Urban-spatial Experiments with Digital City Models in a Multi-dimensional VR-Simulation Environment (Urban Experimental Lab)

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Abstract. *The main focus of the "Urban Experimental Lab" aims at the illustration of urban visions. Dealing with the subject city by covering past, present and future aspects will issue the programmatic approach. Equipped therewith the urban space of tomorrow is to be tackled experimentally and the spatial impact of concrete projects can be clearly visualized. The project Urban Experimental Lab represents the continuation of twenty years of experience with digital city models and experimental simulation environments for urban planning, relying on a wealth of experience accumulated in these fields. The paper describes the technical concept of the "Urban Experimental Lab" as well as desired research fields within urban planning, urban reconstruction and urban archeology and potential benefits.*

Keywords. *Spatial Simulation, City Modeling, Urban Development-Planning*

Theoretical planning background

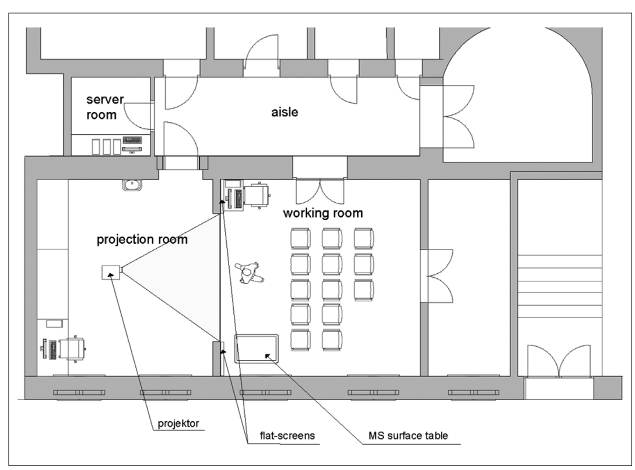
Planners and architects refer to a real, physical world with concepts and plans. Definite actions can be derived from concepts and plans whose definite realization actually changes this world. For this purpose planners and architects first of all abstract this reality by means of models and thus create working models for specific problems and substantiate their planning visions with simulations. So-called laypersons – politicians, citizens, users and investors – also take part in this process to different extents. (see Voigt et al., 2005, p.365). Simulation-assisted experimenting with urban space is to be regarded as an essential contribution to the configuration of our living environment.

There is a great need for supporting these complex planning and decision-making processes with state-of-the-art simulation equipment. The following quality criteria should be applied:

- optimum clarity and comprehensibility for laypersons and experts,
- support of decision-making processes within the team,
- combination of planning and project-related information (quantitative and qualitative information, visual and alpha-numeric information) and synoptic presentation (synthesizing overview),
- real-time simulation.

Technical concept and configuration of the lab

The research project "Urban Experimental Lab" is based on the following boundary conditions: system development is to be provided on the basis of a multi-purpose simulation environment, serving as Virtual Reality(VR)-environment, presentation



Figures a.1 and a.2: Plan of the "Urban Experimental Lab" at Vienna University of Technology, Visualization of the Lab environment and interaction workbench. The system provides interactive real-time visualizations of highly complex graphic data sets in a 3D or 4D accessible walk-through environment. Visual representation is achieved by means of 3D-rear projection. System development of the lab is performed by an interdisciplinary team combining the following disciplines: urban and regional planning, architecture, perception and environmental psychology as well as computer sciences. The team is composed of university staff and planning practitioners. The intended co-operation grants evolution in practice as well as access to meaningful know-how as available at a high performance computer center.

The “Urban Experimental Lab” is installed in an existing, 19th century-building at the Vienna University of Technology (see figure a.1). A door opening between two adjacent seminar rooms was extended to 3,30 m width x 2,50 m height to accommodate a standard flexible back projection screen. One of the rooms, the "projection room" is equipped with an active stereo projector attached to the ceiling. The other is the "working room". During the time when the 3D-projection is not in use, both seminar rooms are still fully functional with the only reservation that the back projection screen does not provide noise insulation. Most of the computer equipment is placed in a nearby server room and connected with KVM extensions.

