



# APPLICATION OF 3D SCANNING FOR THE CREATION OF 3D MODELS SUITABLE FOR IMMERSIVE VIRTUAL REALITY

Marián Matys, Martin Krajčovič, Gabriela Gabajová

*Department of Industrial Engineering, Faculty of Mechanical Engineering, University of Zilina, Zilina, Slovakia*

**Corresponding author:**

*Marian Matys*

*Department of Industrial Engineering*

*Faculty of Mechanical Engineering*

*University of Zilina*

*Univerzitna 1, 010 26, Zilina, Slovakia*

*phone: (+421) 41 513 2740*

*e-mail: marian.matys@fstroj.uniza.sk*

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**ABSTRACT**

Finding a suitable method of 3D model creation for a specific task is becoming more important with the rapid spread of digitalization. This paper deals with the use of 3D scanning as a method of creating 3D models for immersive virtual reality applications. A methodology is presented that covers all the steps, from initial object selection to importing a scanned 3D model into a virtual reality environment. Various objects were selected and scanned to test this methodology and its utilization potential. Finally, the paper evaluates the potential utilization of this methodology for immersive virtual reality applications for education and various methods of industrial engineering.

**KEYWORDS**

3D scanning, 3D model, virtual reality, immersive virtual environment.

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## 1. Introduction

The rapid advance of virtual reality technology allows a complex interactive simulation of processes in various companies [1, 3]. A correct application of this technology brings a vast potential for the improvement of a wide range of processes [2, 9, 10]. This represents a powerful tool for various industrial engineering applications [11]. However, creating such a virtual environment requires a library of 3D models that match the real disposition [4]. On top of that, 3D models used in the immersive virtual environment must meet specific criteria to ensure a smooth immersive virtual reality experience. This paper deals with 3D scanning as a method for creating 3D models that are compatible with an immersive virtual environment. 3D scanning represents a method of reverse engineering along with technologies such as photogrammetry [8]. Various objects are scanned using the available scanner, additionally modified in a 3D modelling software and then imported and tested in an immersive virtual reality environment. Creating 3D models using conventional 3D modelling methods (in a 3D modelling software) may be significantly time-consuming depending on the complexity of the object and the experience of the user. In the case of building a large virtual environment for various design or optimization processes, the acquisition of the model library itself may represent a significant portion of the workload. Therefore, it is important to seek new approaches for this task [5].

## 2. Methodology

The presented methodology covers the process of 3D model creation using a 3D scanner and following adjustments so that the 3D model can be imported and used in an immersive virtual environment. An immersive virtual environment represents a type of virtual reality (VR) that provides a fully immersive experience using a virtual reality headset (such as HTC Vive). A characteristic trait of this environment is higher performance requirements compared to the ordinary 3D PC application. On top of that, to ensure a smooth virtual reality experience, the VR application needs to be rendered at a stable and sufficient framerate to avoid the risk of motion sickness for users. Therefore, the complexity of 3D models needs to be regulated to reduce their impact on overall performance. The final part of the methodology deals with this problem and tries to reduce 3D models' impact on performance while preserving their details. The entire workflow is illustrated by a flow chart that is shown in Fig. 1.

The methodology consists of three main parts. The initial phase that deals with pre-scanning preparation, the scanning phase itself, and the post-processing phase that deals with all 3D model modifications after scanning. The scanning process may vary depending on the type of 3D scanner, however, the principle should remain the same and all specifics should be included in a manual enclosed with a 3D scan. The third part of the methodology utilizes 3D modelling software to sim-

