

A Multivariant Design Tool based on affordable VAM-Technologies

Interactive Design and Flexible Immersion

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The paper presents an effective concept to design virtual architectural models in an immersed environment. The prototype application demonstrates different interactive modes and flexible immersion on mobile devices with emphasis on a new marker-based input device with interchangeable markers as virtual pen. As the system utilizes smart phones as computational device, no extra computer is needed. The display options are affordable head-sets off the shelf, while the new pen is built with small boards and micro controllers around a simple 3D-printed hull.

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INTRODUCTION

The architectural design process as creative activity requires actions and interactions. While there are a lot of tools in the physical world to support the design process, the design of virtual models on computers are limited to mouse and keyboard, and common visualizations are bound to front-facing screens.

Applications providing immersive experiences are separated from them, often as simple viewing tools. The added complexity to introduce at least some interactivity is not easy to overcome. If existing at all, these tools have either limited functionality like a clicker, or handling them is not easy to master.

BACKGROUND

Computation in architecture presents a long list of software tailored to the architectural design process.

Most of them have a decades long history of developing. These software packages have special features inbuilt to support both the drawing as CAD and also special techniques like BIM or parametric design. They are complex and they are huge. Something like a little app won't do it.

Their user-interfaces are convoluted and display a lot of menus and palettes. Selecting one out of many options of such a palette or menu defines a specific functionality. When that tool, like drawing a line or a selecting pointer, is in use, other palettes or menus are presented accordingly to render the tool more specific, like a line color or pattern. Architectural CAD-software packages have even more choices to present, like mechanisms for creating stairs or openings in walls with then even more options. Looking at a screen there are always dozens of tiny squares around, each representing a tool or sim-

ilar. It is almost a signifying feature of architectural software packages, and it seems to be inevitable to employ such UIs for the tasks at hand in architecture. As side effect these systems have a steep learning curve.

VAM

VAM-technologies (virtual, augmented and mixed reality, Schnabel 2009; Moleta et al. 2018) are widely used to simulate architectural designs. Most recently representative exemplifications are thematically gravitating around one-to-one simulations in virtual environments (Eloy et al. 2018; Moleta et al. 2018). Modern devices like the Oculus Rift, the Hive, or the HoloLens employ powerful HMD (head-mounted displays) to offer visual simulations at a not yet seen quality. As systems they have still some limitations, some need external workstations for rendering or some calibration in a defined setting.

All system are limited to special software environments. A typical example has been recently presented (Sheldon et al. 2019), where a plugin was developed for the HoloLens. It can not be used on any other system, nor are the devices widespread like mobile phones.

VAM-techniques, sometimes also labelled as XR for AR, VR, and MR, share similar characteristics. They present always a virtual model in a somehow immersive environment. There is one important distinctive feature regarding the display or presentation that should be mentioned.

Compared to mixed or augmented systems where images are composed out of two different sources virtual systems present only their model. Visualized virtual models on a display do not inherit any physical components from the real world besides the display itself.

Interestingly this does not apply to interface devices beyond the simplicity of a clicker. Something like a pointing device demands in all cases the handling in both the real and a virtual world. As long as those mixed tools are part of both worlds, they have to be registered somehow. Even in an otherwise ab-

solute virtual environment the physical body of a user still persists.

Augmented Reality

The overall bandwidth of VAM as established in the architectural design process is by far more differentiated and the special cases, based on whatever new device is at hand, are filling the conferences year by year.

What is still missing though is a kind of technique, which handles both the interactions to modify a three-dimensional model in a workspace and the immersive simulations to evaluate and examine the model in a real world environment.

Complexity

The complexity of AR-systems, composing two images from different sources in real-time, is a demanding task. As result the gear added to a user to secure the perception of the virtual component is cumbersome, very often lacking and complicated as well. Controlling the virtual models, if applicable at all, in all three dimensions of the real world is a task on its own. Therefore it needs special attention to develop some intuitive user interfaces.



Figure 1
Early AR: a) on a desktop computer, Peter Anders 2005. b) on a mobile device at ACADIA 2009.

Historical development

Retrospective the development of AR came in waves. One important step was triggered by the development of designated graphic cards and OpenGL (Fig. 1a), another with the introduction of smart-phones, their camera, graphic capabilities and their wealth of

inbuilt sensors (Fig. 1b). Every wave came as a result of a break-through in technology both in minimization and performance.

