The experience of an academic simulation laboratory

The use of visual simulations for education and research

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Abstract. An overview of the research activities of a university simulation laboratory is presented. The mission of the laboratory is to anticipate the design and to support the evaluation process of urban design projects from a perceptual viewpoint through the use of digital and physical models. We have research and educational purposes. Founded five years ago, the laboratory has implemented different simulation tools, often combining existing techniques and finding new applications of existing ones. In particular, we focused our interest on visual perception tools, investigating the use of physical models and digital ones, and combining them in different ways in order to enhance the experience offered by the perceptual simulation.

Keywords. Visual simulation; city modelling; augmented reality; game engine; simulation laboratory.

INTRODUCTION TO THE LABORATORY
At the beginning of 2007 at the Politecnico di Milano, Department of Architecture and Planning, prof. Fausto Curti instituted the Laboratorio di Simulazione Urbana (Curti et al, 2007; Piga, 2009) in collaboration with prof. Peter Bosselmann, professor of Urban Design and director of the Environmental Simulation Laboratory at the University of California at Berkeley (Appleyard et al, 1973). From then on scholars together with students, work on theoretical and experimental researches about the effects of urban transformation/renewal projects with a specific interest on the perceptual experience and the environmental quality. For instance, the main aim is to anticipate the design and to support the evaluation process through different kinds of simulations. In order to achieve this goal we integrate various digital and physical three-dimensional modelling techniques and constantly upgrade representational skills by inventing combinations of new and proven techniques. The theoretical approach is tested and reinforced through experimentation and the successful methods are applied to different case studies, both in the professional and the educational field.

LABORATORY WORK MODALITY
Most of the work conducted at our research laboratory was developed in collaboration with students (bachelor, master or Ph.D. students). In this way, the research and the didactic experiences become a unity through practice. Students in architecture and urban planning collaborate to the ongoing researches during their internship at the laboratory. Thus, they have
the opportunity to work with a professional team that instruct and drive them; for instance, the team work applied on a real job help students to feel more involved in the process and at the same time to improve their technical and relational skills. After their internship some students developed an experimental thesis at the laboratory, and few of them continued to collaborate with us after their graduation as collaborators or within a Ph.D. program.

Since its establishment five years ago the Laboratory started several collaborations with others research laboratories. Typically, they belong to the same School (the School of Architecture and Society) and to the same Department, but we started to collaborate with other Departments and Schools at international level as well.

**RESEARCH TOPICS**

Following the premises that led to the foundation of the laboratory we pursue a multilevel approach, working on the same case-study area with different scales, typologies of simulation and topics. Three main areas of interest have been identified as over-riding: perceptual, environmental and economic effects of urban design projects. At the moment we are working on the first two ones; we started to deal with visual outcomes of proposed urban design projects, then we included a study on some environmental aspects, i.e. shadowing and temperature, to study the comfort of urban public spaces, and now we are beginning a new research field on urban soundscape from a perceptual point of view.

We work on the cases using different types of simulation techniques in parallel, and looking at projects from different viewpoints. We think that this approach can support and facilitate a cross-reading of the complex relationships between urban design and the existing physical context, thus ensuring a better control of the cumulative outcomes.

We use both physical and digital models (two-, 2.5- and three-dimensional urban models) with a multi-scalar approach. We believe that the correct use of simulations can improve the whole comprehension of the different aspects of an urban project, even if a deep experiential interpretation of places is apparently very ambitious and complex. In any case, our aim is to study urban projects by using these models in an integrated way, starting from the visual and the environmental impacts. We always consider ‘time’ as a key factor: for this reason our approach deals mainly with simulations that can help us to understand the effects of urban design schemes from a dynamic perspective (Bosselmann, 1998). We work on conceptual and perceptual simulation together, and we focus on the complexity of projects in order to understand the mutual and cumulative impacts of multiple design alternatives. For this reason we privilege the use of dynamic simulations that combine and express together different effect of the urban projects in their context.