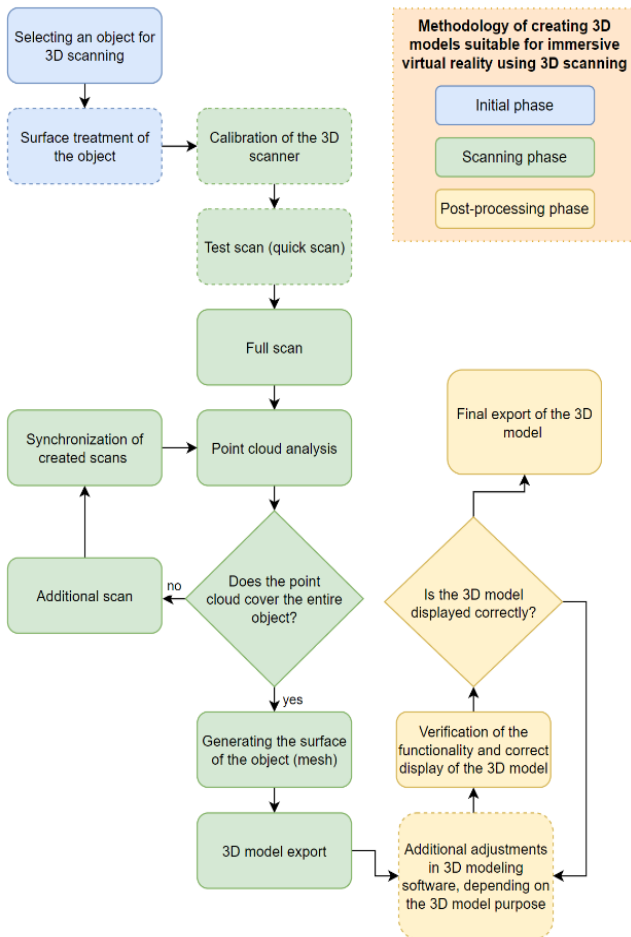


Fig. 1. Presented methodology (authors).

plify created 3D model and remove all imperfections to ensure that it can be imported into the software for immersive virtual environment creation (i.e., game engine Unity 3D).

### 2.1. Initial phase

The initial phase consists of selecting an object for 3D scanning and optional surface treatment of the chosen object. If an object contains too many transparent or highly reflective surfaces, it may cause issues and imperfections during the scanning phase. The suitability of an object for 3D scanning may be difficult to decide, therefore, it is good practice to test various objects with various parameters to determine the limits of the owned 3D scanner. Removing the stains or any other surface imperfections may help, additionally, treating the surface with an anti-reflective substance can also be helpful if an object seems too reflective.

To test the methodology, various objects were chosen for 3D scanning on the available 3D scanner, for example:

- lathe knife – angular and metallic object,
- small containers – plastic and hollow objects,
- rubber duck figurine – not an angular object with smooth edges.

The main goal is to test various objects and set limits for the available scanner. The high versatility of 3D

scanning means the high potential for utilization, such as the digitalization of machine tools equipment (lathe knife) or 3D simulation of material flow and transport in between manufacturing processes (crates and containers). With subjects of 3D scanning selected, the 3D scanning phase may begin.

### 2.2. Calibration and a test scan

Before the scanning itself, it is important to make sure that the 3D scanner is calibrated. This process may vary depending on the type of scanner and should be explained in the scanner's manual. The presented methodology uses a desktop 3D scanner Matter and Form, which has a simple calibration process using a calibration card [6, 7], as shown in Fig. 2.



Fig. 2. Used 3D scanner and its calibration process (authors).

After the calibration process, a user may run one or several test scans. They represent quick scans with low-quality 3D model parameters, some 3D scanners may also include quick scan as a separate scan option. Test scans may help a user determine if a selected object can be created using 3D scanning with sufficient quality. In the case of our selected scanner, these quick scans did not take longer than 15 minutes. The smaller imperfections may be fixed with a full-scale scan, however, in the case of bigger issues, a selected object may not be suitable for scanning. With an optional test scan completed, a user may proceed to the full scan. A full scan can take up to several hours, therefore, it is a great practice to do a test scan and save time in the case of major problems with a selected object.

### 2.3. A full scan and a point cloud analysis

With objects selected and tested, a user may now run a full scan. 3D scanners usually run with their scanning software where users can determine various parameters, such as final 3D model quality (density of geometry) or scanning range. Lighting conditions are also important. Objects should not be illuminated by direct light (such as a lamp), while natural light is preferred. It is vital not to move the object during scanning and place it in the correct spot. Figure 3 shows a scanning process of various objects.



Fig. 3. Scanning process (authors).

