3D laser scanning of the structure during reconstruction based on BIM technology

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Abstract

This paper analyzes the application of Industry 4.0, namely building information modelling, in construction and civil engineering. It provides an overview of the advantages and opportunities of using BIM in structural design, construction and operation. Discuss the practical aspects of implementing BIM technology, including increasing the project team's efficiency, reducing errors and costs, and improving project quality. Using the example of scanning a building, the methodology that can be used to reconstruct a building, namely for quality control or comparison of the designed dimensions and actual ones, is shown. The experimental approach shows that the proposed methodology can also be used for reverse engineering of existing buildings.

Keywords

BIM, Laser 3D scanning, reverse engineering, design, reconstruction

1. Introduction

Industry 4.0 has transformed several economic sectors, including civil engineering. This new era of technology, characterized by the interconnection of devices and the digitization of processes, has significantly impacted how infrastructure is planned, designed and built. [1]

This industry in the field of construction and civil engineering incorporates the trends of the Internet of Things [2], Building Information Modeling (BIM) [3-5], 3D printing using machine learning [6]), and Artificial Intelligence, Remote Sensing for the Sustainability of Civil Infrastructure [7].

In the modern world, the construction and reconstruction of buildings are complex and multifaceted processes that require not only high qualifications but also the use of

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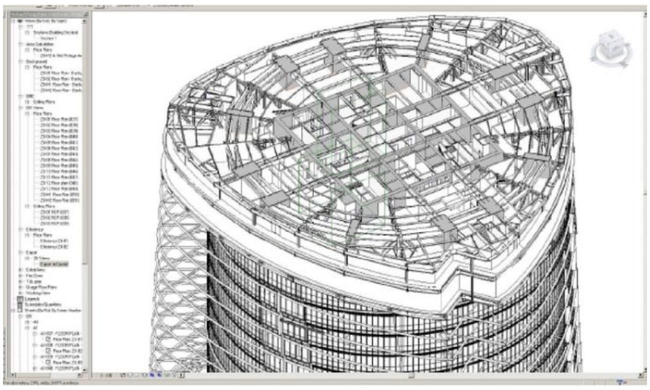
advanced technologies. In this context, Building Information Modeling (BIM) technology is proving to be key, providing an integrated approach to project and information management throughout the entire life cycle of construction projects.

BIM plays a significant role in ensuring the efficiency and quality of construction processes by providing a convenient and effective platform for collaboration between all project participants, including architects, engineers, clients, contractors and other stakeholders. BIM creates virtual models of a building that include information about all aspects of the project, from geometric parameters to information about materials and technical characteristics of elements.

The advantages of using BIM technologies include reducing the mistakes and conflicts in the project due to the ability to detect them at the virtual modelling stage, increasing the efficiency of the project team through shared access to a centralised database, as well as reducing costs and increasing quality through optimisation of design solutions and construction processes.

The analysis of recent research is devoted to various issues related to using BIM technologies in the construction and reconstruction of facilities. The research topics are related to the theory, practice, and evaluation of the impact of BIM technology on construction processes in terms of efficiency, quality, and innovation. According to these studies, implementing BIM saves time and costs and minimises mistakes in the design phase, preventing possible virtual modelling and analysis [8]. In addition, the accuracy and quality of projects are also guaranteed by more detailed modelling of engineering systems, as well as how all building elements interact with each other through the use of BIM.

BIM became Gensler's main tool in the design of the Shanghai Spiral Skyscraper (Fig. 1). Building information modeling helped to make a 120-degree turn of the tower. As a result, the project authors minimized the impact of typhoons on the structure and reduced energy consumption by 21% [9].



(b)

(a)

Figure 1: Rendering of Shanghai Tower (a) and BIM implementation (b).

Another subject area that is also covered by scientific research is the impact of BIM on construction and operations. Research confirms that cost savings can be attributed to the proper allocation of resources, while significant improvements in project management efficiency result from improved information availability and productive teamwork between all project participants. Some studies have focused on the use of BIM in renovation and restoration projects. They provide evidence of how BIM can be used to accurately model the condition of a building, identify problems that may arise, and develop effective strategies to address them.

Laser 3D scanning is an important component of reconstruction [10]. This is a modern technology for collecting spatial data. As a result of scanning, a three-dimensional model of the object is formed - a “point cloud” consisting of a set of vertices, the position of each of which is determined by the values of the X, Y and Z coordinates.

Figure 2: An example of the scanner operation.

3D scanning can be carried out in two ways - stationary (individual buildings and structures, interior spaces are scanned) and mobile (large areas, linear objects are scanned). The 3D scanning technology allows for simultaneous horizontal and high-altitude surveying of the area. As a result of the laser scanner's operation, a “point cloud” is formed, based on which orthophotomaps are created.

