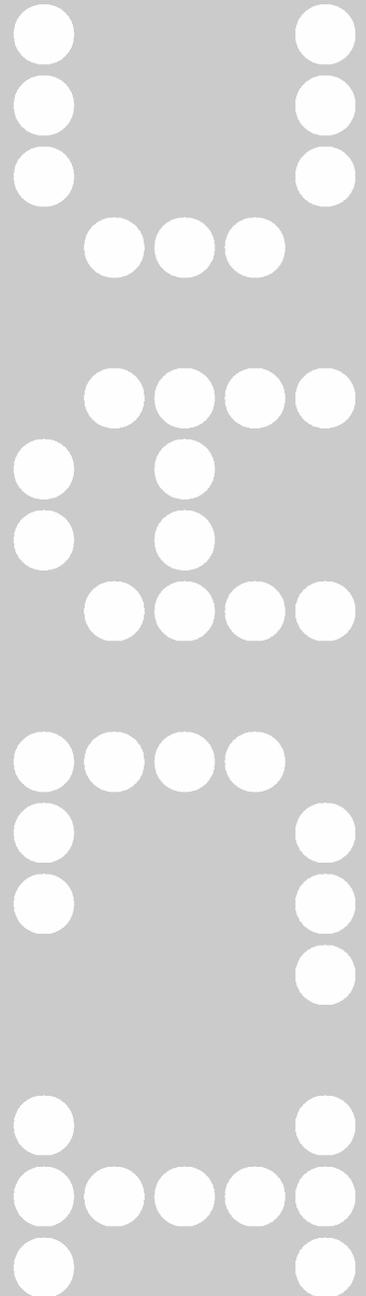


Augmented Reality Aided Design

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Ten years after Nielsen wrote about the “next generation interface” [1] we are still largely confined to WIMP [2] interfaces in design computing. A big question that lies ahead is ‘Does the integration of computing technology through Augmented Reality help the formal design investigation process?’ There are several suggestions that the conventional desktop metaphors are counter-intuitive for understanding spatial relationships [1, 3, 4]. Main concern is the mismatch in mapping of presentation and interface. Looking at other research areas, one can see that the application of Augmented Environments (AE) can enhance the speed of decision making [5] or creates better understanding of complex spatial arrangements [6] due to the fact that information is displayed where it occurs. Obviously, the representation and interaction is crucial for perceptive performance in design sketching as it is in AEs.

This article will discuss a software prototype called sketchand+ and the implications of Augmented Reality for digital design.

1. Preface

Depicting ideas through sketches, in architectural design, is a crucial creative task that a designer faces. Nothing else in the design process needs to incorporate such a variety of media. Moreover, the media describing spatial arrangements are fuzzy, incomplete, but still connected. As a consequence, the sketch as a meta-medium is a complex structure describing and interlinking ideas. It is syntactical glue, because the overall meaning is created by the sum of sub-media like text-notes, elevations, plans, diagrams and sections. The quality of a design can partly be measured by the intensity and richness of the communication of the used media. That means a tool that provides sketching capability, has to integrate support for a large variety of media. Gathering information is just half the problem. The information needs to be arranged in order to be presented suitably for further discussion.

What can be done to go beyond the current sketching techniques? Is not a sketch about arranging space? If it is then is it suitable to have a two-dimensional medium, carrying textual, drawn or perspective data – what about the third and the fourth dimension? A design sketch is a dynamic rather than a static medium. One can argue that making video [7] and creating working models is enough. The question arises: how can we connect them directly to create a better understanding? A problem, which needs to be considered, is that the usage of the computer has changed the media paradigm, and the paradigm needs to be changed again. At the moment, architectural computing – whether virtual reality or CAAD – mostly only adapts certain parts of the architectural design process, but does so without interlinking them [8]. The hypothesis in this paper is, that complex linking of media can result in better understanding of interrelations of problems in design. But it also needs to take into account that this complexity needs a new interaction technique as well as a different representation medium.

