Urban Sketcher: Mixed Reality on Site for Urban Planning and Architecture

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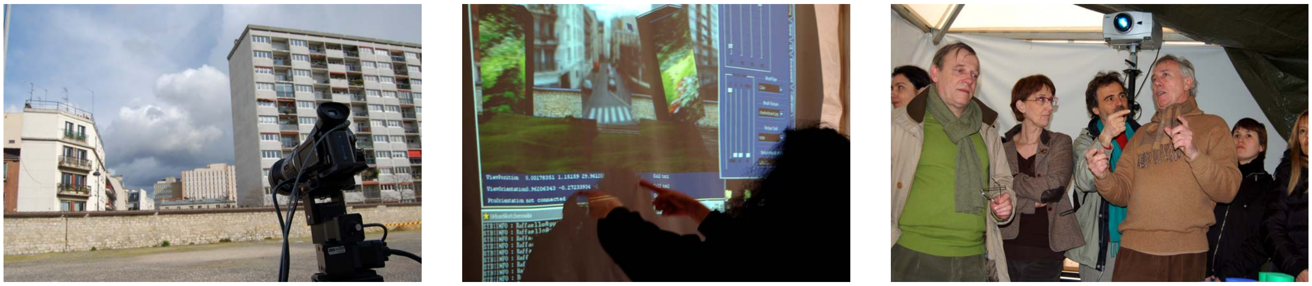

Figure 1: Mixed Reality installation on site to discuss the architectural modification (left). Using the Urban Sketcher to redesign the wall (middle). Group engaged in a discussion during the sketching (right)

Abstract

Urban Sketcher, a Mixed Reality application, is designed to encourage and improve communication on urban design among stakeholders. A mix of multimodal input devices enhances collaborative interaction in real-time, while visual feedback is given to all participants on a projected live video augmentation from Urban Sketcher. Sketching, modifying the scene on site, in the space of the video augmentation supports the exchange of information with interactive visual support. Urban Sketcher is instrumental for developing visions of future urban spaces by augmenting the real environment with sketches, facades, buildings, green spaces or skylines.

Keywords: Mixed reality, augmented reality, urban planning, architecture, natural multimodal interaction, collaboration.

Index Terms: H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems – Artificial, augmented and virtual realities; J.5 Arts and Humanities - Architecture

1 Introduction

Urban planning is a melting pot for architectural visions in progress. Stakeholders – architects, politicians, citizens and others – bring individual viewpoints into the process. The objective is to refine these viewpoints and ultimately achieve mutual consent of all parties.

In the research project *IPCity*, we are investigating the use of Mixed Reality (MR) tools in urban environments. Our hypothesis is that MR can provide communication channels for collaborative activities which are richer than conventional approaches, leading to an improved, shared vision of the future urban environment. On the site of the urban reconstruction the setup in a tent incorporates MR as well as conventional planning activities.

The MR application used is *Urban Sketcher,* an application that allows users to directly alter the perceived reality by sketching on canvases in a video see-through augmented representation of the urban scene (Figure 1). The Sketcher with the spacial registered virtual scene also serves as a common focus for all the participants to concentrate on the space currently being discussed.

The Urban Sketcher is an ongoing development and has been tested on site in a real urban reconstruction process.

2 Related Work

Commercial applications for 3D CAD allow rapid prototyping of architectural content and are integrated into the workflow of the design and visualization process of architects. Well known software packages such as Autodesk Revit,, ArchiCAD or MicroStation serve as specialized tools. However, these tools are not directly intended to serve as interactive discussion aids.

A large body of work both in research and production exists for using immersive Virtual Reality (VR) to design and present architectural models [4].

Computer-aided tools for urban planning have often been linked to tabletop displays. Interactive tabletop displays with MR capabilities [1, 9] and tangible user interface approaches have been developed to facilitate architectural education and also design negotiation [20, 8].

In contrast to these indoor "studio" setups, there is a limited amount of work that considers the use of MR directly on the construction site. A pioneering example is Architectural Anatomy [5], a tool for in situ visualization of hidden architectural structures. Later work introduced wearable computers for construction using MR displays [15, 2].

Another popular class of tools related to our work derives geometric models interactively from images or video, for example the commercial tool SketchUp[1]. Lee et al. [11] describe an MR environment for 3D modeling and texturing. However, their work considers only acquisition, but not modification of reality. Neumann et al. [13] describe Augmented Virtual Environments combining VR models with live video textures.

