Virtual Reality for Enhanced Urban Design

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Abstract

The application of virtual reality to cultural heritage, environment, and landscape planning is extremely useful to experiment various scenarios which could not necessarily be realised in the real world; both for educational and research purposes. The aim of this paper is to demonstrate how 3D representations can be utilised as a valid support for urban planners and designers in order to verify beforehand a variety of interventions or modifications for a particular area, and to establish the best strategy in order for the later to be reclaimed and re-qualified. We describe a research project concerning the colour planning in urban environment, held in cooperation with the urban furniture department of Milan City Council; the main goal was to collect the chromatic data of urban furniture inside a sample area in the historical centre of Milan and to use virtual reality to evaluate the proposed actions. In order to verify the aforementioned process, we have decided to create a model of Piazza Cordusio which is situated in the historical centre of Milan

Keywords: 3-D, Virtual Reality, Urban Planning, Colour Plan

1 Introduction

For years, the application of 3D modelling to territorial representation as well as to the interconnected field of events simulation has been an active field of investigation. With the introduction of software packages for automatic design, numerical models are increasingly replacing or at the very least complementing physical and studio models. A numerical model created by extrusion in the information system can be exported in VRML format which, in addition of being a standard for exchanging models over the Internet, can be easily converted to various formats which can be exported into a multitude of connected software packages.

The ultimate modelling phase in such a modelling process is the so-called ‘detail’ phase which aims to reproduce realistically the object both from the shape and appearance point of view. A greater level of detail can be achieved with the digitalisation, in three-dimensions, of whole sections of buildings with a laser scanner or a time of flight system. From the cloud of points generated by the scanner, it is possible to fusion the various views, to extract the original topology and to create a realistic and accurate model of the original. The definition of the digital model can also be improved with the help of photogrammetric techniques and digital photographs.

Digital models, apart from their photorealism, are able to act as true virtual prototypes endowed with behavioural and performance similarities. They allow us to observe, simulate and analyse the design project, as well as its behaviour, in a much better way than physical models, both from the visualization and a database point of view.
The further shift from the hyper-realistic model to the virtual reality system enables the planner to appraise the planning decisions in relation to the urban re-organization, including new modes of intervention in the pre-existing urban landscape.

The requirements of the virtual environments are analyzed from a conceptual and technical point of view. Among them are: photorealism, scalability (both from the virtual scene and the virtual theatre size points of view), intellectual property protection (for collaborative work), and content-based information retrieval (for database access). The architecture and the implementation of the mobile virtual environment are described; the later being grid-based.

A content-based approach is adopted for information retrieval and algorithms have been developed for the indexing and retrieval of both 3D objects and 2D images based on their 3D shape and composition respectively. Such a visual approach to information retrieval is intuitive and follows a semantic typical of art and architecture without any invasive interface since the object under consideration acts as its own interface.

The present is applied to the evaluation of the impact of the re-design of a square in the historical centre of the city of Milan in Italy.

2 Urban Landscape Visualisation

The correct representation of “land” has turned out to be of fundamental importance when the design aspect of new planning projects has to be divulged and made “visible”, not only to government officials, engineers and administrators, but to city-dwellers alike. The plans that are drawn, not to mention the technical and thematic documentations prevent large sectors of the public, which are not familiar with such an information representation, from fully appreciating the situation. The 1980s saw the introduction of systems that employ a series of instruments representing and illustrating design projects as well as new urban initiatives. Those were required in order to help the general public to better understand the “technical” aspect of the situation with a range of instrumentation ranging from plastic and digital models to geographic information systems equipped with multi-media applications; not to forget the internet, of course (Shiffer, 1992).

Starting from analytical schemes like the ones proposed by Lynch (Lynch, 1960), we have been able to re-create and utilize such concepts for the study, the planning and the modification of urban spaces such that the “best possible form” can be obtained (Lynch, 1976). Such subject matter has been improved and utilised in other research projects by employing virtual technologies. The later have been able to plan and spread the message that the design project intended to create.

Since the city and the land upon which the city lies form a reality that is difficult to describe (and, above all, to represent) an efficient analysis of the whole situation is nonetheless mandatory. This enables us to understand in a fully comprehensible way all the characteristics, features and choices that might arise during any sort of structural intervention.

The city possesses numerous pieces of information that are either descriptive or visual. In the first case, the widespread use of territorial information systems - GIS has made the management of the data related to the various features that make up the area of land considerably easier. In the second case, the use of digital models is a powerful instrument of representation and a valid form of help that enables people to see and appreciate both the current state as well as the hypothetical modifications even before the latter come into reality. Furthermore, it allows for the correct evaluation of outcomes and effects before a real intervention effectively occurs.