2. Exploring the ‘sketch’

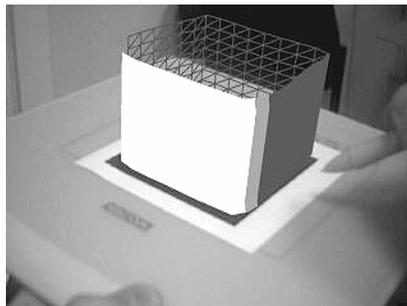
The term sketch will be used in this paper to refer to broad collections of media including volumetric models. Ideas are represented by sub-media (instances) and linked in a dedicated order, thus, forming a sketch.

Often used in architectural design are small infills for urban design context models. This approach of tangible media has been introduced into simulation environments by Poupyrev for displaying instruments [9] by using the markers from AR ToolKit [10]. Sketchand+ uses a similar approach and enhances the technique with 3D models rendered on top and special interaction modes attached to them. These markers play an important role as they bridge between the real world and the virtual world. Behind the scenes the software prototype is based on the TAPframework [11], which

glues together other third-party API's, namely: NURBS++ (the NURBS geometry kernel – non uniform rational b-splines), AR ToolKit (marker based recognition), PortAudio (audio recording and replay) and ffmpeg (video encoding/decoding). Sketchand+ has been created as a Windows®-application written in C++, but it can be ported to Linux® and MacOS® X environments.

2.1. Creating a model

The modeling part of the prototype shows an experimental way of creating volume models. First of all, it utilizes a freeform modeling technique. The idea behind is, that even at a low level, rulers and other such drawing aids do not belong to the environment needed to create a sketch and they can actually disturb the creative design process. In order to recognise this, the main creation tool is an augmented digitizer tablet with a stylus. This tablet is used to create a plan, which is extruded to a predefined height. Technically behind this geometry creation environment is a NURBS geometry kernel, which uses the input data from the tablet to create control points on a NURBS-curve. These points will automatically be extruded to a surface according to predefined values. Performing a single stroke creates a footprint. Additional strokes are used to refine the curve by inserting more control points. For instance creating a box needs an initial square shaped stroke (Figure 1). If the user performs a subsequent circular-shaped stroke, the software uses this one to round the box from the step before.



◀ Figure 1. creating a box on the graphics tablet

This interaction technique tries to adapt the style of a pencil used on paper. If using a Wacom Graphire® Tablet (or any other digitizer with more than one button at the input device) it is possible to modify the objects more precisely. For instance, pressing another key on the stylus and performing a stroke affects the geometry in the section by refining the shape and height of the extrusion rail curve. Thus, it needs only two strokes to create a quite complex design. Most tablet pens are equipped with an eraser button, and this is used in sketchand+ as it should be – to clear the geometry from the tablet. In the background all these actions are tracked by sketchand+'s repository function. Finalizing a stroke adds an iteration to the design and opens a new branch in the design tree. The

repository module takes care of the additional data, which need to be stored for a design step.

This modeling technique is just an experimental way to create models. It should not be seen as the final definitive way to produce modeling architectural designs. Rather it should be seen as an opportunity to explore spatial arrangements with three-dimensional volumes.

2.2. Easy collaboration

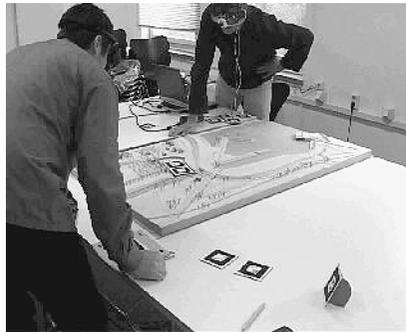
While sketching, one should not need to care about something like networking and handling extra interfaces for communication. Consequently Sketchand+ is designed to integrate tightly into the modeling process. Therefore, it introduces a non-intrusive interaction technique, bound to the usage of markers also known as props. It utilizes special storing slots. The interaction with them is quite simple. All that it needs is for the user to put them directly alongside the graphic tablet's marker and the software then assumes that the designed geometry should now be stored and distributed (Figure 2).