All components are commodity off-the-shelf components:

- Projection: High resolution Projectiondesign AS3D projector, standard back projection screen, NuVision active stereo shutter glasses and emitter
- Optical tracking: Imagination IO tracker
- Visualization computers: Dell Precision T7500 with Geforce GTX 295 graphics board
- Tablet User Interface: Dell Latitude XT2 laptop
- Multi touch table: Microsoft Surface SP1

COVISE (Collaborative Visualization and Simulation Environment), a research software developed by the High Performance Computing Center Stuttgart (www.hlrs.de), is currently used as VR-software. Due to the standard hardware setup, any other VR-software can also be used simultaneously. It is planned to test other software systems in the future.

The COVISE visualization system has been chosen because of the

- optimized work flow between modeling (e.g. 3D-Studio MAX) and VR,
- easy integration of numerical and visual simulations,
- combination of Virtual and Augmented Reality,
- advanced interaction methods for architectural projects like TUI (Tablet User Interface) and tangible interfaces.

Current experiments & research fields

This VR-simulation environment is designed for experiments that provide benefits commensurate with the efforts invested.

In recent years, numerous projects have been realized in the immersive environments CAVE and single back projection of the HLRS as well as other facilities (see Kieferle et al. 2001, 2007, Wössner et al. 2004). It became apparent that beyond the visualization of simple walk-throughs, it is vital to implement

- direct interaction with the models,
- visualization of semantic information and
- interactive numerical simulations

in order for this technology to turn into a productive tool.

Sample Field 1: Real time interactive simulations

The "Stuttgart 21” urban design project (see Kieferle et al. 2007) might illustrate some of the above-mentioned approaches. In Stuttgart 21, the main surface railway lines into the city will be replaced by underground railway lines running at right angles to the current routes. Hence, wide areas in the center of the city will become available for urban development. Due to Stuttgart’s particular topographic situation with a valley-like setup, the air quality in the center of the city is very poor, especially under inversion conditions. It is essential to enable the flow of fresh air unhampered by buildings. The goal of this project was, therefore, to supply the planners with easy-to-handle tools to understand the impact of their planning on the air flow. Normally air flow simulations are calculated by specialists and take days. This makes it difficult for urban planners to understand the impact that changes in their design might have on the quality of the air flow.

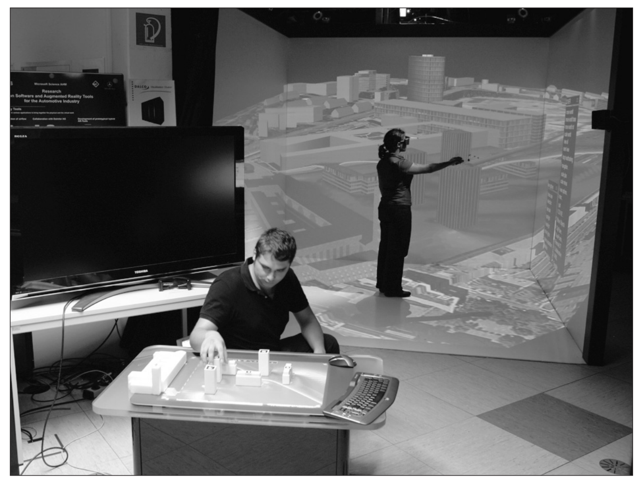


Figure b: Urban simulation of Stuttgart 21 project - visualization overlaid with the near real time simulation of air flow

To overcome these limitations, the CFD (Computational Fluid Dynamics) simulation of air flow is parallelized using a domain decomposition approach which improves the speed of the simulation by using large clusters to reach interactive response times. The partial differential equations are solved iteratively. The first, albeit very rough, results are available after approximately 15 - 20 seconds and further results become available every other second. The final, converged results can be expected after approximately one minute. It is important, particularly for non-air-flow specialists like urban planners, to introduce intuitive interfaces that allow users to work efficiently with the system. Only then can they try out a maximum number of variations, understand the impact of these changes and optimize their design accordingly. The idea was to develop an interface with elements that the planners are used to - a physical urban model. The building blocks in the urban situation can be placed on a plan of the area projected onto the touch table (MS surface) The positions of these blocks are tracked and the computational model is adjusted accordingly. The CFD results are then immediately displayed in the virtual environment on the stereoscopic projection. With further interaction methods, such as placing cuts or tracing particles, the air flow can be analyzed in detail in the virtual environment.