The idea of painting on virtual 3D surfaces has been first identified over a decade ago, for example consider [7]. More recently, dynamic ShaderLamps [3] have been introduced as a tool for projector-based MR painting. Similarly, projector-based dioramas are used for architectural simulation in [12]. Grasset et

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[1]http://www.sketchup.com

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al. [6] present an approach for video-see through MR painting loosely related to ShaderLamps. Our Urban Sketching tool is a direct descendant of Grasset's work. We transpose the basic idea of video-based painting in a collaborative outdoor situation and investigate tools and workflow for supporting actual urban planning.

3 Supporting the Urban Renewal Process

Representation plays an important role in the design process for urban renewal projects. Early stages of this process are intended to evoke new design ideas, and are the foundation necessary for exact planning. Stakeholders have their own view on the situation, but do not share a common background, nor are they able to understand conventions and vocabulary typically used by professional architects and city planners.

Consequently, it is necessary to present the current plan in a comprehensible way to all participants, and enable them to contribute to the design. This negotiation and participation should eventually lead to a joint decision, which often triggers another round of presentation and negotiation.

The key in the early phase of the design process is efficient communication of the design ideas among all participants. As Ishii et al. [8] put it: "*the urban designer is in critical need of a platform that allows the simultaneous understanding of a wide variety of representations, including drawings, physical models, and digital analysis"*. While Ishii et al. consider a tangible interface for planning occurring in a studio, we are aiming at a computer-mediated process that occurs on site, relying on MR.

3.1 Sketching interface

In the conceptual phase of design, architects often make quick sketches rather than accurate scale drawings. Sketching has interactive qualities because it can be performed during a discussion, and informative sketches can also be created by unexperienced people to a certain degree. Therefore, we decided that a sketch-based interface would be most appropriate for the intended use. The envisioned sketching should follow the familiar conventions of 2D painting programs, but the digital paint should be applied directly on 3D surfaces in the video augmented scene. In that way, the appearance of existing architecture can easily be modified without relying on 3D modeling tools, while retaining the qualities of an MR scene registered in 3D. In particular, the chosen perspective on the video see-through MR scene can be interactively modified by reorientating the video camera which is registered and therefore linked to the virtual camera visualizing synthetic content in the real scene.

As pointed out in the related work, such 2.5D-Painting (2.5D means working in 3D space while one dimension is locked static) on surfaces in a 3D scene has been extensively investigated for digital content creation of purely virtual scenes, but there is little painting/modeling work for MR scenes. An intrinsic problem of outdoor MR is that painting on surfaces in MR scenes requires an accurate model of the environment, which is often not available. Even if such a model can be obtained, it may be unsuitable for painting, because the geometry is too detailed, or because the sketch should be created in a region of 3D space that does not contain any virtual object. To overcome this obstacle, the concept of a *canvas billboard* was developed.

3.2 Canvas Billboards

A canvas billboard (Figure 2) is a simple textured rectangle with alpha channel within the video augmented scene. Originally, the canvas is placed upright in the environment on the ground plane at a user defined distance; the alpha value is set to fully transparent. The user can paint on the canvas with either a 2D or 3D input device, thus applying paint in 3D space. Multiple canvases will provide proper occlusion among each other and with 3D models of real and virtual objects.

If real objects are visible in the foreground, they should correctly occlude virtual objects and canvases with a larger depth value. This can be approximated by *phantom billboards* (Figure 3). Phantom billboards are similar to normal canvas billboards, but the applied paint is interpreted as a mask for the z-buffer, i. e., the video image shows through while the depth order with other virtual content is correctly resolved, leading to the desired occlusion effect. Phantom billboards are quickly created by placing a billboard at the appropriate depth distance to the observer, then over painting the object for which a phantom should be created and finally defining a flag indicating the phantom state.

Canvases can be filled with arbitrary user-created content relying on a variety of painting and sketching tools similar to the ones known from 2D painting applications. Users can choose from a variety of brushes and colors. After we observed that architects prefer "sketching" with thin pencil-like tools over "painting" with brushes, a special sketch mode which creates sharp thin lines with high contrast was added. Textures can be loaded from arbitrary images. The Sketcher also provides a stock library of textures such as brick, stone, wood etc. to use with painting. Moreover, predefined architectural billboards (e. g., decorative elements, plants or even whole houses) complete with alpha masks can be used to quickly populate an environment.