► Figure 2. Snapshot from a collaborative session with virtual models within a real model



In order to this, it copies the geometry of the design tablet to the marker. When Sketchand+ is running in collaborative mode, it also sends the geometry-data including additional metadata to the server. The server stores this data in an internal repository and parallel to this it distributes it to the other clients, who can then see it inside their augmented environment exactly on the same marker. The simple act of storing a design internally generates a complex distribution mechanism. The advantage of this technique is quite simple: Sketchand+ is supporting distant collaboration as well as direct collaboration without changing the interface. Users can communicate with each other directly and discuss design proposals (Figure 3).

Currently the software works on a first-in technique. That means that there are no policies such as assignment of privileges applied to certain participants in a design session. This issue will be tackled in the ongoing development process. Based on the TAPframework user-policies will be implemented.



◀ Figure 3. Collaborative design using Sketchand+

2.3. Working medium appearance

A typical problem a designer faces is that computer-generated output is regarded as a final product. For sketching that would be confusing, thus extra effort has been given to the appearance of the visualization. The sketch is a working medium and never becomes perfect in appearance. It is a psychological phenomenon as well, because even if the sketch is not holding all of the information needed, the architect tends to extrapolate, and by perceiving fuzzy visual signals, reassembles the signals and sketch into a new mental representation [12]. According to this, the sketch represents a syntactical medium following the psychological laws of the “Gestalt” which are described by von Ehrenfels [13]. Representations can be derived from roughly defined data and for this reason uses roughly defined appearance. That observation differs completely from what normal virtual reality applications try to achieve with vivid photo-realistic rendering and high-resolution models. In contrast, Sketchand+ avoids adapting reality by utilising a non-realistic rendering (NPR) and special tessellation (triangulation of higher defined surfaces) methods. The rough tessellation and the black and white shaded and outlined rendering simulates the appearance of a sketch. Stroke intensity is taken as a parameter for the unique processing of the meshes for the models. Thus, slowly drawn strokes result in smooth lines and shapes, whereas swift strokes produce less well-defined surfaces. Furthermore, the normal vectors of the surfaces are flipped, so that the designer can have a look inside the volume. All these features can be tweaked on the options panel to get the desired appearance.

2.4. Direct attached comments

One thing, which can be seen on fuzzy sketches is, that they are frequently augmented by multiple notices or labels. It happens that the pure visual representation does not show all the intentions behind a decision. Therefore architects often label parts with descriptions about material, textures or just explaining what this thing literally is. If this follows certain rules, anyone can take in the notes in parallel to looking at the visual representation and can thereby construct a more detailed image in their mind. This process works

through the spatially coupled representation and therefore can create meaning even if the information is incomplete [14]. Thus, the media based complexity or richness of a sketch can lead to a better design. Sketchand+ uses two possibilities for commenting: one possibility is a simple text message, which can be attached to a design. This is readable through a special marker. Another possibility provided is the direct attachment of audio messages. To every storing marker an audio file is attached, which can be dictated or listened to by just connecting a play/record marker aside it. The idea behind this is to store additional information directly with the representing geometry. Consequently, the Sketchand+ prototype provides a consistent interface for all actions.

2.5. Review designs from everywhere

Even nowadays not everybody has the chance to use augmented reality equipment. To provide a possibility for non-augmented participants, Sketchand+ also can create an internal repository. This repository currently is only for reviewing, not for reusing, but could easily be extended to this function. The application renders HTML and VRML97 files for any design step made and signposting it with an index including a brief overview to the linked steps. These pages can be accessed with any web browser. If the output directory is located in the root path of a web server, they can be accessed from everywhere. The stored data contains information about the designer, a timestamp, a screenshot (which shows the contextual situation) and an embedded VRML97-world. Everybody with a VRML97 plug-in can have a look at the design-steps made and reuse them in other software.

2.6. Export to other software

It has proven to be the case that the rough output might not be suitable to explore the geometries created by Sketchand+ in all circumstances. For this purpose, every design step also is stored as a RenderMan® RIB, taking advantage of the NURBS description capability of this file format. With visualizing in RenderMan® or any compliant rendering program this feature adds an additional level for reviewing and reusing design proposals.

