanoCAD metal structures), develop site plans, land management, surveys and master plans (nanoCAD GeoniCS). NanoCAD can be used for creation of architectural drawings based on point clouds [19,20].

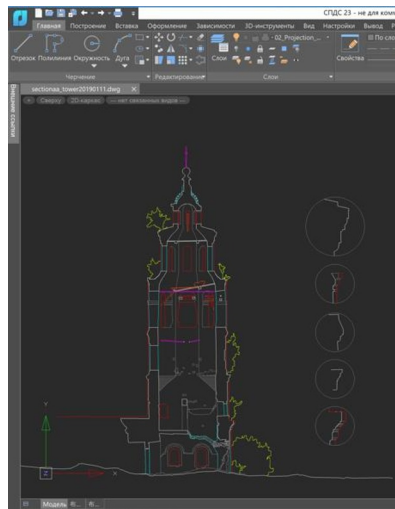


Fig. 4. Section, prepared by the section of the discrete model. Church of Vladimir icon of the mother of Got (Rubezhskaya)

Renga includes Renga Architecture, Renga Structure and Renga MEP. These components are combined in one software. It allows to issue project documentation based on Russian drawing standards and norms. It is possible to convert files into file exchange format (IFC)(fig.5).

The advantage of Renga is that information model designed in the software can be used throughout all building life cycle, and it can be accessed through 1C platform for project management [17,19].



Fig. 5. HBIM ArchiCAD – .ifc HBIM – renga – .ifc. Church of Vladimir icon of the mother of Got (Rubezhskaya)

3 Results and Discussion

After analyzing the current literature and practical examples the following sequence of work is proposed: 1) pre-project analysis; 2) engineering technologies for obtaining a spatial 3D data, such as 3D scanning, photogrammetry, etc.; 3) obtaining a point cloud and import into BIM software, and 4) working with digital information models and digital twins with a focus on Russian software.

The advantages of engineering methods of survey and obtaining three-dimensional data are as follows: accuracy and reliable dimensional drawings, high level of details, in compliance with the existing geometry.

Russian software products that allow performing architectural design, creating information models of buildings and structures, and carrying out other related work are viewed.

All in all, along with the methods of obtaining a three-dimensional data for architectural projects, creating and working with digital building information models provides a wide range of opportunities for architects and various specialists of the professional field.

4 Conclusion

Engineering methods are constantly evolving, due to the emergence of new software, data collection, more accurate analysis and work with data, the emergence of new approaches to creating digital information models of buildings and working with them. These methods have to be constantly analyzed and used both in practice and architectural education as they can be integrated into architectural projects [20].

Mastering engineering methods for obtaining 3D data, using point clouds in a project, and integration with an architectural project are important competencies that are needed in architectural design and architectural education.

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