From Floor Plans to Condominium Rights Through an Augmented Reality Approach

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Key words: Austria, condominium, 3D cadaster, holographic-like model, interaction, floor plan

SUMMARY

The creation of a 3D cadaster faces a number of different challenges. Two of them are the collection of data on already existing 3D structures and the visualization for non-experts. The paper uses Augmented Reality (AR) technology for the visualization of models created from plans required in Austria to create condominiums. The advantages of such an approach would be:

- Since the plans are required for the creation of condominiums, the data already exist and no additional surveying work is necessary.
- AR technology might be more intuitive than 3D CAD-systems. Experts in 3D CAD have no problems to work with complex models but the typical person interested in a condominium will have a background in law (e.g., a notary) or economy (e.g., a real estate agent) and people interested in acquiring ownership may have any kind of background.

The paper shows how to create a model of condominium from floor plans, import it in the AR environment, and interact with the model. The test setup is described and first results are sketched.

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1. INTRODUCTION

One of the typical examples for 3D cadastres is condominium rights (see for example Stoter and van Oosterom, 2006, p. 24 ff; Razza, 2009; Dalmasso, 2012; Wang, 2015). Condominium rights have several properties that make them interesting to investigate:

- A single building may hold many condominium rights.
- Condominium rights do not spatially overlap but may have complex boundaries since condominium rights may cover several floors and may even consist of separated volumes (e.g., the apartment and a garage).
- Condominium rights present a complex legal situation because there are legal responsibilities between the rights holders (e.g., it will be illegal to remove walls that are essential for the building superstructure, see Navratil 2012).
- Condominium rights may be valuable so security about spatial extent may be critical.

However, there are two aspects in connection to condominium rights where research is necessary. One aspect is collecting information about the geometry of existing condominiums. In Austria, floor plans are available and in this paper we show how they can be used to construct 3D models for a 3D cadaster. It has to be noted though, that the presented process still requires manual work. Another problem is the visualization of the resulting model. Not everybody can interact with 3D models in CAD-like computer environments. Solutions are necessary that are more intuitive and can support people in working with 3D cadastres. In this paper we demonstrate one possible approach.

Austrian law requires a floor plan to create condominium rights. Figure 2 shows an example for such a plan. There is such a plan for each floor of the building, serving as the data source for the creation of the 3D model. Different software products can then be used to create this model. Standards like Building Information Modelling (BIM)/Industry Foundation Classes (IFC, see, e.g., Atazadeh et al., 2016) or CityGML can be utilized but there are also specialized software products to model buildings in 3D. The software ArchiCAD was used to create the model shown in Figure 3. Finally, the model needs to be visualized. One approach is a CAD-like view (e.g., Seifert et al., 2016; Atazadeh et al., 2016). Pouliot at al. give an overview on the current knowledge on cadastral visualization and discuss the requirements for future research directions with respect to 3D cadastres (Pouliot et al., 2016). We are discussing one of the presented directions, augmented reality (AR) teachnology with a focus on holographic-like visualization and interaction. We demonstrate how to import the data into an AR system for further experiments and development. Figure 1 shows the utilized environment providing visual feedback and possibilities for interaction. It consists of Meta2-glasses that let the user see a holographic-like 3D-model. The glasses us the surroundings to orient itself in relation to the model. Therefore the user can walk around a model or even look at it from the inside. The computer (on the right side of the image, behind the operator) provides the graphics for the glasses. The operator can see on the screen a flat representation of the image that the user perceives. The obvious disadvantage is the necessity of cables. However, the computing power allows larger models and more complex interactions are possible than possible with integrated solutions.