3. Intermediate results

3.1. Using the software

To make it easier to use, a setup wizard guides the software installation. Internally the software also provides guiding wizards helping the user to get the system up and running. Nevertheless, first-time users seem to be confused about the HMD and the handling of the props. This is due to some technical restrictions as well as a first-usage barrier regarding an augmented reality application. Because of the powerful and easy to learn interaction techniques they feel confident with the system in a very short time. This

needs to be investigated in upcoming usability studies. In order to this, heuristics have to be developed for Augmented Reality (AR). Several approaches are available for normal desktop software environments but none has been developed for AR yet. The approaches for Virtual Environments are not really applicable because interface handling is different in AR. VEs have to 'rerepresent' actual input devices in contrast to AR, which provides direct visual and haptic feedback with them. Particularly in sketching or modeling, the measurement of user performance is difficult as it involves more than point and click methods which could be addressed by using Fitts Law [15]. Indications by Shelton and Hedley [6] in relation to Geographical applications shows that there is a positive impact. Further research will consider these observations and suggesting a methodology for Augmented Reality Design related usability heuristics and user performance measurements.

3.2. Technical issues

The development and the tests of this project clearly showed its limitations. First of all, video see-through augmented reality is highly limited by a number of optical constraints: the field of view of the camera, the field of view of the HMD and additional lens distortions. Moreover, the frame grabber in the camera, the usual bus-systems like FireWire (IEEE 1394) and USB and the recognition algorithms introduce a delay in the video pipeline. The problem with this is that the user needs to adapt his movements to the processed video while acting in a real environment. Thus, the user's visual perception does not completely match the actual movement. For instance, hand movements, which are visually round shaped, appear actually as an ellipse. Mimesis helps human beings cope with such a lack of direct mapping. After a very short learning phase the user is able to act within system and compensate. Another issue is the occlusion with the user's hand, which naturally happens when grabbing and interacting with the markers of AR Toolkit. If the marker is occluded or halfway out of the picture, the system loses track of the location. There are workarounds and a new version is capable of position prediction. Usually lightweight HMDs are monoscopic. This adds additional perceptive indirection. Pointing with one eye closed to an object is quite difficult and so is the vision through a monoscopic system. The movement parallax helps to overcome that problem. Finally, HMDs are a compromise between quality and comfort for the user. Especially in mobile applications, comfort is more important than quality but the level of importance might differ from case to case.

For other applications than mobile AR, it is also possible to use projective systems, which are usually easier in providing stereoscopic vision. An initial development is on the way to examine how tangible interaction and stereoscopic vision could help in designing spatial complex structures.

4. Future development

4.1. Other modeling techniques

As already explained the modeling system described is just a first attempt to design geometrical objects inside an Augmented Reality system. Even if it is quite intuitive, it does not serve for all design tasks. One approach would be to refine the current modeler and make it more precise in the results. Another possibility is to introduce certain recognition (similar to gesture recognition) within the sketching system which in consequence creates objects in the augmented space. However, this approach needs to be developed very carefully, because it would make assumptions about the designer intention. Such automated systems have been avoided for the prototype described here, as the aim was to create an aiding rather than a generating tool. In addition, the digitizer tablet approach is not ideal for in-situ sketching, which will be discussed later on (section 4.3).

4.2. Extended repository

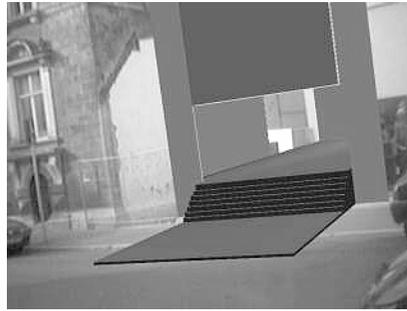
In order to understand a design, one may need information about the process and the history of its development. Knowledge about the past can lead to better design in the future. This attitude should start in the very early stages of a design. Bringing it together in a repository has consequences for the interface. It has to represent the logical and hierarchical order of the entries to be easily accessible. The display in Sketchand+ maps iconographic pictures on a website in a horizontal and vertical direction. Continuing amendments on a particular design end up in a long row whereas abandoning a design generates records in vertical direction, starting a new row. A genealogy of the design process is thus generated, which can be understood in outline just by its layout.

Further experiments will reveal whether the visualization and access of the repository is a suitable feature to aid the design process. The repository is at the moment only available through a website on the server. Of special interest is how the hierarchical order can be spatially arranged in order to use it as a reviewing system within the Augmented Environment.