It is important to note that this approach cannot substitute the traditional one in any case; rather, it can be used in parallel with it. Each type of representation and simulation can highlight different aspects of an urban condition (Appleyard, 1976).

**CASE-STUDY APPLICATIONS**

In the few years from the foundation of our laboratory, we have worked on different case studies. One of them in particular was used as a reference to test different simulation techniques. This was the main case study we worked on, and we worked continuously on it for four years. In fact, using the same map and the same model as a base we had the chance to focus on the challenges and limitations of different simulation techniques. By comparing the outputs on the same area and on the same topic, e.g. visual effects, it was possible to better understand the different analytical possibilities of the different kinds of media used. This also represented a stimulus to develop some specific simulation tools that could integrate existing ones, already in place in the urban design praxis. The case-study area, situated in Milan (Italy), is an urban transformation project that takes its name from the site where it is located: Garibaldi-Repubblica, also known as ‘Porta Nuova’
from the historical gate close to it (Arcidiacono and Piga, 2007; Bosselmann, 2007, ibid 2008). It was chosen because of its relevance and dimension at the city scale, and because of the complexity of the project itself. Those two aspects made the case appropriate for testing our approach, methodology and tools. This urban redevelopment design project has a central location and a significant extension: 300.000 m$^2$ [FIGURE 1]; the scale of the transformation and the height of its buildings, which radically change the traditional horizontal skyline of our city, make the case pertinent to understand the potentiality of the simulation laboratory we were setting up. The construction on site was to start when we began the research in 2007, and now many parts are almost concluded. This allows us to validate the simulations we did initially and to learn something more about the correctness in the way we have processed it (Sheppard, 1989), as well as their usefulness or limits [FIGURE 2].

It is our opinion that, in dealing with these kinds of projects, our traditional decision-making process is not completely satisfying, and that the whole process and the final result could have taken advantage

Figure 1
The location of the case-study area of Garibaldi-Repubblica in Milan.

Figure 2
Two snapshots showing the comparison of the simulated outcomes of the design scheme superimposed to the real context taken in 2007 (left) and the video recorded in May 2010 with the real building under construction.
of the use of simulations to anticipate some important outcomes. Not only the understanding of some particular effects could have been better cleared to the audience, but also the sharing of ideas among the various professionals involved, as well as the citizens, could have been improved by the use of accurate simulations (Kwartler and Longo, 2008). Realistic perceptual visualization can be particularly helpful for the involvement of lay people that can have difficulties in interpreting abstract maps. Nevertheless, even when the actor involved can easily read maps and sections it is not always granted that s/he can correctly comprehend how it would be to walk along a street when the design project will be realized. Moreover, even for professionals, it is not always easy to mentally visualize in dynamic terms the different outputs of an urban transformation project from a static map, i.e. views in movement and shadowing in different hours of the days or seasons. Hence, in this direction the use of simulations, and especially dynamic ones, can become useful tools for supporting the design phase the and evaluation process. Furthermore, discussions on the project with a concrete visualization at hand could reduce the possibility of misinterpretation, and could reinforce the transparency of the whole process.

As said above, using different types of analysis and tools at the same time can favor a more comprehensive understanding of an urban design project. We used this approach in the study of the Garibaldi-Repubblica project, where traditional representational and analytical tools were applied together with simulation ones. The study was an opportunity to experiment the application of some tools, conventionally used in other disciplines (i.e. movie techniques), for urban studies purposes, besides being an occasion for designing and developing some new useful simulation tools. Those are intended to be useful both for the design phase and the decision making one, and can be applied in the professional sector as well as in the educational one.

We work both with static and dynamic simulation, since each typology can support a specific understanding of a situation, and we intend dynamism as a key factor to interpret urban conditions. For this reason we tend to use static images in dynamic terms, i.e. sequences of images to describe an urban path. To elaborate the simulation we use analogical and digital tools; for this reason a digital and some physical models of the case study were built.