3.3 Urban Sketcher Interface

The intention for the design of the Urban Sketcher user interface was to enable natural interaction and a low cognitive load [18], so working with the Sketcher can easily go on in parallel with the creative process. The Urban Sketcher's interface is divided into a painting area and a control interface. While the most frequently used functions are directly available when working in the painting area, the control interface is arranged in sections of commonly used command groups, available as a tabbed dialog. The most important sections are paint tools, color palette, and scene management. The paint tools section is for defining tool types and attributes. Tool types are brushes for painting color and revealing original texture a pen for sketching and a eraser. Attributes define color and size for the pen and additionally falloff and flow for painting brushes.

The scene management has predefined quick load/quick save slots for saving and recalling the scene as well as views of interest. Despite the fact that the painting interface primarily operates in 2D, the scenes created in Urban Sketcher are composed of 3D geometry, both flat (canvases) and polyhedral stock models. Texture size is freely adjustable within memory restrictions, so more detail can be provided if necessary.

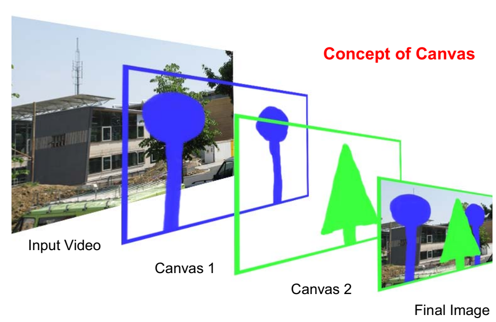

Figure 2: Mapping virtual placed canvases to the video background

4 System Architecture

Figure 4 shows an overview of the tent which incorporates the Urban Sketcher application when deployed on site. Stakeholders gather in a tent structure with sufficient space containing a large projection screen connected to a pan-tilt-zoom camera. Input can be either 2D input devices such as a mouse or 6DOF devices e.g. tracked with an ARTTrack2[2] system. A barcode scanner allows quick selection of content such as textures prepared in advance, to be loaded into the Sketcher application.

4.1 MR Framework

Urban Sketcher is built with the *Studierstube* 4[3] MR framework, which relies on a number of components, most of them developed in-house. The acyclic directed graph of OpenTracker is used for filtering, transforming and transferring multimodal device input to the Sketcher and the computer system. OpenVideo handles the video stream of the IEEE 1394 interface and provides access for the video background node of the scene graph. All persistent information such as the meta data of the stock texture library or user interface settings, are stored in a database for increased failure resistance.

4.2 Texture Painting and Performance

Painting operates directly in texture space, by determining the texture coordinates where the user intends to apply paint, thereby affecting the targeted texel and its neighbors according to the current chosen brush and color. In sketching mode, a line drawing algorithm and filter is used to create a closed curve between two consecutive points avoiding gaps or artifacts to appear between sample points due to not entirely continuous and smooth input data.

We use ray picking for determining the 3D location on the hull of the triangulated object being painted. It is needed for coordinate transformation from scene to texture space. When painting with the mouse the picking ray is cast from the camera position via the mouse position on the front plane (screen), otherwise the ray is cast according to the devices input position and orientation. The picked point is then translated into normalized texture space while taking the current brush size into account.

When an object or canvas is created the size of the texture and the texture applied for painting is set according to user preferences. Individual resolutions for multiple objects are supported. The raw image for the texture is reformatted to square

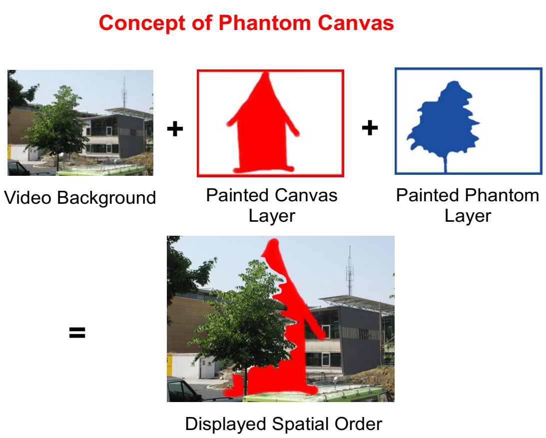

Figure 3: Phantom canvases revealing parts of the video background

[2]http://www.ar-tracking.de
[3]http://studierstube.icg.tugraz.at/

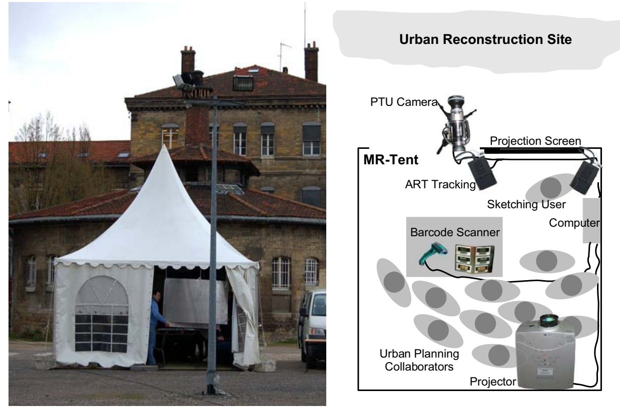

Figure 4: Mixed Reality Tent (left) Top view of tent layout(right)

