The use of mixed reality in construction

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Abstract. This article describes Mixed Reality and its differences from Virtual and Augmented Reality. The article also deals with the concrete use of Mixed Reality in the construction industry, which is checking the conformity of the real building and the designed model. As part of the article, this method of use was actually used on the construction site. The work describes the procedure for using Mixed Reality to check the match between the real building and the model. Obstacles and problem areas that were discovered during use and will be subject to further research are also described in the article.

1 Introduction

"Construction 4.0" is a term used to describe the new generation of construction technologies and processes, also known as the fourth industrial revolution or Industry 4.0. It is a vision for a more efficient, sustainable, and innovative construction industry that enables the integration of advanced technologies [1]. Therefore, digitization plays a significant role in the construction industry, which helps with identifying, assessing, and mitigating risks while also improving project certainty [2]. Technologies that fall under Construction 4.0 include Building Information Modeling (BIM), 3D Printing, Internet of Things (IoT), Robotics and Automation, Virtual, Augmented and Mixed Reality, and Artificial Intelligence (AI).

Virtual, Augmented and Mixed Reality are elements of the construction 4.0 platform that help increase the level of digitization of the construction sector. VR, AR and MR offer excellent opportunities for architecture and construction through new approaches to Building Information Modeling (BIM). These technologies offer architecture and construction professionals the opportunity to personally experience the built environment in an immersive atmosphere and enable professionals to perform on-site visualization for construction planning and as-is verification [3]. Virtual reality is an interactive, computer-generated representation of a real or artificial world or activity [4]. A computer, smartphone, special headset or other display device can be used to view VR. Augmented reality essentially creates a digital window in which digital content is overlaid on the physical environment you're standing in. It can be said that Mixed Reality combines virtual and augmented reality. Only the headset is used for MR. In this case, the user is immersed in digital content but still aware of his physical surroundings, so he can interact with both physical and digital objects at the same time. VR, AR and MR can be use in stakeholder engagement, design support, design

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review, construction support, operations and management, training, but today estimated levels of adoption this technologies in construction in stage of testing or basic implementation [5].

2 Methodology

The use of mixed reality (MR) in construction has great potential and provides many opportunities for improving individual procedures and construction as a whole. In the framework of the article, the procedure of one of the ways of using MR was experimentally verified. Mixed reality was used to detect deviations of the BIM model from the real building and incorporate them into the model (transformation of the BIM model into a digital twin) for the purpose of its further use for facility management or other uses. The procedure of the experiment is shown in Fig. 1.

In the case study, building documentation in the form of a BIM model was used (1). The next step was pairing the model with the real building and looking for divisions between them (2). When a specific discrepancy is detected, a task must be created with a description of the discrepancy, photo documentation, etc. When creating a task, it is necessary to enter the responsible person or responsible persons. This procedure is repeated after each detected discrepancy (3). Next, the model is edited by the project participant who is responsible for the part in which the error was found (4). If necessary, the already repaired model is re-checked for compliance with the real building. The result is a digital twin of the building that can be used for facility management or other uses.

Fig. 1. Procedure of the experiment.

3 Using mixed reality to create a digital twin

The proposed procedure was used on the "C" building, which is part of the multifunctional complex "Popradská". An apartment building designed as a ten-story building with two underground and eight above-ground floors. The built-up area of the house is 1441.74 m². The procedure was repeated on a smaller part of the building - an apartment unit, the area of which is 87.44 m². BIM model of building was created in ArchiCAD.

3.1 Creating a project in a common data environment

A Common Data Environment (CDE) is a platform that allows project teams in the construction industry to share and manage project information from a central location. The CDE is used to store, manage, and share project data and documents throughout the project lifecycle. The purpose of a CDE is to provide a secure and structured platform for all project stakeholders to share, manage and collaborate on project information. The benefits of using a CDE include improved communication, reduced errors, faster decision making, and better project outcomes [6].

CDE from Trimble - Trimble Connect was used in this work. This software makes it possible to create projects and add to them various project documentation in the form of BIM models, drawings. text documents or other formats. Trimble allows you to add all project
participants to one workspace and divide them into groups. Groups are created by the user (CDE manager) himself, so there can be both standard construction participants and specific participants. As part of the experiment, a full-fledged working group was not created, because it did not affect the result of the experiment. The project group consisted of two participants. The first participant uses mixed reality in construction site and adds tasks when finding inaccuracies. The second participant represents all construction participants who can be represented on the project and to whom the first participant gives tasks, if inaccuracies are found. After adding participants, 3D models of the building and an apartment unit were uploaded to the project. The files were uploaded in IFC format. Any computer, phone or tablet can be used to reproduce the scope of the project. To display the volume in mixed reality, you need to use a headset. Trimble XR10 with HoloLens 2 was used as part of the experiment. They are distinguished from the usual model of HoloLens 2 by the presence of a helmet that ensures safety on the construction site. HoloLens 2 must have the Trimble MR app loaded to display mixed reality. Pairing the model with the building and searching for deviations

### 3.2 Alignment of the model and the real building

In order to compare the model with the real structure, they need to be combined. There are two ways to do this automatically. The first method is pairing using a QR code. For this, it is necessary to create a QR code in the Trimble Connect program and place it in the selected place on the model. The QR code on the model must be placed in such a place that can be accurately determined on real buildings, for example, the corner of a doorway. The QR code must be printed at the appropriate scale. Then it must be placed in the appropriate place on the building. After completing the preparatory steps, the model is imaged using Microsoft hololens 2 in the Trimble MR program. To combine the model and the real building, select the Align tab from the main menu and select the Marker tool. The program will open a tool for reading QR codes. It is necessary to scan the QR code that was previously placed in the appropriate place of the building. After that, the building is automatically aligned with the model. Next, it is necessary to check whether the comparison was accurate and if it was inaccurate, then manually correct it. To do this, select the Fine Tune tool in the Align tab. After that, a cube will appear with which you can move or rotate the model.