The principle of operation of a laser scanner is similar to that of a reflectorless electronic total station and consists of measuring the time of the laser beam's passage from the emitter to the reflecting surface and back to the receiver. By dividing this time by the laser beam propagation speed, the distance to the object is determined. The scanner consists of a laser rangefinder adapted for high-frequency operation and a laser beam scanning unit. The scanning unit comprises a servo drive and a polygonal mirror or prism. The servo deflects the beam by a specified amount in the horizontal plane while the entire upper part of the scanner rotates. Scanning in the vertical plane is carried out by rotating or oscillating the mirror

Scanning buildings using a LiDAR (Light Detection and Ranging) scanner in construction is a modern and effective way to obtain an accurate three-dimensional model of a building and its surroundings. LiDAR technology uses laser radiation to measure distances to object surfaces and create an accurate image of the environment.

In general, scanning buildings with a LiDAR scanner opens up great opportunities for obtaining accurate and detailed information about construction projects, which helps to improve the quality of design, construction, and management of real estate.

This paper presents a methodology for scanning a building with its subsequent recognition and creation of a 3D model.

2. Methodology of 3D scanning

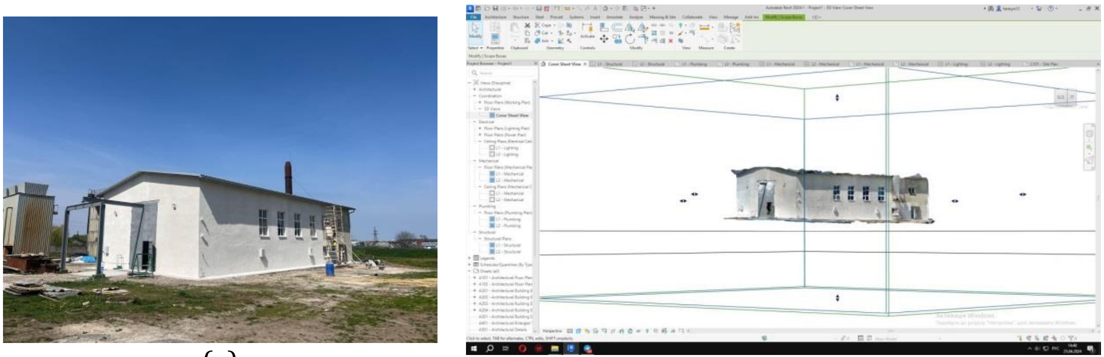
The experimental study methodology using a LiDAR scanner integrated into the Autodesk Revit program can be described in several stages. The first stage is preparatory and critical for the successful implementation of the study. At this stage, the study's main parameters are determined, work with the object is planned, the necessary equipment is selected, and a general strategy is created. It includes the definition of the research object, i.e. it is important to know what exactly will be investigated. It can be a building, structure, infrastructure, or any other object requiring a detailed three-dimensional model. The object can exist or be subject to construction or reconstruction. Next, a LiDAR scanner is selected depending on the size and complexity of the object, the required resolution, availability, and other factors.

The scanner must be able to provide the required level of detail and accuracy of the data. The next step is to develop a research strategy, i.e. at this stage, the main goals and objectives of the research are formed, what kind of information needs to be obtained through scanning is determined, and the method of data collection, processing and analysis is planned, including the time and resources required for each stage. The second stage is the stage of scanning the object with a LiDAR scanner. This stage includes the scanning process, data collection, and quality control to ensure reliable information data is obtained. At this stage, the scanner measures distances to the object's surface using laser radiation and analyses the received reflected signals. The scanner can be placed on a moving platform (e.g., tripod, car, drone, etc.) to ensure coverage of all desired areas of the object. LiDAR generates a large amount of point data representing the object's surface during the scanning process. Each point contains information about its XYZ coordinates, distance, and possibly other parameters such as colours.

After the scanning is completed, it is important to conduct quality control of the data obtained, including checking the coverage of all planning areas and identifying and resolving any errors. The obtained LiDAR scan data needs to be prepared for further processing, which includes cleaning the data from noise, removing unnecessary points, dividing the data into different layers, and other operations to improve quality and accuracy. Generally, this stage requires high precision and attention to detail during scanning. The third stage is integrating the scanned object into the Autodesk Revit program for further use within BIM technologies. The output file from the scanner needs to be imported into Revit. For this, we need to choose a suitable format that will provide optimal quality and convenience for further work After importing the model, it may be necessary to make adjustments to ensure that the model is displayed correctly and meets the needs of the study or project. This may include placing additional elements that can be added in Revit and removing unnecessary details.

One of the advantages of using Revit is the ability to add metadata and attributes to model objects, which can facilitate further analysis and work with the model. For example, you can add information about materials, dimensions, costs, and other characteristics of the object. After integrating the model into Revit, you can use it within BIM technologies to perform various analyses, plan reconstruction, assess the impact of changes, etc. The model can be used to create additional structural and architectural elements, create layouts, study the location of communications, energy analysis, etc. The next step after integrating the LiDAR data into the Revit program is usually a detailed analysis of the model and its use for various purposes related to constructing and reconstructing structures. This is model analysis, meaning you can perform a detailed analysis of its structure, data, and characteristics. This may include reviewing the geometry, checking the availability of the necessary elements, placing objects, identifying materials, etc.

