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Immersive Spatial Planning in Healthcare: Developing a Pipeline to Automatically Convert Computer Aided DesignData to Virtual Reality

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Abstract. Equipping rooms used for medical purposes, like e.g., intensive care units, is an expensive and time-consuming task. In order to avoid extensive subsequent adjustments due to inappropriate layout visualization or geometric conditions difficult to identify in 2D plans, it is of utmost importance to provide an optimal planning environment to future users such as physicians and nurses. In this paper we present the concept of a fully automatized pipeline, which is designed to visualize computer aided design (CAD) data using virtual reality (VR). The immersive VR experience results in improvement of efficiency in the decision-making process during the planning phase due to better spatial imagination. The pipeline was successfully tested with CAD data from existing Intensive Care Units. The results indicate that the pipeline can be a valuable tool in the field of spatial planning in healthcare, due to simple usage and fast conversion of CAD data. The next step will be the development of a plugin for CAD tools to allow for interactions with the CAD models in Virtual Reality, which is not yet possible without manual intervention.

Keywords. Virtual Reality, Hospital Planning, Computer Aided Design, Automation

1. Introduction

The main objective of this paper is to increase transparency and imagination of the spatial planning process of medically used rooms, i.e. Intensive Care Units (ICU) or operating rooms, by medical professionals such as doctors and nurses who need to work efficiently in these environments to improve patients' healthcare status and save lives in emergency cases. To accomplish this, spatial planners or architects create 2D plans and 3D models of the desired rooms, or even entire buildings, based on various metrics [1]. An important problem which often occurs to customers of spatial planners is the lack of imagination and spatial understanding. To imagine how a space fitted with real medical equipment will look like and more importantly feel like, when standing inside, might therefore be a hard task to accomplish for medical staff.

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Virtual Reality (VR) systems are developed to give the impression of being physically present inside a virtual world and it can be expected that VR approaches support the previously described needs of medical staff and improve the planning processes. This kind of immersion offered solely by VR is currently used successfully in the field of medicine [2], [3].

Han et. al. focus on computer aided design (CAD) data conversion for VR in ship and offshore construction and present a whole framework, which enables users even to change file formats [4]. Lorenz et. al. focus on integrating a pipeline for converting kinematic CAD models to VR [5]. They developed a workflow to be independent of CAD and VR system, delivering flexibility while also automating model complexity reduction, animation and kinematic mechanism adoption. However, the proposed approaches for CAD to VR systems within the literature contain complex operations, which result in high efforts with low flexibility and adaptability to specific situations.

In contrast to common 3D based interior planning, the processes taking place in the planned rooms are put into focus (supporting efficiency of medical workflow), instead of changing material-design or surfaces (i.e., kitchen). The addressed challenges are to decrease decisions which cause misplannings and potential consecutive remodeling of the constructed rooms. Such changes are linked to high financial burden and impact on the time schedule of construction.

Therefore, the objective of the new pipeline, presented in this paper, was to provide a quick way to integrate changes in the CAD data in VR through an automated process, supporting for immersive and transparent planning process for the user (medical professionals).

2. Methods

In order to create the proposed pipeline only already established tools and files formats were used. The tools used for this study are Unity 3D for rendering and Blender 3D for automatic corrections and file conversion. The used file formats are fbx and gltf. To convert gltf files into objects usable within Unity, the gltf converter from Khronos Group was used. The user interface for selecting files and starting the process was written in Python. The prototype was tested on an Oculus Quest 2.

The initial step for displaying a CAD model in VR is to obtain the CAD data in a form the pipeline can work with. Most CAD software is capable of exporting created content in widely used 3D file formats like obj, fbx or cada. Therefore, the starting point of the pipeline is a file containing the created content in one of the formats above. For the VR app being able to render the data, the exported CAD software file is converted into a gltf file by the Blender 3D software. The gltf standard fulfills all the requirements and was therefore the choice for the pipeline.

Blender 3D is a free to use 3D computer graphics software which is capable of importing and exporting all common 3D file formats and therefore can be used to convert files. In addition, Blender 3D can run headless and python scripts can be passed into Blender 3D while running headlessly. This offers the possibility to write a python script for the conversion as well as to apply automated corrections to the 3D model. In order to make the files accessible to the VR app, the design of the system includes a server which saves the files coming from the CAD software. The whole process is shown in Figure 1.