4.3. In-situ sketching

One of the most interesting possibilities of this software prototype is the usage directly on a site. Some experiments have taken place (Figure 4).

The required equipment is a notebook equipped with good accelerated graphics card and WLAN network adapter. It should be noted that normal augmented reality rendering is not working correctly when used on a gap site that is surrounded by high buildings. The infill virtual buildings would occlude the surrounding real world. The buildings have to be registered into the software and they then can be used as culling geometries to get a visually correct view of the site with the infill building in place. Sketchand+ is



◀ Figure 4. In-situ design review on an empty plot with Sketchand+

capable of using an external geometry-file for culling the actual model and can show a visually correct infill.

Another feature is that Sketchand+ can instantly change the rendering mode. Standing in front of the building site the designer can decide whether to use non photo-realistic rendering or photo-realistic rendering, which is probably needed while discussing with colleagues or clients.

There are many problems that need to be solved to make the system finally usable for on-site design. For instance, it is necessary to get rid of the markers. The optical limitations of contemporary web-cameras lead, in the mobile version of Sketchand+ to bigger markers in order to track the user. The problem is that the optical distortion of those cameras is usually non-linear between near and far focused setting. Future research needs to tackle that problem by extracting linear features dynamically from the surrounding buildings or site appearance to get data for position and orientation. The software is also not aware of the real environment. A general ambient lighting, without reference to the actual conditions at the site, is currently used. To overcome this, the surface of a white sphere could be used to get information about the surrounding lighting conditions and these could then be applied to the virtual model. By doing so physically correct shadows and lighting in the model could also be simulated.

4.4. Distribution with video streaming

As mentioned before, not everybody is able to use augmented reality applications due to limited equipment capabilities. However, it would be helpful for a discussion to brief other experts and gather more information on a task. The deployment of mobile devices like PDAs and mobile phones could assist in attaining complete bi-directional communication between architects and clients. Therefore, the new Sketchand+ can provide a MPEG4 video stream. The video is the raw video produced by the camera captured from the augmented working user and additional, so-called opaque, video frames for distributing additional data. This can be the computed positions and orientations of the visible markers or other metadata. The final composition is then transmitted to the mobile client.

4.5. User input

Despite mobility and more output methods there is a major reason for investigating the tangible input itself. The use of a digitizer tablet is quite intuitive but it also introduces limitations. The sensor area is restricted and so is the size of the models. Changing scale is not implemented because it would introduce an asynchronous mapping of input and output, which in consequence, is counterintuitive. Therefore, bigger input devices are needed like a SmartBoard (commonly used whiteboard with sensor interface, product webpage: <http://www.smarttech.com>). Current research on design support in an urban design scale will use these new possibilities for review and development of spatially complex spaces. Furthermore, it makes more intuitive interaction techniques possible.

Experiments with the mobile Sketchand+ prototype yielded that a digitizer is not a good choice for outdoor equipment as it requires use of both hands to control. Usually one has better motor control when the wrist is attached to solid ground. A mounting could solve these issues but this would still just be a compromise. The development of better and intuitive two-handed input devices is on the way.

5. Conclusion

With Sketchand+ it has been shown that it is possible to express spatial arrangements in a sketch-like manner. It also has been demonstrated the possibilities of annotating, reviewing and distributing are significant. The existing implementation is quite crude but it shows how future design systems could be developed. According to this, the features implemented in Sketchand+ need further investigation. It has to be proven if this kind of technique can have a significant impact on architectural design. Thus, a heuristic for performance measurements in Augmented Reality Aided Design need to be devised to subsequently test the usability of such applications. Results and refinements will lead to new experimental implementations and prototypes. Furthermore, the work on Sketchand+ has a direct influence to the TAPframework. New developments in Sketchand+ are back-ported to TAP and therefore the developments are available for everybody as the system is Open Source.

Finally, the Sketchand+ prototype is a sketch for sketching design software. Research is going on, in order to bring creativity to virtual reality software and not leave creativity behind when “going immersive”. The creative user does not need a tool to automate thinking, rather they need an aid to thinking ahead.

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