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Efficient Use of Mixed Reality for BIM system using Microsoft HoloLens

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Abstract: Recently, a new independent concept used to classify the spectrum of reality technologies, as referenced in the reality virtuality continuum is MR of Mixed Reality. As an independent concept, MR mixes the best of both Virtual Reality (VR) and Augmented Reality (AR) int the same environment for the user's gaze. It covers essentially of all possible variations and compositions of real and virtual objects. Which is the result of blending the digital world and the physical world together, brings new advancements and challenges to human, computer and environment interactions. Thus, they offer potential for acquiring at least coarse point clouds and meshes of single rooms or even complete building structures that can be used in the context of building information modelling (BIM) in the future instead of manually modelling existing buildings based on 2D floor plans or manual measurements with laser scanners or computationally expensive image based 3D reconstruction techniques. In this paper, we proposed an efficient usage of MR techniques to manage the items of furniture of rooms using Microsoft HoloLens to create a BIM system. Therefore, we succeeded to map the occupied and unoccupied spaces of the rooms using the method of spatial mapping in 3D. In this case, we can add the items of furniture for each room in the order we choose in respecting its original organization. One hand, our BIM system allows moving the furniture from one side to the other side in real time. In the other hand, we applied the flexibility to rotate and to resize all items of furniture of our BIM system.

Keywords: Building Information Modelling, Microsoft HoloLens, 3D, Virtual Reality, Augmented Reality, Mixed Reality .

1. INTRODUCTION

Virtual Reality (VR) is a generated environment using a special device to simulate a virtual world instead of real world presence. The user wears a headset and through specialized software and sensors is immersed in 360 degree views of simulated worlds, see Noor (2016). Augmented Reality (AR) links the physical environment with the device generated environment such as sound, video, graphics, or other useful information essentially overlaying digital information on top of the physical world. AR is a technology that uses sensors either on the device to locate and orientate a camera in a 3D computer generated scene. The scene is then superimposed over the image captured through a device camera thus merging the real world and computer generated scene on the device display. This creates the illusion that, the 3D objects are present in the real world through the device display. Thereafter, as AR tracks the location and orientation of the camera, users wearing the device could manipulate the objects freely in the environment. This feature allows users to better understand the location, and the orientation of 3D objects. The items superimposed can also contain textual information about objects and their properties, see Cyrus et al. (2019b).

Mixed Reality (MR) attempts to combine aspects of both VR and AR. Through merging the real and virtual worlds, new environments and visualizations are generated where physical and digital objects coexist and interact in real time. The virtual objects are anchored to be adjusted points by the user in real space.

AR and MR have recently become easily accessible to a range of professional applications due to the release of the developer edition of Microsoft's HoloLens in April 2016. Some AR platforms, and the underlying concepts, have been around for many years (as have related VR technologies) but HoloLens represents a significant technological step, and a great opportunity for many professionals to incorporate the head mounted AR into their projects, see Moropoulou et al. (2019). As many new technologies, the core application is to use it for MR, and for the hardware development, see Cyrus et al. (2019a). Where Augmented and Mixed reality present exclusively a 3D visualization environment which can combine between the existing real world objects with computer generated objects. In this spirit, we detail in this work a sample of MR application for BIM system using Microsoft HoloLens. Since BIM is a set of 3D geometric objects defined by a property and relationship database, these models contain all the necessary information to be applied to MR and more. In BIM

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system, users can show a realistic perspective of the objects in the scene by superimposing a scaled 3D building model over the camera image, which they can use it as a base to evaluate and to perform tasks accordingly. Since users want to interact with the adequate environment by adding some parts, zooming on others, building perspectives, they are able to manage overall virtual environment objects on real world scale. Some currently available programs like BIM Holoview and Furnie also offer for BIM concepts, but their deficiency is mostly about interaction of real and virtual world.

The main contribution of this work that we considering a spatial mapping manipulation to created a BIM system, based on MR technology by the Microsoft HoloLens device, to make items of furniture (TV, sofa, table ...) interactive with the real environment and flexible for moving, rotation and resizing on each place. The interactivity relation between the items and the real environment is due to the spatial mapping step that we have applying at first to sweep all building area which will be used for the BIM system. We have adopted in these items the manner of being sensitive to move, to resize and to rotate it using the HoloToolkit library of Microsoft. The paper is organized as follows: first, explain and demonstrate the BIM theory and its relation with MR applications. Next, we describe the spatial mapping step to cover each location of the real environment of BIM system. Then, we show the result and the discuss of our BIM construction. After, the conclusions and an outlook on future work is given.