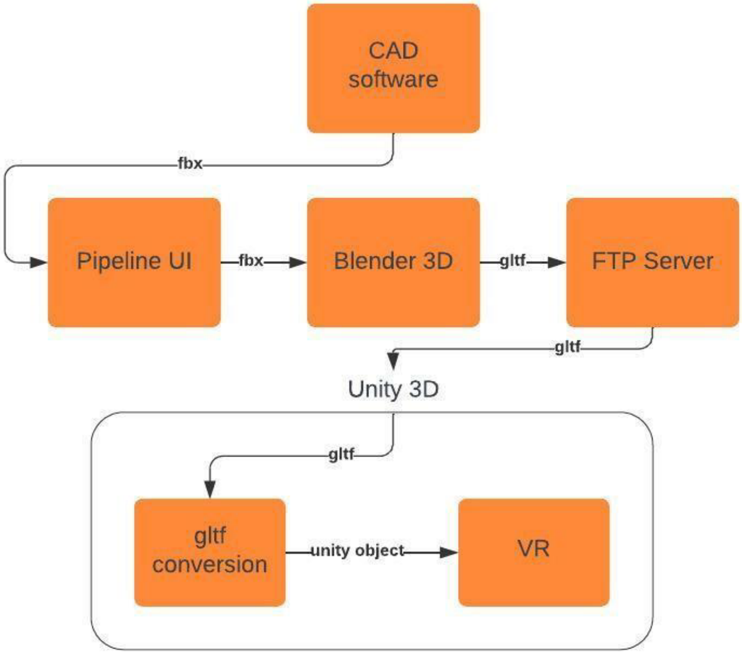

Figure 1. Schema of the developed pipeline

A first testing phase with 3 planning professionals from the partner company GSM Medizintechnik GmbH was conducted to evaluate the performance of the pipeline, under live usage by 5 medical professionals (3 doctors, 2 nurses) in one partner hospital. The goal was to identify the acceptance and usability of the automated virtual planning process with the pipeline integrated. The measure for usability was the System Usability Scale (SUS) Score, including 5 positive and 5 negative questions and a result per test person between 0 and 100. 3D models created with ArchiCAD for successfully completed projects were exported in the fbx file format and fed into the pipeline by using the provided user interface. The files were a mix between fully modelled rooms including medical equipment and single medical devices.

3. Results

The current result of this project is a working pipeline between CAD software and the VR environment. The medical professionals testing the application emphasized on the increased transparent planning process through the application. Especially the possibility to quickly (within seconds) integrate change requests in a live presentation setup, enabled through the pipeline, were highlighted. The resulting SUS Score was 84.44.

Exported CAD files can be processed and displayed as virtual 3D models. For testing purposes, the pipeline was set to work with fbx files. A user interface allows the user to select 3D files and start the conversion process. Within the pipeline, Blender 3D (headless mode) applies corrections, like recalculating normals. This might be necessary in case of user error during modelling, resulting in rendering of both front and back faces within the CAD software, and corresponding incorrect normals of the model. After this correction process, the model is exported in gltf file format and uploaded to a ftp server. The Unity 3D app listens to changes on the server and downloads the new gltf files. Finally, the gltf file is converted into a unity object by the gltf converter and rendered as shown in Figure 2.