The scanning process will generate a point cloud inside the scanning software (Fig. 4). These points define the shape of the 3D model. However, it is common that 3D scanners will also capture parts of the surroundings, mainly the surface of the scanning table. These excessive points need to be removed, either directly in the scanning software (if selected 3D scan allows that) or additionally in post-processing (removing excess geometry in 3D modelling software)

It is important to analyse the generated point cloud after its completion. In some cases, there may be a significant absence of the points in some parts of the scanned objects. These parts may not be reconstructed properly during the mesh generation (mesh defines the

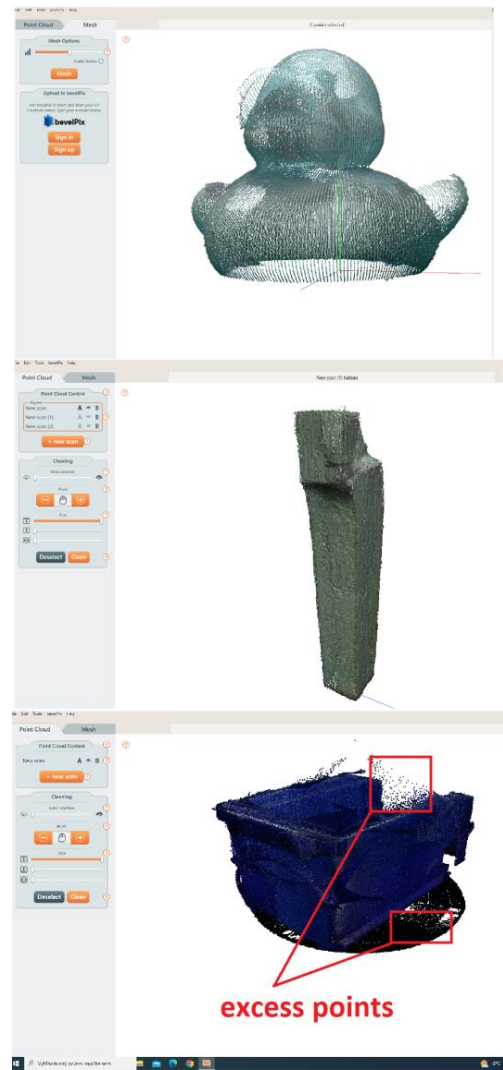


Fig. 4. Generated point clouds (authors).

shape of a 3D object) and the 3D model may miss some parts or details. In those cases, the 3D scanning process may be repeated to generate a new point cloud. This new point cloud may then be merged with the previous one to fix potential imperfections. This process may be repeated several times until the results are satisfying.

### 2.4. Mesh creation and 3D model export

With a successfully generated point cloud, scanning software may generate the 3D model itself. Once again, some parameters can be changed to affect the final look of the 3D model, such as mesh density or application of captured object texture. These settings may vary depending on the type of 3D scanner and its software, but a vital part is the density of the generated mesh. Since the purpose of these scanned objects is to be used in an immersive virtual environment, it is important to consider the performance limitations. Therefore, the density of generated mesh should be lowered as much as possible without significantly affecting the model's details. This will ensure a better performance for VR applications, but it may still not be enough. For that reason, the next step in the methodology is the post-

processing phase. Figure 5 shows an example of generated 3D model (mesh).

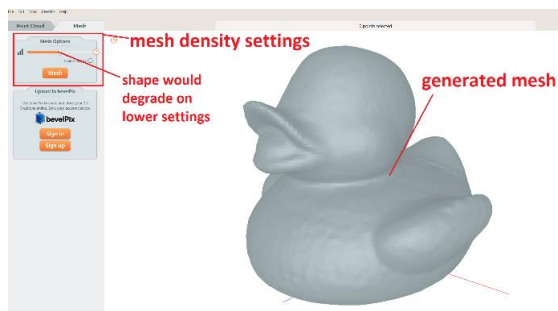


Fig. 5. Mesh generation example (authors).

## 2.5. Post-processing and final export

Even after lowering the mesh density settings, created 3D models would be too detailed for comfortable use in an immersive VR environment. Therefore, the next step is to export the model to the 3D modelling software for additional changes. The software used for this task is Blender. All scanned objects (their created 3D models) were imported into this software and modified. Firstly, a “decimate modifier” was used to lower the number of vertices for each model. This modifier simplifies the model by the chosen percentage by the user (lowers a mesh density). The density of vertices for each model were lowered as much as possible without affecting the shape. For all models, the density of vertices (mesh) was lower by around 70-95%. With even more cuts, the 3D models started to slowly lose their definition. For example, the number of vertices for the small container model was lowered from around 193 000 vertices to roughly 10 000. The usage of this modifier is very simple and suitable even for a beginner. Additionally, there was also some excessive geometry left that was not removed from the point cloud before. These extra parts can be easily selected in 3D modelling software and removed.