size while keeping the original aspect ratio by filling in a transparent area. Afterwards resampling is done because size and resolution significantly influence performance of painting. Thus, these parameters should be selected considering available processing power and system architecture. Painting is performance sensitive and has been optimized for using multiple threads and CPU cores if available, thereby taking advantage of recent hardware developments for acceptable performance.

5 Experiences with Urban Sketcher

In the early stages of the development the setup was done inside a building with a view outside a window used for augmentation. This mock-up had a similar allocation of equipment as later on in the tent.

The outdoor field trial was located at a hospital. Surrounded by a wall, shielding the patients from the outside world and vice versa. A reconstruction of the wall to yield to a more open space is desired. The goal of the trial was to explore possibilities of modifying the wall and the surrounding space to balance openness and necessary separation of the street from the park of the hospital. The evaluation was performed by letting stakeholders experiment with the system, while they were videotaped and observed by human factor experts. The following transcript suggest what activities took place during two extensive sessions carried out at two consecutive days in February 2007 with different user groups.

5.1 Session 1

The first session was led by a professional urban planner, an associated architect at Architecture Studio[4]:

She wants to create an opening in the wall of about 25m. What will people see from the main hall at ground level of the new building? Is it like the pedestrian's view? And how would it look like from the city, when the historical part of Saint-Anne is revealed? She states the desire to be on both sides of the wall at the same time, switching perspective – looking from inside and outside.

There is an exchange with the young woman from the cultural heritage institution – to her the window seems far too large. The architect stresses that the opening will be covered by a glass surface for sound control. The opening is reduced so that a bystander can just look down the road. Then they place two towers at both sides of the opening, playing with them, testing how the perspective will work. The urban planner wants one of the towers to be slightly tilted. Next step is covering the floor with

[4]http://www.architecture-studio.fr

a green grassy texture with a slight relief and positioning a red carpet at the opening to the road.

5.2 Session 2

Major collaborators in the session of day two were: A journalist at Alternatives Economiques, a representative from Troisième Design architecture office, a general delegate of the Institute City on the Move, a person with a leading position in the Institut français d'urbanisme (Paris 8 University) and of TMU laboratory, an architect and project manager, a representative doctor of Sainte-Anne Clinic, an architect, specialist on sound, university teacher and researcher at Cresson Laboratory and a representative of the communication service of Sainte-Anne Clinic:

This session was much more cooperative, and visitors had a different outlook and appreciation. The first step was opening the wall. However this group did not care so much about the size of the opening. They wanted to design their own objects. One of the interventions was to keep the wall and build a bridge, a kind of stairway up the wall – can it be made more transparent? There is a need for a more sophisticated design, using another type of material – e.g. wood. The wall should be made higher on one side of the opening and lower on the other side. The idea of the bridge is one of a Belvedere or Mirador, for people from both sides to meet, have a view onto the other side without necessarily having to pull down the wall. A similar idea is the one of placing towers. They place several of them, they would like to make them transparent and change their size.

6 Conclusion and Future Work

We have developed a first prototype of Urban Sketcher, a MR application supporting a range of devices for collaborative multimodal interaction. Currently interactive view space modification, painting, sketching and simple content creation is possible in real-time. The spacial integration of canvas and 3D models as well as a distributable user interface were designed with respect to usability.

Overall, the trial was successful, although a long list of desired improvements was recorded. Informal feedback from the participants was encouraging to enthusiastic, and the outcome of the planning sessions was considered useful for practical purposes. While participants were in general able to to use the system, at this point instruction and supervision by the developers was still necessary. However, one must take into account that this was the first serious trial with external users, and a certain learning curve has to be expected.

The continuous process with evaluation and refinement of the application will be continued. There is a demand for tools allowing to capture colors or textures from the video background of the augmented scene. Time management between the components and optimized strategies for data and event distribution could significantly improve performance. In particular when using the sketching tool this would contribute to usability and give more room for supporting more intuitive features.

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