Recent progress

After once all important components, camera, computer, sensors and screen, have been integrated into the smart-phone, the remaining drawback, a lack of performance, was addressed. As latest break-through smart-phones with their permanent increasing powerful CPUs got capable GPUs inserted. Their specially developed software kits are combining sensors and optical feature tracking to calculate the exact position of the device. The technique labelled as VIO (visual-inertial odometry) now separates the development of AR-applications from their technical constraints.

One focal point now are interactive models on mobile devices. Their simulations at a model scale on a virtual work space, where rather information than visual sensations are displayed, have become widespread. Watching three-dimensional models on a mobile device has become a standard feature for a lot of different applications, leak e.g. for real estate.

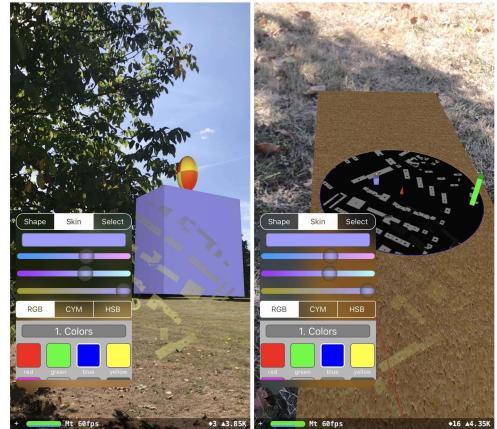
SYSTEM ON MOBILE DEVICES.

Mobile devices have already proven their capabilities both in hard- and software, although displays and input devices have their limitations. As mobile phone are employed, other applications have to be stopped from interfering. The overall beneficial effects, especially the mobility and flexibility more than compensate these drawbacks.

The project presented here, specifically developed to accommodate the architectural design process, is an attempt to utilize modern AR-technologies on mobile devices. It provides different scales and interactive modeling tools on mobile devices at almost any location. In addition it offers different display modes to immediate switch the representations and a specifically developed design tool to work on the model while being immersed outside any studio environment.

Different Scales

The core of the project is a single model to be displayed in different scales. The concept is based on the idea of employing a virtual platform on which three-dimensional shapes can be created, placed and modified, while at the same instance a real immersive impression in a one-to-one scale could be established.



The first mode is a scaled model displayed on a virtual table based on its real world location. A selected area of interests is transformed from a map into a layer which serves as platform for the virtual model in the work space (Fig. 2). At this stage the model is completely editable, ready-made models can be imported and basic three-dimensional shapes created and modified. As a full immersive one-to-one scale naturally the models can't be moved anymore, however, all other options like rotating, resizing or skinning are still available.

Different Displays

With some additional gear the model can be displayed in four different modes: a normal mode, where the device can be accessed like a normal handheld mobile phone, and three modes for different immersive experiences depending on the specific display, as a closed display, a view-through as holo-

Figure 2
Workspace virtual mode both as immersive mode or on the virtual desk with radar interface for orientation.

display, and stereo or not. This technique is only available on mobile-devices, wherein the device itself is mounted inside a mask or viewer. The technique is labelled as flexible immersion as part of the system..

The first mode is actually the normal touch mode users of smart phones are already used to. It is the main mode for interactions, because the screen is not mounted yet and no visible areas are obscured. All kind of touches and gestures are implemented in order to modify the model.

The other modes consequently do not permit any touches except those to switch the mode itself. Instead a specifically designed tool is deployed.

TOOLS

Users blindfolded with an HMD can only interact with the virtual model they are watching with a registered or calibrated input device. One option is a laboratory environment with dedicated devices like the Vive or similar, which commonly deploy base stations and auxiliary location devices.

Voice recognition

Lately, with the advance of both speech recognition and modern AR based on VIOs voice recognition is considered an option for interactions. "When interacting and communicating people naturally use their voice; it is this fundamental human behaviour that needs to become a more prominent means of interaction in AR" (Sheldon et al. 2018).

There are however some few minor limitations that renders voice recognition suboptimal. At first there is a double time lag. The first one is the duration of speaking the command itself, the second one is the time the system recognition needs to recognize the command and to execute it. These two lags very soon may up to some 10th of a second, which is a notably delay.