The second modification was the use of the 3D modelling method – sculpting. This was used to straighten the bumpy parts of 3D models that are smooth on the real object. This is mainly important for angular shapes with defined edges. This method is more complicated as compared to using the modifier and is recommended for a more experienced user. Examples of post-processing are shown in Fig. 6.

After finishing the post-processing process, 3D models can be then imported into the software for the creation of a virtual environment, such as the Unity 3D game engine. Figure 7 shows the 3D models imported and tested in an immersive virtual environment created in Unity 3D.

All 3D models were successfully imported into the virtual environment and were displayed correctly. There were some small imperfections, and some models required a heavier modification but all models were usable in the immersive virtual environment.

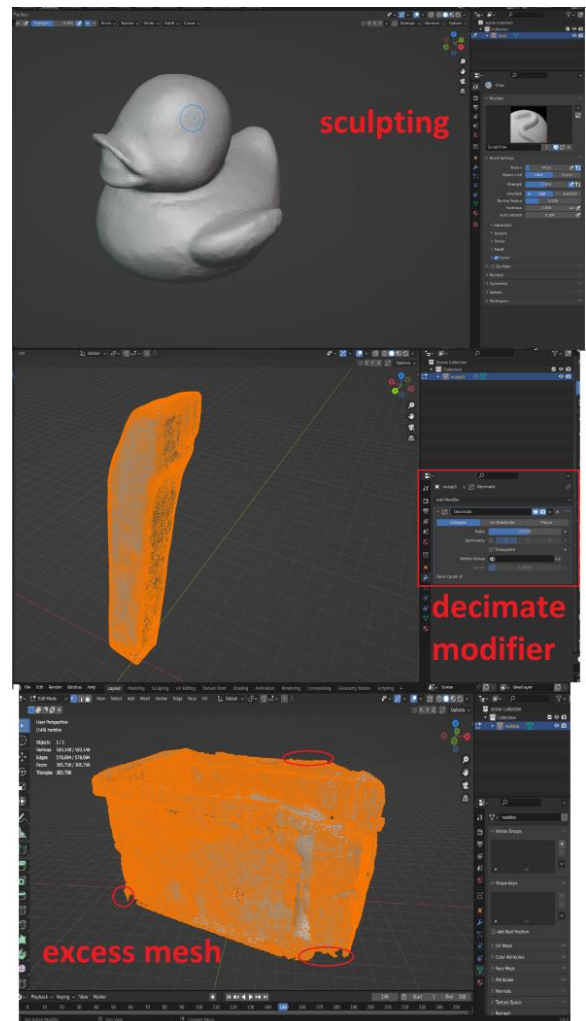


Fig. 6. Post-processing (authors).

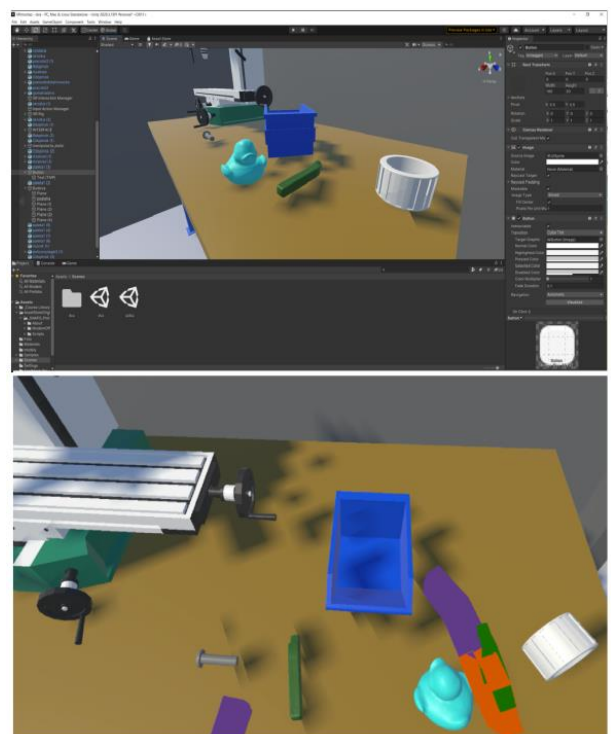


Fig. 7. Scanned 3D models in a virtual environment (authors).