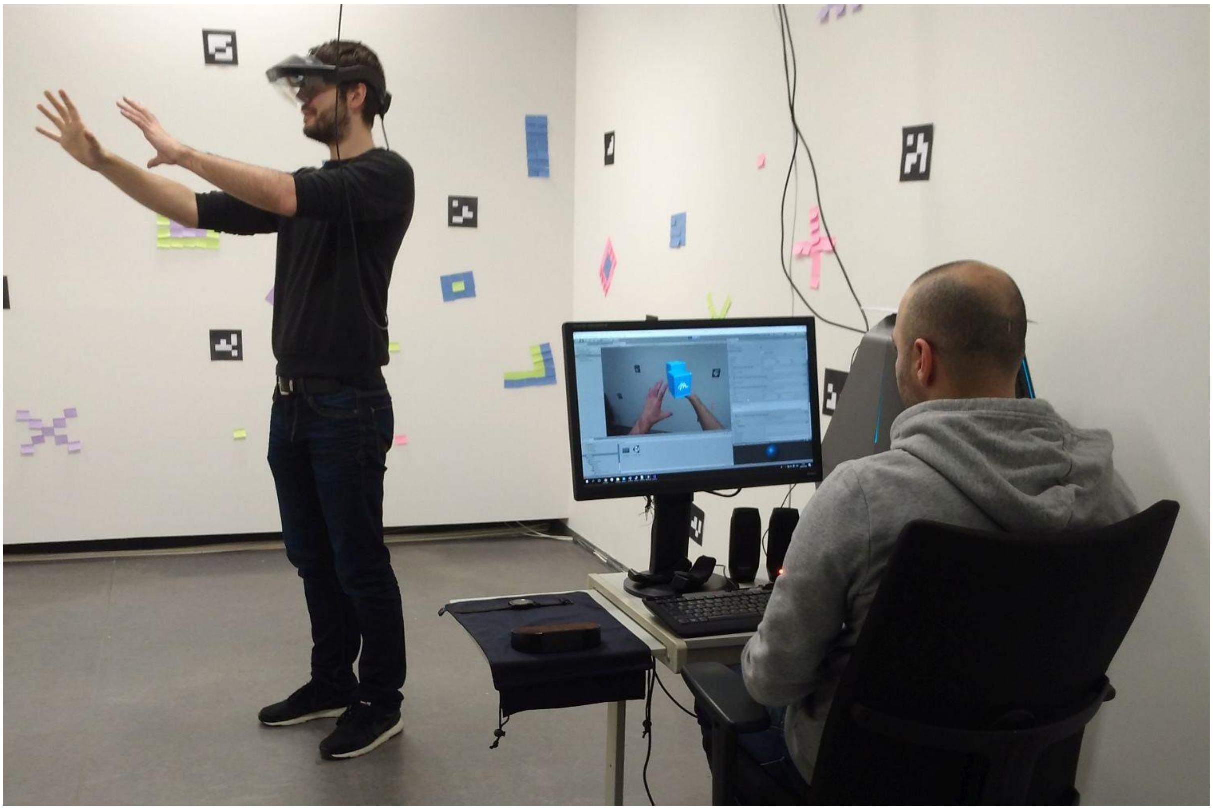

Figure 1. The Spatial HCI Lab at TU Vienna used for research on interaction with spatial data in an AR environment (User N. Jankovic, operator P. Fogliaroni, picture taken by G. Navratil)

The main questions in the paper are:

- What kind of interaction dialogues are necessary for a holographic-like model of condominium?
- How can the missing interactions be implemented?
- How can the performance be tested?

The remainder of the paper is structured as follows. We start with a description of the available data for condominium rights in Austria. Then we show the creation of a 3D model in a CAD system and the conversion to a model suited for AR systems. We then discuss interactions with the model and provide first impressions from user testing. We end the paper will some conclusions and ideas for future work.

2. AUSTRIAN CADASTRE: CONDOMINIUM RIGHTS AND FLOOR PLANS

The Austrian cadaster is currently a pure 2D cadaster. Representation of ownership volumes is not possible. Still, concepts like condominium, building below or above other people's property, or a separation between land ownership and mineral resources. The topic addressed in this paper is condominium. This means that person or a group of persons owns an apartment. In terms of a 3D-cadaster this requires the definition a volume, which is the spatial extent of the property right. In the Austrian cadastral system, the description of the property extent is based on floor plans.

