Use of a 3D scanner technology to create an information model of historic buildings - a case study

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Abstract. Digitization in construction has become increasingly important in recent years. Digital technologies are a way to facilitate some activities and thus save time and money on construction projects. Creating an information model of an existing building can be relatively time-consuming. The 3D scanner allows you to perform personal tasks with time savings, which is very important when managing construction projects. Digital technologies are also an effective tool for these activities. This research discusses the issue of 3D scanning of a historical building for real state surveying purposes. In this case study, the subject of the study was the chapel of St. Rosalie in Košice. The aim of the research was to describe the course of digitization in the building in question, i.e. the creation of an information model of the building. At the same time point out the possibilities and limitations of a 3D scanner on this specific construction.

1. Introduction
The overall design of the building depends on various factors that result from the construction system of the building, the technological process of construction, the size and location of the land used for the construction site, the possibility of delivery of material, etc. This topic is even more complicated in the case of an existing building. Creating an information model from an existing point can be a problem if the original project documentation is not in order [1]. This topic can be all the more challenging if it is a historic building, the actual state of which may be different from the old project documentation. A prerequisite for the successful completion or reconstruction of a building is the planning of optimal conditions for the design solution, as well as the design of the final building in the new project documentation. The information model, which is based on three-dimensional model systems, has the potential for much faster and better preparation of drawings or modification of existing solutions in terms of implementation of construction conditions [2], [3]. The advantage of these systems is a clear illustration of the reduction or even elimination of possible errors in design solutions.

2. Theoretical background
The building preparation is one of the prerequisites for the successful implementation of construction [4]. At this stage of processing the documentation, the method of construction is proposed and ensuring its continuity in terms of environmental protection, quality, compliance with deadlines, and costs. Unfortunately, this assumption is not realized by many participants in the building process. However, the current conditions cause a significant change in the status, interests, and goals of the construction participants. This is the reason for looking for a new approach to construction preparation. Another situation arises if it is already a building that is being built and it is necessary to reconstruct it. Especially
when it comes to historic buildings that have their own specifics. It is also very important to take into account situations where project documentation is not available, and it is necessary to find out the current factual state of the building. In this case, modelling a 3D model based on the measurement is a time-consuming process. However, there are currently several digital technologies that are shifting the potential for saving time and energy [5], [6].

BIM technologies represent a great potential for further work and saving time, energy as well as costs [7]. Working with a 3D model is more efficient [8]. However, the modelling itself in some situations is demanding on the mentioned resources [9]. For constructions that already exist, there is room for reverse engineering. In practice, this can often mean finding out the actual state of the building for which a 3D model needs to be obtained. In these cases, a 3D scanner may appear to be a useful tool.

At present, the construction industry must significantly improve the quality and efficiency of project documentation and construction implementation in order to reduce costs, construction duration, shortcomings, and problems already in the preparation phase. One way to achieve this is to use digital technology [4], [10]. Digital technology allows the designer to create a geometric model of a building. This model can be supplemented by other buildings [11]. This method represented a virtual model of future construction. The designer can select the necessary elements, building structures, construction site objects, and insert them into 3D space [12]. The situation is different if the building exists and there is space to use the aforementioned 3D scanner.

3. Methodology
This case study is intended to map the course of a 3D scan of a historic building, from which it is necessary to make a 3D model determine the facts. The survey and study aim is to describe the situation and possibilities of using this advanced technology in information modelling of buildings. On the other hand, describe the shortcomings and limitations that must be taken into account when using a 3D scanner for similar purposes.

The main reference object was the Chapel of St. Rosalie in Košice. This object is suitable for target and research purposes for several reasons. It is a building with a rich history, which is conveniently logistically located for the above-mentioned research purposes. Ground laser scanning of the historic sacral building - Chapel of St. Rosalie in Košice, was aimed at capturing the actual state of the building as a whole to the required extent, i.e., the interior space except the truss, the exterior of the facade and the vicinity of the chapel with focus on the main entrance.

A FARO Focus 3D X130 laser scanner with a carbon telescopic tripod and 12 reference balls with a diameter of 145 mm was used for digital fact-finding. As part of the digitization of the actual state of the chapel building, the work performed is divided into two parts:

- digital focus of the building - Chapel of St. Rosalie
- processing of measured data – scans

4. Results and discussions
3D scanning of buildings requires a certain amount of time. The digital focus of the object brings certain steps that need to be followed. One of the possible restrictions or rules is the scanning procedure and position. The direction of the scanning process is shown graphically in detail in the figures below, where the order of standing of the scanner in which the chapel was aimed is numerically indicated. The scanning process began in the interiors from the sacristy area (scan 1 - 3), from where it was smoothly passed by the chapel ship (scan 4 - 6) to the exterior (scan 7 - 9), then via a side staircase to the choir (scan 10 - 13) and from the position 14 was continued continuously around the perimeter of the chapel until the scanning at position 20 was completed.
**Figure 1.** View the scanner position in the scanning process