A restored building in the Ternopil region was chosen for scanning (Fig. 3a). The building was scanned using a LiDAR scanner integrated into the iPhone 13 Pro to provide new opportunities for inspecting and analysing the condition of the building using an affordable and convenient device.



(a) (b)

Figure 3: Photo of structure (a) and 3D model in Autodesk Revit (b).

The starting point and final trajectory are shown in the green line in Fig. 4. With the help of apps, you can scan a building by moving around it with your phone to get an accurate image of its geometry and structure. Polycam software was used for scanning.

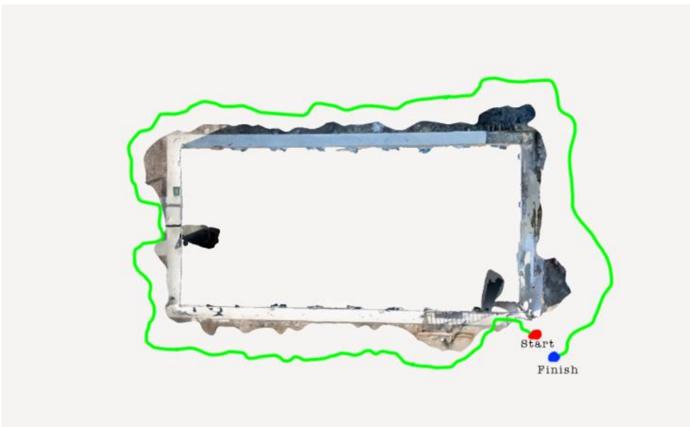


Figure 4: Trajectory of the LiDAR scanner.

The resulting point data is stored in a special format that allows for further processing.

3. Results and discussion

After scanning, a three-dimensional model of the building (Fig. 3b) was received. The resulting model allowed us to conduct a detailed analysis of the building's condition. We studied various aspects such as dimensions, construction and damage. Using a three-dimensional model to analyse a building's condition allows you to draw more objective and accurate conclusions about its current state, identify problems and risks, and develop effective plans for further management and maintenance. This allows for a further lifecycle approach of BIM. Using the obtained model and Revit software, a 2D drawing of the building was created (Fig. 5).

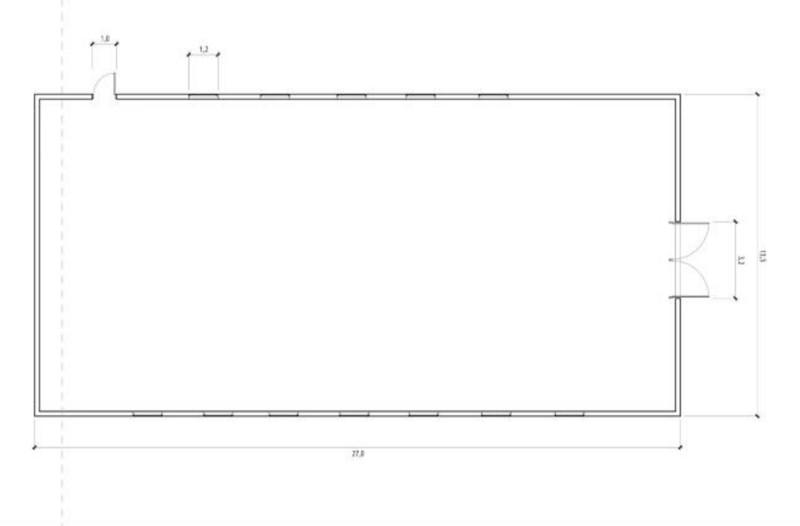


Figure 5: 2D project.

The proposed methodology can be used for reverse engineering of existing buildings. Typically, reverse engineering is used to renovate, modernise, or maintain existing structures. The main idea is to recreate or restore a three-dimensional model of a building based on available data or information to investigate its condition and characteristics.

It could be summarised that the use of BIM technology in the construction and reconstruction of buildings proves to be a very promising and useful approach.

4. Conclusions

An overview of Industry 4.0 technologies in construction is provided. The use of BIM technology in the construction and reconstruction of buildings proves to be a very promising and useful approach. The use of BIM increases design efficiency, reduces costs and risks, improves the quality and accuracy of construction works, and increases the level of cooperation between all project participants. It was shown that laser scanning plays an important role in modern construction and engineering. It is an important tool for obtaining detailed information about objects with high accuracy and speed. Its use opens up new opportunities for accurate analysis and can significantly improve the research, design, and construction processes. The study shows that laser scanning can reduce the time and cost of research, as its speed and efficiency ensure the rapid collection of large amounts of data without the need for heavy equipment. Therefore, the use of Industry 4.0 technologies, such as BIM and laser scanning, is an important tool to support various tasks in the field of construction, reconstruction and architecture.

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