The Austrian cadaster consists of cadaster and land register. The cadaster defines a tessellation of the surface of the earth and defines identifiers for each element (called land parcel) of the tessellation. The land register uses these identifiers to link rights, responsibilities, and restrictions to the land parcels. The land register requires a legal document to establish a right. These documents can be text only but can also contain graphical appendices like maps. These appendices can restrict rights to specific areas, e.g., restrict a right of way to a specific corridor instead of the whole land parcel. This restriction can be included in the text document but graphical representations are typically easier to interpret, especially after boundary changes in the cadaster. This possibility of graphical appendices is used to register condominium rights. The condominium right is the shared ownership of the land parcel combined with the exclusive right to use a specific apartment[1] (WEG, § 2 lit. 1). The ownership share depends on the "use value" (orig. "Nutzwert") of the apartment. The ownership share is 10% if the value of the apartment represents 10% of the use value of all apartments on the land parcel. The use value depends on the size of the apartment and includes deductions (e.g., for insufficient light due to shadowing of other constructions) and price increases (e.g., for an additional shower). Floor plans show the size of the areas belonging to the apartment. These areas are the rooms but also a terrace, a balcony, a parking lot, a garden, or a basement compartment. Therefore, all these elements are represented in the floor plans. These plans are available at the land registration courts in analog form or (since 2006) online as scans in PDF format. Older plans are only available in analog form at the land registration courts.

[1] „*Wohnungseigentum ist das dem Miteigentümer einer Liegenschaft oder einer Eigentümerpartnerschaft eingeräumte dingliche Recht, ein Wohnungseigentumsobjekt ausschließlich zu nutzen und allein darüber zu verfügen...*"

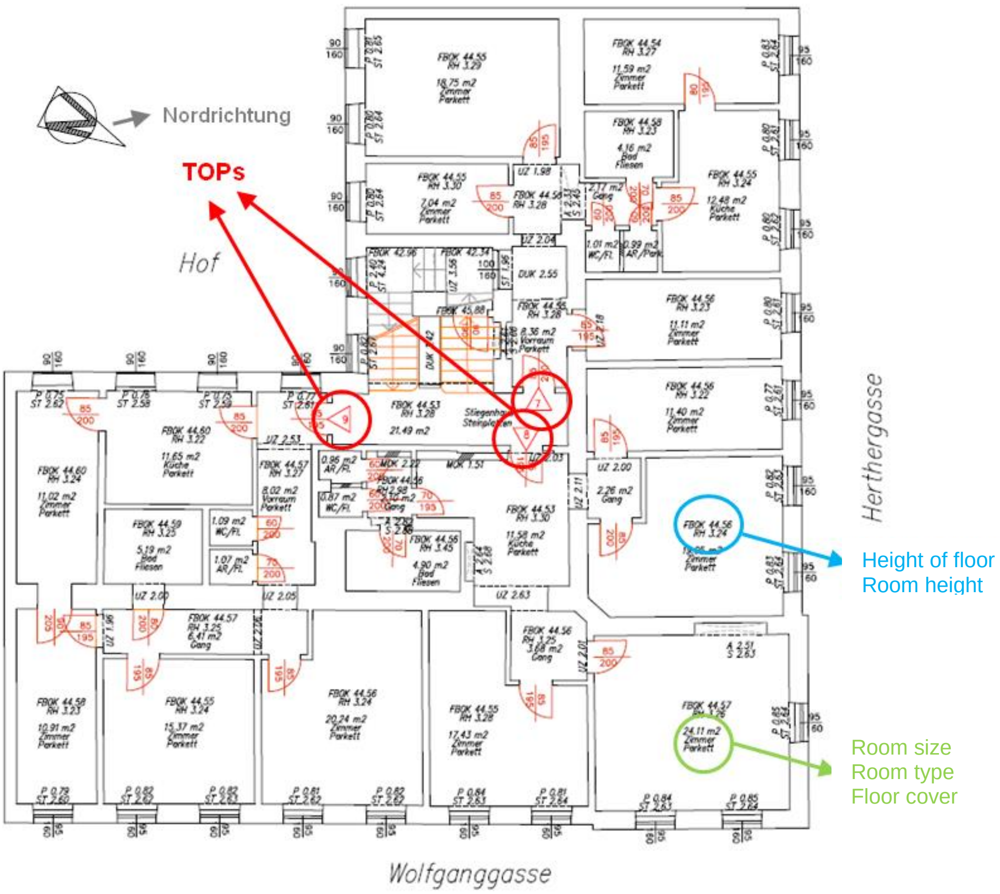

Figure 2. Example of a floor plan (adapted from Schwai, 2017, p. 68, data: Vermessung Fuchs)