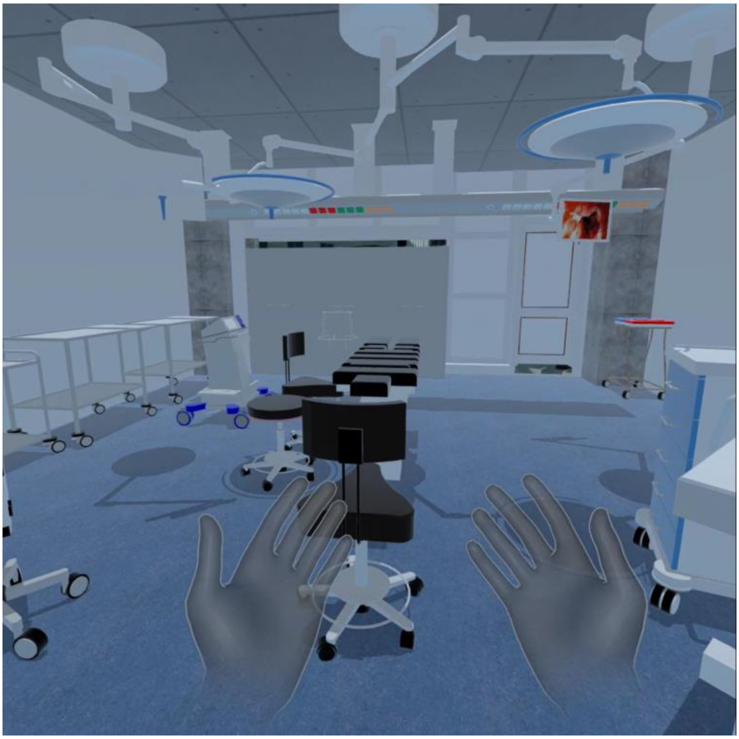

Figure 2. Model of an operation room loaded via the pipeline

Summing up, the pipeline is able to successfully convert and display CAD models in virtual reality. The testing phase was performed with selected planning professionals. Some of the problems encountered during this testing phase were fixed by small changes in the process and adjustment of settings, e.g., artifacts, flickering due to z-fighting and inconsistent texturing. Unintentionally transparent objects were fixed by adjusting some of the shader properties:

- _ZWrite = 1
- _DstBlend = 0
- _SrcBlend = 1
- _SrcBlend = 1

- RenderQueue = 2000

Concerning issues due to overlapping geometry, this needs to be addressed by the 3D designer and therefore fixed within the CAD software.

4. Discussion

The field of research related to conversion of CAD models for VR has become more popular in the last few years [6], [7], [8]. Currently the state of the art in medical room planning, is based on printed 2D representations. Additionally, visualization approaches include 3D rendered representations. Although there are other papers in the field of converting CAD data for usage in VR apps, none of these proposed a simple, fully automated pipeline, created with only readily available tools for use in the medical sector.

The main goal was to offer an automated solution for transferring geometric data from CAD software to a 3D model in VR. The added value compared to other available approaches is besides its simplicity and usability also the consideration of requirements within the medical domain.

However, the proposed solution is currently a first prototype, still entailing high potential for improvements and more advanced extensions, also meeting more specific requirements of medical professionals and room planners. Currently the accepted CAD file format is limited to fbx. Future versions will include further formats as for example obj and cada. Some of the already mentioned conversion issues, like unintentionally transparent objects, have already been solved. Others may need higher-level support from software designers. While no performance problems with the Oculus Quest 2 have been experienced so far within the first testing phase due to the models not being heavily complex, loading entire buildings could still lead to performance issues in the future. To reduce the polygon count of models and therefore improve performance, again the Blender 3D, which is already part of the pipeline, could be used. The decimate modifier implemented in Blender 3D allows to reduce the vertex/face count of a mesh with minimal shape changes and therefore can be easily integrated into the workflow.

The next steps will include the creation of a plugin for a widely used CAD tool like ArchiCAD to further improve the usability of the pipeline by letting the user directly start the process within the CAD software. This step also includes the availability of interaction with objects in the VR room, which has not been implemented so far. The user of the CAD software would therefore be presented with a user interface for naming objects in a specific way so the VR application can then automatically add Scripts according to the naming of the objects. As example, a name "rotatable_X_Axis_360" would lead to an object being rotatable by 360 degrees around the x axis.

Alternatively, a configurator could be implemented, which lets the user select objects from an already established list and build a room by dragging and dropping those objects into the room. This results in exceptionally fast room creation due to not having to create the objects. However, it restricts the user to the available objects. Especially in the medical field, a large variety of medical devices from different manufacturers are in use. By long-term use and continuous addition of objects to the configurator a large assortment for medical room planning could be made available. This would also allow medical professionals to create their own room with the familiar equipment and to meet their requirements.

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