**NAVIGATING THROUGH THE PHYSICAL MODEL**

Beside the work on the case study, we developed a project with a professional company (BetaNit), for realizing a micro-car able to drive and carry a micro-camera inside the physical model [FIGURE 3]. With this hand-held tool it is possible to have a stable visualization from different points of view from the maquette in real-time. The usefulness of this tool is twofold: first, it can be used to check representative subjective views in a quick way; second, it can support the participation process and the involvement of people by facilitating their comprehension of the possible outcomes of design projects. The way we mainly use it in the laboratory at the moment, is for the study of the visual effects of an urban project in its physical context. In fact, with this technique it is possible to study visuals from a fixed point in space, or to move along a street at different velocities. This approach presents some vantages and some limits: portability, the ease of use and the immediateness of the output make it an helpful solution, while the fixed eye-level (eye-level changes only if we change the scale of the model) and the characteristics of the images, i.e. medium quality and still life (people, cars, and other elements), make the overall output not completely satisfactory. For this reason, within a Bachelor of Science Thesis (Miniello, 2010), we experimented the use of physical dynamic elements inside the model. This procedure enhances the communicability of the views, but requires a small scale model, which means a large size maquette if the analysis has to be done for urban studies purposes. So this solution can be useful just in some specific cases, i.e. in-depth examination at the scale of the road.
DYNAMIC SIMULATION: COMBINING VIRTUAL MODELS AND VIDEO RECORDING OF PLACES

Realistic subjective views from the physical model are useful to easily identify the representative point of interest that can be used to conduct a deeper analysis. Then, other techniques can better explain the final outcomes of the design projects in relation to its physical context. The important paths towards the project were therefore simulated using different methods. To do that we concentrated on typologies of simulation that could produce visualizations in motion. We started using simple tools like sequences of realistic photomontages. This kind of technique is quite simple and allows to easily describe a walk in the city. Since likelihood can be confused with accuracy, it is important to pay a great attention to the correctness of the processing method. If the superimposition is inaccurate, e.g. distorted in size or location in comparison to the existing context, the visualization can lead to a misunderstanding of the real outcomes of the urban transformation (Sheppard, 1989) that would probably have an influence on the evaluation phase. To avoid this problem the render of the project should be produced in an identical way as the original photographs, i.e. point of view, target and field of view, so that the two images can be superimposed without any adjustment. If correctly produced, sequences of photomontages are a simple method to describe the dynamic visual experience of a person in the city.

One of the limits of this technique is that the visualization in motion is not fluid; for this reason, within a Bachelor of Science thesis (Canzanella and Secchi, 2008), we experimented the use of a cinematographic technical technique for urban purposes. We superimpose dynamic renders of the project to a video recording of the real context, paying the same attention used to produce the sequences of images [FIGURE 4]. This technique allows to create a virtual camera that traces out the same movement of the real one used to shot the existing context, hence the final video presents the virtual urban project on the real video. Thanks to the communication skills proper of this medium, the final output is really suitable; the video has a high quality and the richness of details of the existing context assures a better involvement of the observer. The main limit is that the view is confined to the pre-determined views chosen by the author, even if this can become an advantage if this kind of simulation is used in parallel with more flexible ones (for example interactive simulation). In this case the audience can look through the eye of the simulator, who is an expert in simulation and urban design, and so the observer can take advantage of her/his professional ability in showing important views that need to be considered to comprehend the final result of the urban project.