2. BUILDING INFORMATION MODELLING

The main process of BIM is to create a well defined conceptual models of the buildings, geometric properties, structural elements, and all the architectural details. In the field of architecture, engineering, and construction industry, BIM is being the most important step to start the project, because it enables the 3D visualization of a building (see Fig.1), before construction has even begun. It seems interesting to visualize the final product from the customers in the early stages, which can reduce the time and the cost to replan.

Otherwise, the BIM systems can be used as building blueprints and describe each instruction for a project stakeholder. As an example, Interior decorator is able to view the model and determine the locations of each partial objects to be installed and can plan its work accordingly. However, most scenarios are limited to either viewing on complex BIM software or printing to 2D shop drawing. To not complicated or congested the scene and it can create a detrimental confusion to the project, MR can further improve the visualization for work in the field, presentation, and overall clarity of the project.

BIM is more than a simple canvas to capture information about a building, it is a methodology for information sharing and communication between all stakeholders at all stages of the building life cycle. One central component of this methodology is the parametric 3D model of the building, see Murali et al. (2017). This model allows stakeholders to save information at the object level and describe dependency relation between them to help future modification. For instance, if a window is defined as being

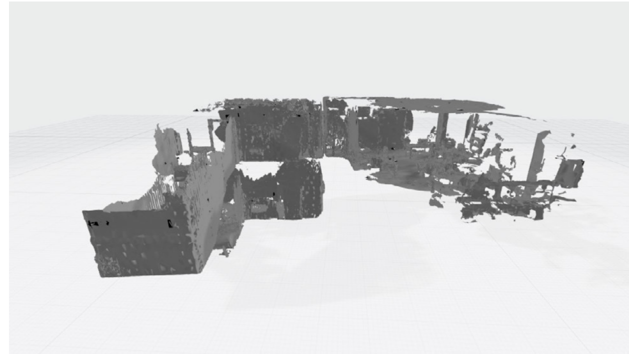

Fig. 1. BIM: building description using HoloLens

Fig. 2. BIM-based Mixed Reality application for HVAC (heating, ventilation, and air conditioning) system using HoloLens

on the center of the wall, any modification to the wall will also reposition the window.

Future BIM desires to smooth the extension of the dataset use beyond a single designer or single plan. Although there is a significant discussion about spreading the use of BIM into early design stages and into the post-occupancy, these are not adequate see Kensek (2015). BIM is able to expand into the management of facilities, maintenance and operations, particularly where integrated with an augmented reality platform such as HoloLens. (see Fig. 2)

3. MICROSOFT HOLOLENS

The HoloLens is equipped by four-core Intel Atom x5-Z8100 processor 1.04 GHz; an advanced HPU (holographic processing unit) and 2 GB RAM. The device works with installed Windows 10 as the OS (operating system). The total memory is 64 GB but maximum of 900 MB is available per app. The device has battery inside with 16.5 Wh which is enough for 2 to 3 hours of dynamic use and up to 14 days in the standby mode. No external positioning services are required, because the HoloLens has an integrated inside-out tracking. This implements four EUC (Environment Understanding Cameras) and an IMU (inertial measurement unit) to detect projecting points of the environment and to wrath the variations with the IMU's information. The images are captured as BGRA-colored images. The API also delivers the necessary transformations to trace the captured posture when taking photos. The projection and transformation matrices are repeatedly

OS	Windows 10.0.11802.1033 32-bit
CPU	Intel Atom x5-Z8100 1.04 GHz Intel Airmont (14nm) 4 Logical Processors 64-bit capable
GPU/HPU	HoloLens Graphics
GPU Vendor ID	8086h (Intel)
Dedicated Video Memory	114 MB
Shared System Memory	980 MB
RAM	2GB
Storage	64GB (54.09 GB available)
App Memory Usage Limit	900 MB
Battery	16,500 mWh
Camera Photos	2.4 MP (2048x1152)
Camera Video	1.1 MP (1408x792)
Video Speed	30 FPS