Evaluations showed that a combination of representation modes commonly used in urban planning - model and 3D-visualization – and non-visible information (simulation results) best supports the planning process.

In the following, we will describe two further priority fields of research and experimentation to be addressed by means of the new Urban Experimental Lab:

Sample Field 2: Decision-making Process

Urbanistic and architectural competitions play an important part in the exchange process between planning and reality. Definite projects (and prize winners) are chosen from the range of possible solutions in the course of jury sessions. The connected decision-making process amongst professionals and laypersons is lengthy and complex (see Voigt et al., 2005, pp.365).

The quality criteria mentioned above, namely optimum clarity and comprehensibility for laypersons and experts, support of decision-making processes within the team, combination of information related to planning and the individual project, synoptic representation and real-time simulation, play a significant role in supporting decisions within the context of competitions.

Sample Field 3: Urban reconstruction and urban archeology

The virtual “re-construction” of ancient settlement structures and public spaces provides essential access to space-related knowledge, which is important for the sustainable construction of our future settlements. Virtual reconstruction technology (anastylosis: from the Greek: ana = "again, anew", "back" and stylos = "pillar"; a method of restoring and/or reconstructing derelict historic buildings) allows us to rehearse different reconstruction hypotheses for archaeological objects (in their urban context) and for complex urban structures by using only digital media, i.e. without any manipulation of endangered fragments. It can be used to support the following functions: testing, plausibility, validation of hypotheses, feasibility (simulation of the reconstruction processes, the localization and visualization of the individual structural elements at their former position), monitoring and, if needed, physical reconstruction with rapid reproduction technologies. This approach introduces fundamentally new reconstruction technologies. Reconstruction of the urban past cannot rely solely on automatic modeling techniques, but also requires knowledge from the field of archaeology in combination with urban design and planning.

Figure c: Urban archeology: Anastylosis of octogon, Ephesos (ÖAI_080115 \ Thuswaldner-Kalasek)

Reconstruction will involve different levels of detail (LoD) and scale according to the available information density: at the urban scale, i.e. the city as a global container of subspaces and buildings (top-down approach); and at the object scale, where we focus on individual objects in their urban context (bottom-up approach). This two-tier approach enables a “progressive refining” of the reconstruction quality as new information becomes available, making it possible to check and reformulate hypotheses regarding the urban form of an ancient site.

The percentage of objects actually available for scanning on an archaeological site is usually very low compared to the density of objects during the actual time of settlement. While there is a heated debate as to the scientific soundness of reconstructions not based on actual, well-preserved finds, there is a growing number of researchers who acknowledge the value of virtual, computer-based reconstructions. Immersive virtual environments as described above can significantly improve the quality of these reconstructions and, most importantly, they support the dialogue between scientists. Moreover, methods to visualize the degree of certainty associated with an object or hypothesis have to be provided in order to keep the reconstruction process on a solid scientific basis. While reconstruction is based on rudimentary evidence and hypothesis, contemporary urban design and planning focus on the future development
of urban spaces based on considerations of the potential spatial perception of ensembles or individual objects.

Outlook

The main focus of the “Urban Experimental Lab” lies on integration development rather than software development. It is intended as a platform to bring together software specialists and planners from numerous fields. Particularly, it is designed to ensure closer integration of end users into the planning process. The visualization of planned projects and their impact will allow PreOEs - Pre Occupancy Evaluations - and thus enable improvement of the projects already at early planning phases. Interactive planning sessions with a high information density will support and advance the communication of interdisciplinary planning teams.

Based on the experiences with usual planning processes, we intend to evaluate the advantages and disadvantages of this new approach. The “Urban Experimental Lab” is still at an early stage, and there is a great deal of experience to be gained until the "perfect planning environment" can be produced.

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