Figure 2 shows an example of a floor plan. It contains important structural elements like walls, doors, windows, and stairs. Some pieces of information, like room size, apartment number (TOP), or wall thickness are also present in all floor plans because they are relevant to compute the use value. Other pieces of information, like the height of the floor or the room height are optional. The apartment entrances are marked by triangular symbols in the plan. The number within the triangle is the apartment number. The spatial extent of the apartment can only be determined by topological relations between the rooms. Rooms connected by a door belong to the same apartment. In some cases, the apartment may be situated on different floors. In this case stairs within the apartment connect the floors. A north arrow and the names of the streets (together with information on the land parcel) provide geographical reference for the apartments.

3. MODELLING CONDOMIUNIUM RIGHTS

The floor plan shown in Figure 2 does contain the necessary height information, However, since this is not the case for all existing floor plans, an alternative solution would be required for these cases. Olivares García et al. (2011) already presented such a solution for Spain by using a height difference of 3m between the floors. This is a decent approach for a solitary model. However, data sets need to be increasingly interconnected with other data sets. For the representation of condominiums this would be a possible combination with architectural models (e.g., based on Industry Foundation Classes, IFC) or 3D city models (e.g., based on CityGML). In both cases, the correct height in the cadastral model is essential and therefore general assumptions may lead to problems.

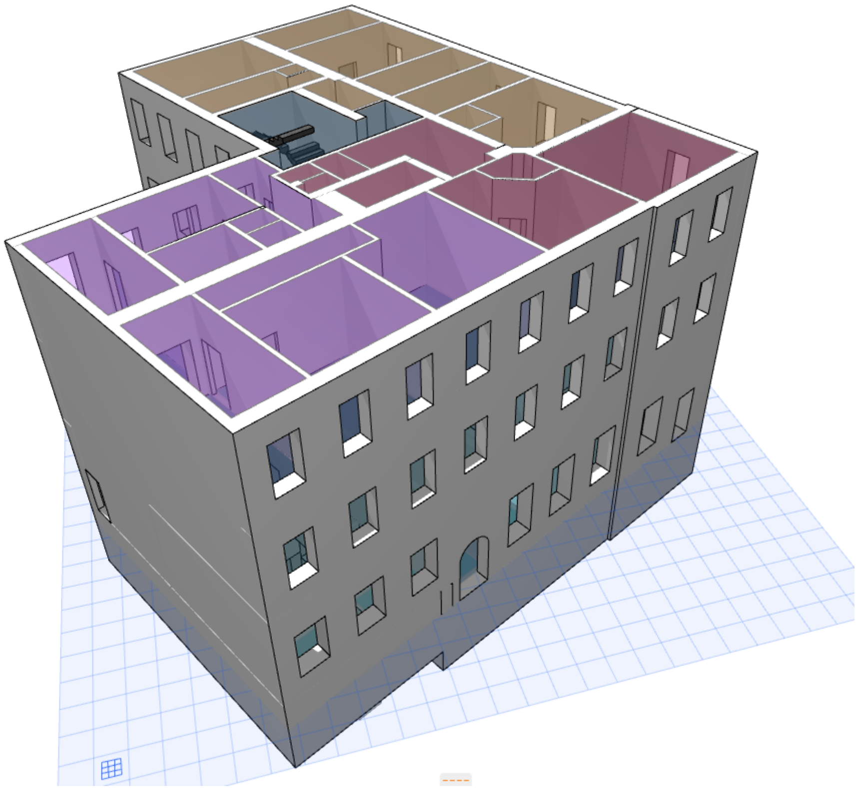

Figure 3. Model of the apartment building without roof (Vollnhofer, 2018)

The floor plans were available as a CAD plan. They were imported into ArchiCAD 21 using the defined heights as a vertical reference. Small vertical deviations up to 15cm were ignored, only the height difference in the basement required two different reference heights. The lines were used to create the walls by snapping to them. Doors, windows, and stairs were added to the design to create a more realistic visualization, they are of limited value for the cadastral model. Each room was assigned to a different apartment and the apartments are visualized by different floor colors.