For a better understanding and display of the scanner position and view, these positions and views from the given places are shown in Figure 2.
Figure 2. View the scanning positions from panoramic photos
There are a large number of trees near the chapel (see the picture below), which required a larger number of scans to focus on the facade and roof of the chapel. The considering terrain around the chapel required a greater distance of the scanner from the chapel for a more complex focus of the rugged roof. The surfaces of the roof structure were oriented indirectly, i.e., they were focused from positions that were primarily intended for the orientation of the building facade, but also the position of the scanner relative to the chapel was such that parts of the roof were also captured indirectly. It can be stated that the roof surface would be completely oriented in a certain quality using aerial laser scanning or aerial photogrammetry (figure 3).

Figure 3. Around the chapel of St. Roses and restrictions in the form of trees

During the scan, we recorded several important findings. Concerning the scanning position, it was very important to find out that it is very important to examine the environment in advance. Buildings that are located on cleaner areas (such as green meadows, etc.) make scenery much easier to implement and more accurate. In our case, the terrain was slightly rugged. However, the restrictions in the form of trees were more intense. That's why we had to run up to 20 scans. The placement of the balls was also more difficult, as it was necessary to place them so that they did not overlap, and at the same time, the individual points could be connected in a cloud of points.

A total of twenty scans were created within five hours of the chapel scan. Scan time includes:

- setting scanner parameters during measurement,
- location of reference points during the measurement,
- the focus of selected parts of the building interior,
- focus on the exterior of the building and the surrounding area.

During the scan, the scanning parameters were changed during the transition from the interior of the chapel to the exterior, which had an impact mainly on the time of the creation of individual scans. Within the interior, the scanning distance was set to 10 m, the resolution to 1/8 and the quality to 3x, which represents a scanning time of 5 minutes and 6 seconds, within the exterior, the scanning distance was changed to over 20 m, the resolution to 1/4 and the quality to 4x, which represents a scan time of 11 minutes and 22 seconds.

Another important finding was found or confirmed in the field of output quality. Scanning time can be affected at the expense of quality. Due to needs, it was possible to set a lower quality at the expense of scanning speed. Of course, in the case of the need for better quality, it is necessary to count on a larger time horizon.
Another result was the processing of measured data. It is also a time-consuming process. It is largely dependent on the quality of the collected data, especially in terms of the appropriate placement of the balls, i.e. the position of the scanner when scanning. The measured data were processed into a point cloud by registration in the FARO SCENE software environment (see Figure 4). After registration, colours from panoramic photographs were applied to the point cloud, and then the point cloud was cut to the desired area.

![Figure 4. Registration of measured data in the FARO SCENE software environment](image)

The registration of measured data is the first step would be to create an information model. The creation of a 3D spatial model was realized using ALLPLAN 2020 software and support for modelling and measuring exported point clouds SCALYPSO MODELER. The work was performed by gradual processing of all scanned scenes and modelling of individual-focused parts of the building with their creation as separate 3D elements of building structures of which the focused building consists.

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5. Conclusions

The 3D scanner is an advanced technology that can be very useful in information modelling of buildings. This is especially true for historical points whose project documentation is missing or does not capture the facts.

The main conclusions of the study may be presented in a short Conclusions section, which may stand alone or form a subsection of a Discussion or Results and Discussion section. For architecture, historic buildings usually have rugged surfaces that are difficult to model. It is not easy to implement various architectural elements from given periods without a 3D model. 3D scanning allows you to create a 3D model that takes into account the facts. This is also an advantage for further work. There are several models for the distribution of balls and positions, according to which it is necessary to proceed in terms of effective work with the 3D scanner. The study confirmed the importance of the layout and position of the scanner and described the layout model for a given model situation for a given type of building and environment.

The case study also confirmed the assumption that the required output quality also plays a major role in addressing data processing time. The output in the form of a point cloud is suitable for further processing. In terms of further research after the implementation of this case study, there are several research questions and possibilities for further research. The research pointed out certain limitations and obstacles in using a 3D scanner. How much do these barriers affect the quality of research? Also in this context, it is possible to solve another research problem, how to shorten the scanning process under given conditions, look for new techniques and verify other layout models for a given type of building and environment. Another research problem that needs to be researched is focused on the type of
construction. It is possible to proceed according to the given scenario for other types of constructions. Respectively search for situations and models for different types of buildings and environments and then find a decision model that takes into account the type of building, the environment for the time of scanning, and the quality of the output.

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