Then voice commands never can be precise in pointing or aiming at spots in a three-dimensional environment, except they are already predefined as markers, which would contradict the design process by itself.

Finally voice recognition, or better spoken commands are seriously interfering with verbal communications in a collaborative environment. Collaboration in an immersive environment would be at least inconvenient, if not impossible at all.

Gestures

Gestures in this context are supposed to be free gestures in space, not gestures on a touch screen. Their recognition is based solely on cameras and image processing, sometimes with additional markers, like e.g. colored fingertips. Gesture recognition is also seen as valuable technique in mixed reality system. A typical system is "a vision based bare hand interface for interaction in augmented reality environment"(Ha and Woo, 2005). "Fortunately, most gestural interaction only requires the tracking of each user's head and hands" (Krietemeyer et al., 2017).

As interface for graphical actions there are two major concerns. At first, the variety of different gestures is limited. While simple gestures like pointing are valuable enhancements more complicated gestures are both for the user hard to learn and difficult to recognize for the machine. Secondly gestures are usually not precise enough for the creation of three-dimensional models, when simple pointing is not enough.

In addition again collaboration is an issue, because the relation between a gesture and the user performing it can not be established without adding some features, meaning markers.

PEN WITH MARKERS

As result, conventional marker-based techniques are implemented. Although markers as artifacts are added to the scene, they are as fiduciary feature identifiable and valuable objects.

ARPen

The ARPen is a multi-tool developed in order to gain interactiveness in immersive environments with mobile phones. The original device was developed by Felix Wehnert (2018) as part of his thesis. By utiliz-

ing a special kind of markers (arUco marker; Muñoz-Salinas et al. 2018, Garrido-Jurado et al.2015) the location and orientation of the pen in the three-dimensional scene can be determined. "The ARPen has six arUco markers on its end. This ensures that at least one marker is visible for the camera even if the pen is pointing away from the camera. Knowing the physical setup of pen and markers, we can determine the pen tip from the marker location and stabilize this location by averaging if multiple markers are visible. Furthermore, the pen transmits the states of three buttons to the phone via BLE" (Wacker et al. 2019).

New Pew

Based on the ARPen a new pen has been developed. The design now matches a real pen in shape and size. The three buttons are arranged similar to a computer mouse. The cubic marker is moved to the tip of pen and the now interchangeable marker are fastened with magnets. A set of 6 different markers has been developed which translates to different functions to manipulate some virtual models. To identify the markers for the human eye they are differently colored (Fig. 3).

Special care has been taken to place the buttons on the hull and to fit all components, chip, battery and charger, into the body of the pen.



Figure 3
Two new pens with interchangeable markers.

The pen is connected via Bluetooth to the mobile phone. The available informations, pressing of the

buttons, are the same as the original ARPen. All other informations are optically retrieved by the mobile devices and their capable VIO (visual inertial odometry).

Future Development

The next step will install small chips inside the markers, which then will be mounted with a simple plug connector. To identify the connected marker said chip sends a code to the pen, which transmits it to the mobile device. From that point on a relation between pen and marker is established.

Such a feature is a requirement to use more than one pen on the scene and is the door-opener for collaboration.

Collaboration

It is contemplated, as there is still only one prototype at hand, that several devices could be deployed at one location interacting with the very same model. Without further development and more sophisticated markers the physical coordination of a couple of almost blindfolded users manipulating a virtual model on an imaginary work space is a demanding task of its own.

CONCLUSION

At present there is no system known yet as flexible as the system presented here. The different use cases cover a variety of distinguishable methods and techniques of designing in an immersive environment. Probably these use cases will become subject to studies on their own like e.g. regarding the beneficial effects of using specific displays compared to others.

While there a lot of discursive points around VAM right now, Hermund (Hermund et al. 2018) examined different scenarios to evaluate the presentation of an architectural design, Moleta and Schnabel (Moleta et al. 2018) are focussed on immersive virtual representations, the creative aspect, the ability to create a design in an immersive environment, is lacking. By utilizing both a designated work-space with an appropriate scale and a useful set of tools the system enables its users to establish a building's design right

on site and offers the opportunity to evaluate it as an augmented reality experience, though it should not be mistaken as simple presentation tool.

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