### 3. Application in the immersive virtual environment

The methodology proved to be useful to create 3D models for the creation of an immersive virtual environment. The question is if the same principle can be applied to create the 3D models for various immersive virtual reality applications, such as virtual training (to generate the 3D models of required objects and import them to the virtual environment of the application). The methodology can be applied to any object that needs to be digitized to create an exact copy of the selected room (for example a workplace). However, some conditions need to be met:

- size of the object – 3D scanner needs to be capable of scanning objects of the chosen size,
- object's surface – the amount of highly reflective and transparent surfaces should be minimized,
- inner parts of the object – 3D scanner may be unable to scan the parts hidden underneath the surface,
- availability of the object – for example, a transport vehicle may be in constant use and its suspension for a few hours to be scanned can have an economic impact.

The 3D scanner used to test the methodology is a small desktop scanner with a limited maximum size of a scanned object. However, the methodology can be applied with the use of a different kind of scanner, such as a handheld scanner. With increased size limits of the scanned object, the 3D scanning method potential becomes much higher and can be applied to larger objects (such as smaller vehicles). Shape complexity and surface of the objects also needs to be considered. Some surfaces may be difficult to scan (transparent and reflective) or the shape of the object may make some parts difficult or impossible to scan. Therefore, it is important to consider, if the selected object is suitable for the 3D scanning method. While every object can be tested with a trial 3D scan, there may be an object that cannot be made static for several hours, when results are not guaranteed.

The 3D scanning method can be useful for the creation of 3D models for various objects while reducing the 3D modelling requirements and yet bringing satisfying results (assuming the selected object is suitable for 3D scanning). For example, the 3D models of machines or vehicles (Fig. 8) may be complex and time-demanding when using conventional 3D modelling methods to create them. It is important to find the most optimal way to integrate virtual reality applications and all their sub-processes (e.g., 3D model creation) into the industrial engineering process or education.

These processes often require a quick way to create a precise virtual copy of the object that can be used in various simulation or design processes. The 3D scanning technology has the potential to be useful in this regard.

The creation of virtual training is a long and complex process while the creation of required 3D models

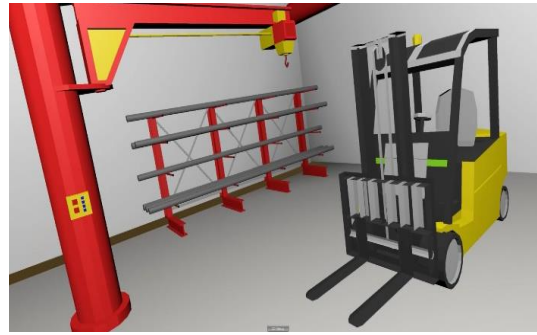


Fig. 8. A 3D model of a forklift in a virtual environment (authors).

may be one of the most time-consuming parts. Virtual training simulates a real process, which means a virtual environment must reflect the real place (a workplace), where the subject of virtual training takes place. Therefore, all necessary objects must be digitized into 3D models to create such an environment. Utilization of 3D scanning can be used to reduce the time required for this task. 3D models can be created with minimal involvement of a person, while they can work on other parts of virtual training creation. Figure 9 shows an example of virtual training creation using the game engine Unity 3D.

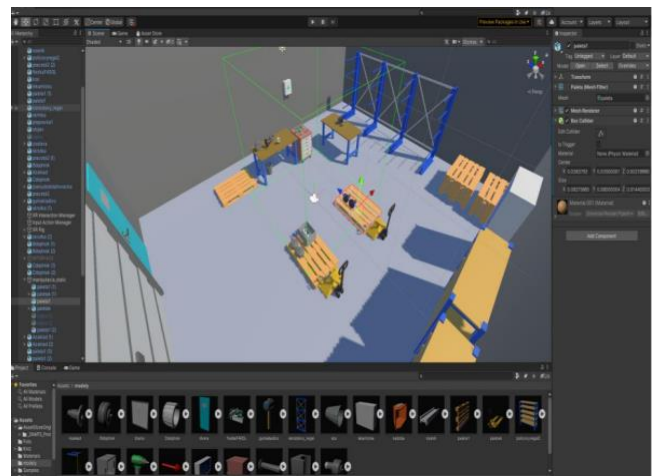


Fig. 9. Virtual training creation (authors).