Fig. 3. HoloLens Hardware Specification

calculated and comprise the intrinsic and extrinsic of the camera constraints. The Spatial Mapping API permits to vary the time between mesh updates and resolution. The mesh deals with resolution of 800 triangles per m^3 and bring up-to-date every 2 seconds. Only points that are at least 0.85m from the device, are used for updating the mesh to avoid falsification by concerning the user's fingers. The default area which we try to scan is 3x3x3 m^3 around the original pose of the HoloLens in this application. The more detailed of HoloLens specification is in Table 1:

4. SPATIAL MAPPING

Usually to build a model, it is necessary the measurement of the environment objects. Furthermore, we have to extract an architectural files as layouts or plans to model the building. Otherwise, we can use the spatial mapping techniques to map or to measure the building by using different mesh tools, see Taylor (2016). In our days, light detection and ranging, time of flight (ToF), and structural light are methods used to provide a spatial mapping to generate a depth map in real-time. The first and the second methods solve distance between sensor and object based on the speed of light, recording the time of light travels or measuring the phase of light wave, see Fonnet et al. (2017). Structural light methods project coded light patterns on to 3D surfaces. By using the distortion of light patterns caused by the shape of 3D surfaces, the system is able to reconstruct the shape of 3D objects.

The capability of mapping the environment through the depth sensors is one of the most exceptional features of HoloLens. To describe the process of the spatial mapping, HoloLens use its depth camera to generate the depth map and then its processors generate a mesh grid according to the depth map, see Chinara et al. (2017). Next, HoloLens rebuild the entire environment and locating itself in the environment using the spatial mapping result and some images taken by environmental understanding. For a best interaction with the environment, developers have to analyze the environment by using a very deep meshing. The mesh grids generated by spatial mapping can be used to help HoloLens understand the environment, see Ong (2017). According to the geometric properties of meshes, such as area and topology, object detection stage can be performed to find continuous planes, small objects, etc. By using surface normal from meshes, we can divide planes into floors, ceilings and walls. The Spatial Mapping API of HoloLens is designed to bring the geometry of real objects into virtual space, see Hübner et al. (2018). The objects already exist and can be viewed through the transparent glasses of HoloLens. In order to be able to interact with these objects, we only need the geometry, which allows a virtual board to be placed on a table or a virtual ball to roll down a ramp (see Fig.3).

Spatial mapping is the technology that enables a HoloLens to place holographic objects into the context of the real world. By making a scan of its surroundings, the HoloLens learns where the walls, floors, and ceiling are, as well as any furniture or other objects, see Liu et al. (2018). This enables holographic characters to sit on your sofa and place their drink on your coffee table. Spatial mapping is the key technology that produces the illusion that holographic objects are actually present in the real world. You can control how detailed you want a scan to be.

Once you have scanned a room in detail, you don't have to do another full scan the next time, you need only update the things that have changed. Once you have scanned an area, you can alter its appearance with one of the shaders in the software Unity that is used to building the project of spatial mapping before deploying it on HoloLens. Once an area has been scanned and shaded, processing can be used to simplify the representation with no loss of realism. This reduces the number of calculations that must be made to keep the representation of the room up to date, reducing the processing load and thus improving performance.

4.1 Data structure

To better understand the API, it is helpful to know what the resulting Spatial Mapping data will look like. During the scanning process, the user walks around with the HoloLens and looks around to let the sensors detect the surface. The HoloLens can determine their own position perfectly. The depth camera, which is mainly used to create the geometry, has a limited field of view. It sees only sections of the room so called surfaces. When, these surfaces are usually no larger than 1m and are managed individually.

4.2 Observer

In order to get to surface data, an observer must first be registered to give the spatial volume to monitor. Only surfaces that are within this volume will be passed to the observer that can be defined differently (box, sphere or a frustration), each type is used it depends on the

Fig. 4. Samples of spatial mapping

application. For example, if a hologram is placed firmly, only the closer environment is interesting. The volume can thus be defined as Axis Aligned Bounding Box around the hologram. In contrast, an application operating within the wearer's view would define the volume as a frustum and as the wearer moves, the volume has to be reset again and again.