The second method of automatic matching does not require preliminary preparation. The Plan tool located on the Align tab is responsible for the second method. After activating which method, must be to selected two vertical structures that are not parallel on the real building and their corresponding structures on the model. The floor level can also be matched automatically or it is possible to match it in the same way (select a horizontal structure in the real building and the corresponding structure on the model). Next, it is necessary to check whether the comparison was accurate and if it was inaccurate, then manually correct it as described above.

Then there is a comparison of the model and the real building. Mixed reality allows to simultaneously see structures in the form in which they were designed and in the form in which they actually exist.

### 3.3 Adding a task to remove the deviation

After all preparatory processes are completed, a visual comparison is made to control accuracy and find inaccuracies. If these inaccuracies exist, the software enables their measurement. An example of measuring inaccuracy can be seen in Figure 2.
The next step is to create a task to eliminate the problem. To do this, select the "To do" tab and the "Create To do" function in the main menu. This tool allows you to create a task that will be placed in a specific location of the model. In addition, the task can be supplemented with a description of the problem, a mixed reality image that shows the real building and the model (with dimensions between them if necessary), and the responsible participant or participants of the project. Also, each task has its own priority (low, normal, high, critical). In Figure 3, you can see an example of creating a task.
3.4 Editing and other operations with the model

After creating a task, the person responsible for its execution receives a notification about the creation of the task. In the application environment, the responsible person can see all the properties and attached files of this task, and its specific placement in the model. A comment can be added to the task, and the percentage of its completion can be marked. After making changes (if needed), it is marked as closed.

![Fig. 4. Display of the task in Trimble Connect. (1 - task list, 2 - display of the task in model, 3 - added mixed reality photo, 4 - close task button, 5 - task details).](image)

3.5 Summary of results and future research

The experiment described in this study was conducted twice. In the first case, the model of the entire building was used, and in the second, the model of a residential unit (apartment), which is part of this building. This was done to better define the problem areas and shortcomings of the described method. During the course of the study, several shortcomings were identified, including:

- insufficient accuracy of alignment of the model and the real building,
- too large a step of manually adjusting the placement of the model,
- inaccuracies in displaying a larger model.

During the research, methods of connecting the model and the real structure were used. Each method was used on both models. In each of the cases, the combination of the model and the building was not perfect and sufficiently accurate. To solve this problem, it was necessary to manually adjust the position of the model in real space. The following problem was detected when manually moving the model: the step of manually adjusting the placement of the model is too large. The minimum step by which it is possible to move the model in real space is 5 cm. In some cases, this distance is too large to precisely adjust the position of the model in space. This makes it impossible to accurately compare the real building and the model.

The next drawback was found when comparing the work with the larger and smaller model. When working with a larger model, it was found that the model is not displayed correctly in each part of the structure. After the model was automatically matched to the building, the position of the model was manually adjusted. For manual adjustment of the position, a point on the border of the door opening was selected. It was found that the position of structures located further from this point is not displayed correctly. To solve the problem, the automatic combination was performed several more times. For each of them, different
points were selected for manual adjustment of the model's position. The model is still displayed incorrectly. Next, the actual dimensions of the structures were checked for compliance with the projected dimensions. The check showed that the projected dimensions fully correspond to the real ones. No similar problems were found when displaying the smaller model. From this, it was concluded that the size of the model affects the correctness of its display. Another reason for incorrect display of the model can be problems when converting the model from one format to another. The model created in Archicad was converted to IFC format for playback in Trimble Connect. Incorrect display of the model could be caused by conversion to the IFC format.

Further research will be aimed at identifying the reason for the incorrect display of the model in real space. It is necessary to determine whether the reason for the incorrect display is the problem during conversion, or whether there is a limitation in the size of the model that can be displayed correctly.

**Conclusion**

Construction 4.0 brought new digital technologies, including mixed reality. This technology has many advantages. With the use of mixed reality, customers can be involved in the design process of projects and thus can visualize the result earlier. Mixed reality makes it possible to test different design options and their effects on a future project. The use of mixed reality in construction helps to minimize errors and disagreements during planning and construction. As part of the work, the possibility of using mixed reality to check the accuracy of the construction was tested. This option can be used either to modify the model after the construction is finished for the purpose of its further use, for example in Facility Management, or to check the accuracy of the structure during construction. When using mixed reality, it was found that behind this theory there are shortcomings that must be resolved before using this technology in practice. Future research will be connected with solving these problems.

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**References**