In this case, 3D scanning was used only for the creation of small 3D models (due to size restrictions of available 3D scanners). The rest of the models were created using a conventional method, that is using the 3D modelling software Blender. However, mixing multiple methods of 3D modelling is also a viable option. Some objects may be easier to scan but some may be difficult to scan properly (such as highly reflective surfaces or windows). Figure 10 shows a preview of the created virtual training (assembly process training).

It is also important to take 3D models' complexity into account. Immersive virtual environments are generally demanding and require a powerful computer to run. A smooth experience is vital for virtual training since stuttering may increase the change of motion sickness

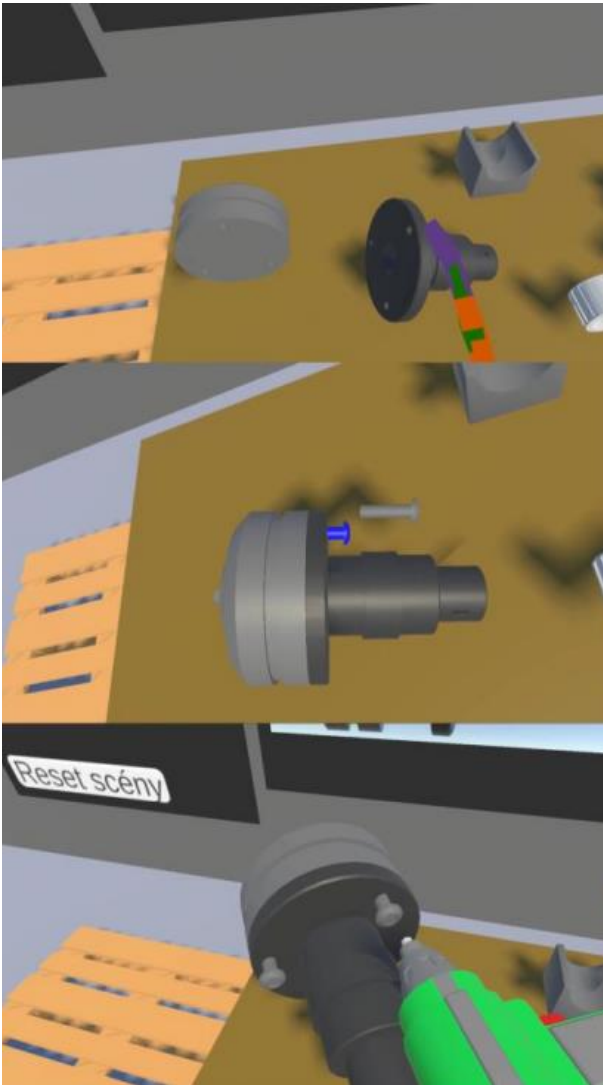


Fig. 10. Virtual training (authors).

for the user. This would also decrease the overall quality of the training and the chance of knowledge transfer from the virtual world into a real workplace. 3D models generated by a 3D scanner are relatively complex, which may cause issues if too many of them are used in one scene. There, they can be simplified using any 3D modelling software (or this problem can be avoided by a smart scene design). If scanned 3D models will be used in a specific interaction, it may be necessary to split them into parts. For example, scanned objects have a control panel with buttons. These buttons need to be separated into standalone objects so they can be pressed for a specific function. Using the conventional method, these buttons can be created as separate objects from the start, however, in the case of 3D scanning, a post-processing phase is often required.

#### 4. Conclusions

In conclusion, the market is filled with high-quality software capable of fulfilling various demands in various spheres. The five presented solutions are just the tip of

the iceberg, but the majority of users would find one of these satisfactory for their projects. However, users are encouraged to explore the market to search for the ideal option matching their requirements. Moreover, both objective and subjective factors need to be considered to reach a balanced evaluation between quantifiable parameters and user preferences. In the end, it all depends on the expectations of an institution or an individual set to satisfy all requirements determined in search of an ideal software solution. In conclusion, 3D scanning is a viable method of creating 3D for the immersive virtual environment. This method can be used on various objects, however, the object's suitability for 3D scanning needs to be considered. The paper describes a process of creating various objects using 3D scanning, making additional modifications to them, and then importing them into an immersive virtual environment. Every selected object was successfully digitalized and displayed properly in virtual reality. However, even after post-processing, the mesh density (object complexity) was relatively high. If too many of these objects were used in one virtual room, performance issues may appear depending on the available computing power. Nevertheless, 3D scanning as a method can be a good addition to the creation of 3D model libraries for immersive virtual reality applications such as virtual training.

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