4.3 Update mapping

The observer passes surface events to the application via the update method. In this step, some events may be added, updated or removed. However, these updates do not contain surface mesh information, just the surface location and how big it is, but if you need the mesh, it has to be baked first. Baking is the official term for this process, when updating and baking is split because baking is a very time consuming process. Due to the division, the application itself can determine which surfaces are to be baked first.

5. CONSULTING OUR BIM SYSTEM

In this section, we discuss and describe the BIM system that we are constructed based on the spatial mapping steps. In the first step, we use HoloLens 1, Unity 2018.3.14 to build and Microsoft Visual Studio 2017 to deploy the project of spatial mapping. We parsing all details of our room to ensure the detection of all components should be include in our BIM system. Then, we have to save this mesh map to be used in the future step that will be the guidance of all items in the virtual environment. Next, we add the items of furniture in Unity project which we will used in our BIM system and we apply for it the necessary scripts to be movable, resizable and rotatable. In this stage, we ensure that the new items should interactive with the physical environment for all feature cited previous. Following, we show a demonstration of practical use of two different in the room, see Fig4. and Fig.5.

5.1 Practical experience

The first step of our project is to create the spatial mapping mesh that will be used in the colliding option with the items of the BIM system. To ensure the mixed Reality concept on our BIM system, we benefited from Microsoft HoloToolkit library due that it has scripts and prefabs specially designed to be used with ease within Unity. This library should be imported to our Unity project with another free library from the Unity Asset Store called "Pack_Gesta_Furniture" that contains different 3D items of home as a bed, table, TV and printer ... etc. From the HoloToolkit library, we used the Mixed_Reality_Camera_Parent instead of the main camera by default of the project. Then, we added the default cursor to be used to access on the items under Input_Manager section, where all feature are defined there as gaze, gesture and voice ... etc. The same step, we invited the Hand_Draggable and the Bounding_Box_Rig as scripts from HoloToolkit library of each items. The first option makes the objects draggable by pinch and move, while the second option is the most usable in our project, it provide the bounding box tool to resize and rotate the objects.

In one hand, the important factor illustrated in this section is to prove that item can fit into the physical environment without colliding with something. It's not cool if you place an item into a chair that a real person is already sitting on. In other hand, the occlusion is also covered in our system, if an item is located behind a real object in the room, you should not be able to see it. However, when it passes in front of such an object, it should remain visible. This means that the HoloLens must know how far away things are as well as where they are so as to know how much of an item to show as it moves out from behind a physical environment object. In this way, we brought a Mesh Colliders script to all items to provide the colliding.

6. CONCLUSION AND FUTURE WORK

In this paper we presented the role of HoloLens device to serve the BIM posed by using a mixed reality system to manage any items of furniture in our room. As results of this system, we proposed an efficient mixed reality system which make interaction of the BIM data from the virtual environment to the real environment. Despite the virtual items can be moved, resized and rotated, also it has to be placed to the right way compared to the real environment. A rigorous evaluation will have to be conducted in the future to determine the quality of the solution proposed. The future work aims to develop a mixed reality system for a full home considering sanitary, electricity, air-conditioning installation and all the necessary furniture for different floors. Therefore, the BIM systems can be integrated to smart home conception as a smart tool to manage and to reorganize each room.

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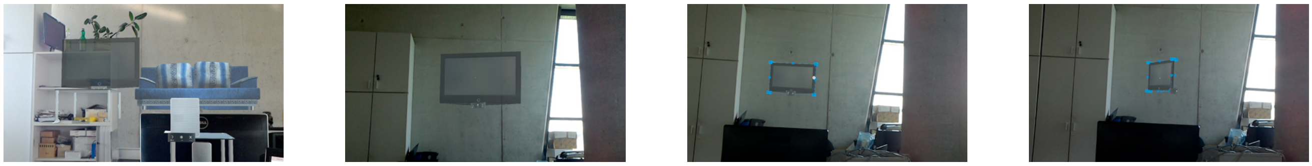

(a) First position of TV (b) Moving of TV (c) Resize of TV (d) Rotate of TV

Fig. 5. Efficient use of TV in our BIM system

(a) First position of sofa (b) Moving of sofa (c) Resize of sofa (d) Rotate of sofa

Fig. 6. Efficient use of sofa in our BIM system

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