Since the goal was to use the model in a holographic-like environment, some details were ignored. Ownership of walls, for example, is not defined. In reality, a wall may belong to a condominium, form the separation between two condominiums, or act as a part of the building superstructure. The wall would be owned by the condominium owner, the owners of the two condominiums, or the body of all condominium owners respectively. It can be modelled in IFC and will be necessary for future implementations but the tasks analyzed with this model do not need this kind of information.

4. CREATION OF A HOLOGRAFIC-LIKE MODEL

In order to use the model with AR technology, the data must be converted to a suitable data format which can then be imported into a gaming engine, in this case Unity3D (version 2018.2.3f1). This includes adaptation of the model to fit the tasks, i.e., the volumetric model was reduced to a floor-based model because it is better suited to attach labels to the different rooms. These labels were added manually in ArchiCAD. In addition, the color scheme does not match the demands of the AR glasses and it was difficult to distinguish the different colors. Therefore, a different color scheme was developed and applied. It was done by try and error achieving a satisfying result. Aspects like color color-blindness were ignored for the moment. Changing the color scheme before the conversion was necessary because Unity does not provide the possibility to do such adaptations during the import.

ArchiCAD can export models in different formats but a direct export to Unity is not possible. Therefore, the model was first exported into a format that Unity can use for data import. Filmbox format (by Autodesk) provided good results. During the process, the new ArchiCAD version was released which contains changes in the Filmbox export. These changes were not tested. Each floor model was exported separately to allow for interaction at this level, i.e., independent handling in the AR system.

During the import, objects had to be defined. These were the floors of the building. Each floor has an independently defined reference point, which is the objects pivot point, that is required for interactions like rotate or scale. These reference points in Unity are the same as the project origin points in ArchiCAD. Therefore the reference points of the floors lie outside of the objects edges, which can lead to unwanted behavior of the model while performing rotations and scaling. Till now there is no inbuild function in Unity that allows the user to change one objects reference point. Thus, the reference points had to be created by using the method ”EmptyGameObjects” that where positioned in the gravitational center of each floor and then declared as superordinate. For Unity, the floor model consists of exterior and interior walls, floor structure, stairs, furniture, and room labels. The result was a data model that then can be used for visualization and interaction in an AR environment such as the one enabled by the Meta2-glasses.

5. INTERACTION WITH THE HOLOGRAPHIC-LIKE MODEL

Visualization of holographic-like models is only the first part of the whole process. As soon as the camera is initialized and the data is in the system such that they are in the field of vision, the user can move around the visualized model and visually inspect the model from all possible angles. The system provides three basic types of interactions by default:

- Grab an object and move it. The object changes the position but neither size nor orientation. This interaction is comparable to pulling a baking tray out of the stove to check, whether the cake is already finished. The interaction only needs one hand and thus the user can interact with two different objects at the same time.
- Rotate an object. This interaction allows rotating an object around all axis. This is comparable to holding a small object in the hand and inspecting it from all sides.

However, in the AR environment, both hands are necessary to perform the interaction because each hand grabs the object at a specific point and the relative position between the hands defines the orientation of the object. It is possible to restrict the rotation, e.g., to only allow rotation around the vertical axis.

- Scale an object. The size of an object can be changed like a balloon with more or less air inside. Again, two hands are necessary for this interaction because the distance change between the hands determines the scale change.