EXPLORING DIGITAL URBAN ENVIRONMENTS THROUGH GAME ENGINE SOFTWARE

For this reason we started to work with simulation tools that can allow an interactive use (see for instance Bishop and Lange, 2005). To do this we tested several game engines software and their potentiality in depicting urban transformation projects. The choice of the appropriate tool for our goal was made in relation

Figure 3
The micro-car equipped with the micro-camera used to navigate inside the physical maquette.
to its friendly usage and to the possibility to use ready-made models and to customize, through the use of various programming languages, some specific interactive features, lastly the capability to interact with a variety of platforms. This was the occasion to merge two important aspects of our research: composition and environmental impact of a design project, i.e. visual and shadow impact in public spaces. It is possible to use the software to take an interactive walk in the context and, with a specific interface we programmed, it is also possible to set time and season of the trip and to change it during the travel, so different condition and effects are comparable. Moreover, it is possible to jump from a point to another in the urban area and to see different alternatives of the project or to go back to the existing condition. This possibility allows a quick comparison between different situations and conditions, and gives the possibility to compare them in motion. This flexibility is really important and gives to the observer/s the opportunity to check in real time several outputs from the point of view s/he is interested in. This can help the dialog among the project, not only between professionals but also with a wider public. In this case too, photorealism is really significant for a good communication, since abstract views in perspective need a stronger process of interpretation to connect the observed view with the actual one.

**MIXING DIGITAL AND PHYSICAL SIMULATION**

One of the limits of this solution is that the perceived scene is on a bi-dimensional surface and it is impossible to appreciate its proportion in a real 3-D manner. At the moment, only the physical model can guarantee a simple interaction with physical 3-D scaled volumes and elements of the city. A frequently asked question is why we still use physical models if we can use digital ones. Each kind of medium has its own vantages and limits, and digital 3-D models can not entirely substitute physical ones, as the opposite is true as well. It is important to consider these tools as possible accomplices instead of antagonists, one versus the other. They are different media able

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**Figure 4**  
One snapshot of the video recording of the path along the construction site of Garibaldi-Repubblica with the superimposition of the digital model of the new development project.
to highlight specific conditions on the same subject, if any, and one can add significance to the other. Of course, they have common aspects too, but their own peculiar qualities make them irreplaceable.

For this reason we decided to study a simulation tool that could take advantage of the potentiality of the two different typologies of the models (physical and digital), and the occasion was a Master of Science Thesis (Cibien, 2010). This field of research started in the nineties at the Massachusetts Institute of Technology (MIT), and culminated in 2000 when the Media Lab developed the first Luminous planning table for didactic purposes (Ben-Joseph et al, 2005). This tool could mix digital and physical elements, but urban volumes were simple wireframe elements. Following the MIT direction, and exploiting Augmented Reality (AR), we developed a luminous table (‘Tavolo Luminoso’) that could use solid volumes instead of wireframe ones. Modeled scaled volumes of the urban setting are placed on an horizontal touchable screen, the luminous table; exploiting the possibilities of AR, physical volumes are directly linked to their corresponding virtual ones. In this way software elaboration, e.g. photographic base maps and shadows can be visualized in real time on the table, which is the open space at street level [FIGURE 5]. This tool is capable to join the vantages of physical and digital simulations together. The user can experience a direct interaction with the model, i.e. there is no interface like a monitor or a keyboard, and s/he can choose in a simple way which effects of the urban configuration to visualize. The visualized elements can be either static or dynamic. The ‘Tavolo Luminoso’ allows considering different aspects of an urban context together, i.e. composition and comfort output, which is one of the important aspects of our approach, and it allows to do it dynamically in real time. Moving a volume, indeed, would create a change in its casted shadows or in the windy condition at street level or both, depending on the settings imposed by the user. This can be useful, in general terms, in order to share ideas among the project, and could result particularly interesting in public participation processes or for educational purposes in architecture and urban planning.

FUTURE WORK

The visual perception of places presented in this paper is just one aspect of the experiential simulation. Today, we extend our research interest in order to include also other senses and reach a more comprehensive feedback about the human experience of places. For instance, we aim at approaching the field of sensorial urbanism (and simulation), by initially juxtaposing the sound experience (urban soundscape) to the visual one.

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Figure 5
The ‘Tavolo Luminoso’ used here to verify the impact of buildings on the solar accessibility of open spaces.
REFERENCES