The last two interactions are connected, i.e., during the rotation of an object also the size can be changed. The problem with this kind of interaction is that it is difficult to get fine changes correct. Small movements of the hands can have dramatic effects on the model. This improves with more experience of the user but it requires focus of the user. Therefore, other concepts were developed and tested with 6 pilot participants based on the requirements of the application (only rotation around the vertical axis):

- Two cubes that start rotation around the vertical axis (one for each direction)
- Rotation with a swipe movement of one hand
- Rotation using a separate cube (while scaling is still done on the object itself)

These concepts showed some benefits but all of them had some problems. The first approach was quite intuitive (if the hand was within the cube, the object started to rotate until the hand left the cube), but the process is time consuming. The swipe movement failed due to bad recognition of the hands. Sometimes it worked well, sometimes not at all. Improvement of the hand recognition will be necessary. The last concept failed to be intuitive enough to be used instead of going around the room. However, although the original concept seems to be the best at the moment from an implementation perspective, the concept with two cubes was used for the study.

Some types of interaction are difficult to perform with this kind of gestures. Thus, a pop-up menu was implemented to access functionalities like reset of size, orientation, and position, or to show and hide different floors.

Once the model worked and the interactions were defined, the setup was tested against a traditional approach using ArchiCAD. The users had to answer 8 questions and perform one task:

- How many rooms are there on floor 1?
- How many rooms are in the building in total?
- How many rooms does apartment TOP 5 contain?
- How many rooms of apartment TOP 3 border to the hallway?
- How many apartments are on ground floor?
- How many apartments are there in total?
- How many square meters has apartment TOP 4?
- On which floor(s) are rooms of apartment TOP 7?
- Hide all floors except the basement!

6. FIRST RESULTS FROM USER TESTS

The user tests are still ongoing and therefore, end results are not yet available. A first impression is that the interaction for moving, rotating, and scaling of the model is quite intuitive. Figure 4 shows an example of a grab operation. The user grabs the basement and moves it to a different position. This allows further inspection. Figure 5 is an example, where the user grabs the model with two hands allowing him to scale the model. The user looks down at the floor and sees the interior details.

The use of the pop-up menu (see Figure 6) required some explanation and training. However, after an initial phase the interaction with the menu worked well. However, sometimes the collision detection between finger and button failed.

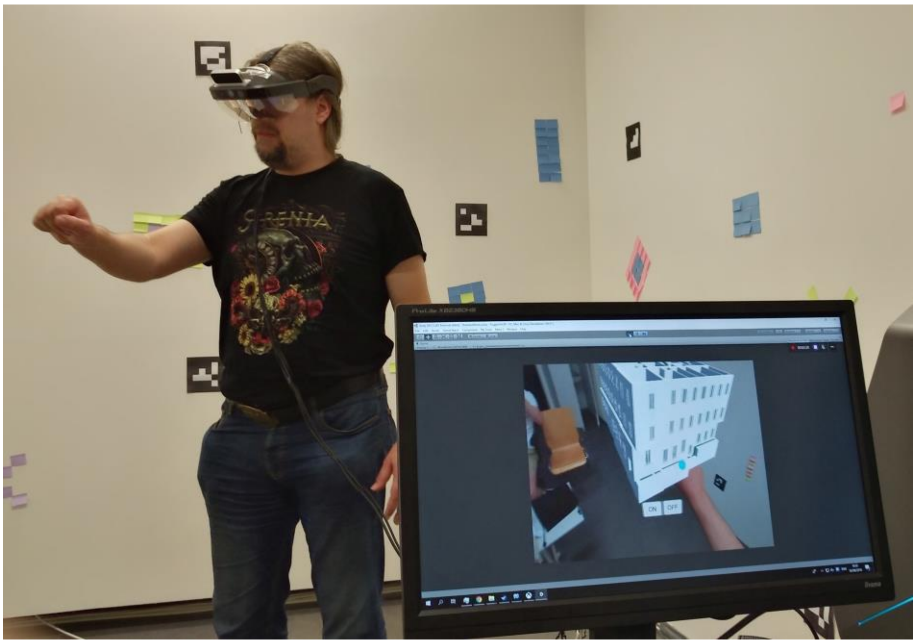

Figure 4. Grab operation (User G. Navratil, picture taken by P. Konturek)

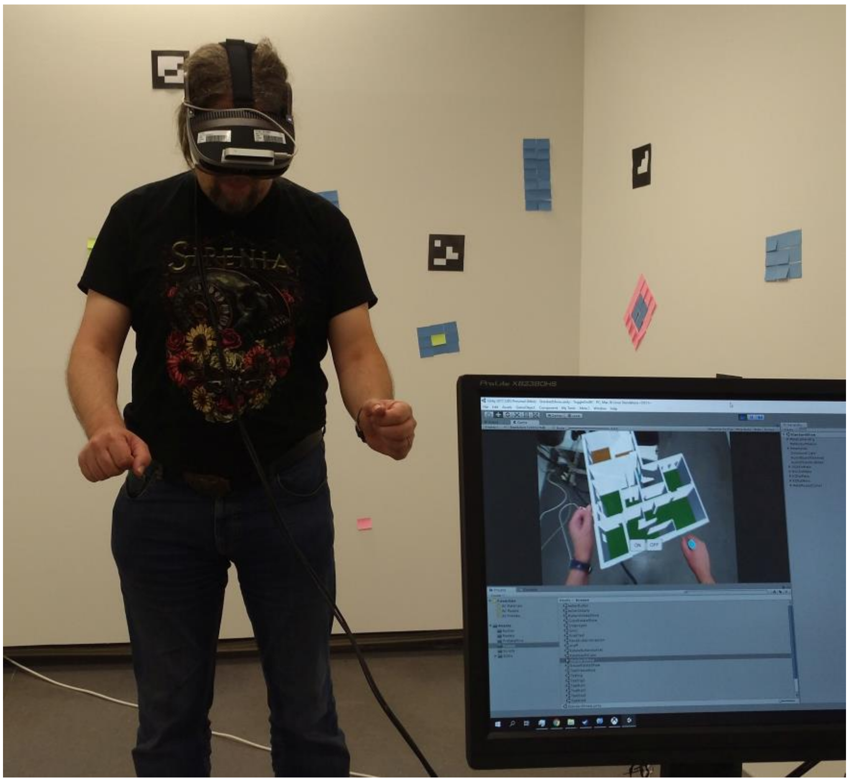

Figure 5. Scale interaction (User G. Navratil, picture taken by P. Konturek)

Figure 6. Menu interaction (User G. Navratil, picture taken by P. Konturek)

7. CONCLUSIONS AND FUTURE WORK

The experiments so far proved that it is possible to take floor plans required for the definition of condominium and transform the information contained in them into a holographic-like model for AR technology. The first results from the experiments have shown that such a model is useful to answer questions that a non-trained expert might have.

User tests of the environment shall compare the AR approach with the more traditional method of CAD and compare the cognitive payload of the approaches. These results will show, if the approach is reasonable and shall be further investigated.

It already became evident, that the current gestures for interaction are not sufficient. The original Meta2 glasses support only a limited number of different gestures. An additional sensor has already been fitted to our glasses to identify each finger. This will allow more detailed gestures, e.g., the swiping movement for rotation. However, the development and testing of the required algorithms is not yet completed.

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BIBLIOGRAPHICAL NOTES

Gerhard Navratil is a senior scientist in the geoinformation group of the Department for Geodesy and Geoinformation at TU Vienna. He has a strong interest in legal and technical aspects of 3D cadaster including question of quality, data collection, verification, and updating.

Marco Schwai is Diplomingenieur für Surveying and did his master thesis on the topic of creating models for a 3D-cadaster based on floor plans. He is currently working in a surveying company.

Stefan Vollnhofer is a master student of Geodesy and Geoinformation at TU Vienna.

Philip Konturek is a bachelor student of Geodesy and Geoinformation at TU Vienna.

Ioannis Giannopoulos is Professor for Geoinformation and head of the geoinformation group of the Department for Geodesy and Geoinformation at TU Vienna. He has a strong research interest in augmented reality, especially in interacting and using the data in both laboratory environments and the outside word.

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