This is even clearer in the case of territorial representation for which the level of detail (which is the fundamental guarantee of the 3D GIS simulations) adds an irreplaceable merit to design projects (Raper, 1991; Brail and Klosterman, 2001). Indeed, it is an instrument which is of the utmost efficiency since, a part from representing a particular environment, it enables us to freely navigate as well as to observe features of interest from a variety of viewpoints. For instance, just...
consider how useful such a representation is for landscape planners and architects when they evaluate the progress of a certain phenomenon or when they evaluate the impact of an urban intervention upon the surrounding environment (Dodge et al., 1998). Therefore, its indispensability can be best understood when a high level of detail and a total level of adherence to reality are mandatory. Moreover, this hyper-realistic model allows us to reach further and get to the very construction of virtual environments (Raper et al., 1993; Kraak et al., 1999).

2.1 Urban Furniture Colour Design

The importance that the chromatic component covers in the architectural and environmental design revealed herself, also in Italy, in a strong attention towards all urban planning and design actions through the colour plan tool. The Colour Piano of Torino on the late ‘70s, represents the first attempt in Italy to give a rational answer to the façade restoration problem on urban scale on the basis of an objective historical documentation.

The colour plans drawn up later in other towns were set up, till today, as a useful town planning tools to recover colour tones, original materials and manufacturing techniques of historical buildings, to ensure the maintenance and the conservation in time, contributing to define a coherent image of the town.

In this context the Urban Furniture department of Milan city Council entrusted a study to the Colour Lab of the Indaco Department of the Polytechnic of Milan focused on the management and the planning of the urban furniture chromatic component. Those elements and handmade objects, with their own characteristic, connote and characterize the public space and represent the "urban detail".

In detail, the database manages the technical aspects related to the chromatic component using:

- NCS chromatic notation for all colours present in the object;
- other notations such as RGB and CMYK obtained by conversion from NCS;
- CIE and RAL codes, when provided by companies.

The decision to use the chromatic system NCS - Natural Colour System - in the subsequent planning phase is due to its representation as a common and shared language and as a support to visual data, through a real reference colour sample. The NCS is internationally recognized as well as the most diffuse colour standard in Europe. The information on RGB and CMYK is supplied with the purpose to offer a useful reference for colour representation in displaying and printing.

A plan which regulates the use of colour in the urban furniture elements, must also consider the relations inside a chromatic map. Therefore the Colour Lab arranged some synthetic reports to point out the perceptive chromatic dominant characterizing the furniture elements and the chromatic relationships inside elements belonging to the same functional group.

At last was created a visual representation of the whole range of the detected colours during the research in relation with the 1950 colours available in the NCS chromatic system: with this colour table it is possible to read how mostly used colours in the urban furniture could define some homogenous areas, both concerning hue and chiaro-scuro, compared with others barely used.
The study highlighted some data that form a necessary tool to perform a cognitive investigation; a preliminary action to define a colour plan to control the use of colour in the elements of urban furniture.

2.2 Urban Design through 3D Models
The use of 3D models has been for years the object of investigation in the field of territorial representation as well as the inter-connected field of event simulation. With the introduction of programmes for automatic design, the usage of numerical models has attempted to replace their physical and studio homologues (Batty et al., 1998). Consequently, the use of simulators that are more or less automatic has tried to create the right conditions to generate urban environments. Nevertheless, these programmes, based upon pre-defined libraries, find it hard to adapt to the morphological features of most Italian and European cities. Many Italian cities like Florence, Milan or Rome call for detailed and well-articulated models with particular characteristics that cannot easily be standardized.

![Visualisation of Piazza Cordusio in Milano; model with texture rendered with the virtual theatre.](image)

That means that volume extrusion models must be enriched with details and particular features which make them more similar to their real counterpart. This operation has been made possible by the creation of maps and facades of buildings (as well as photographs) which have been chosen for such experimental purpose. The photographs are used to create the necessary texture to apply to the models, a part from being particularly helpful in the definition of size and construction details. The last outcome in the modelling phase – the so-called “detail” phase – is, therefore, a digital object which reproduces its own corresponding figure in reality both in form as well as in appearance. Although the various steps have been subjected to a methodological approach, the time involved in each one of them should be taken into account as well. Indeed, in order for the research to be fully carried out, it is absolutely essential to evaluate the feasibility
of the process as a whole as well as to revise the process step by step in order for the later to be as rigorous and scientific as possible.

A greater level of definition can be achieved by using 3D laser scanning systems which enable the acquisition of whole portions of buildings as clouds of points which can be later modelled into forms. Technological processes like the aforementioned, in addition to digital photogrammetry systems (Guidi et al., 2004) have been extensively used at the Virtual Prototyping and Reverse Modelling Laboratory at the Polytechnic of Milan and they have enabled us to perfect the definition of digital models, as required. However, at this point, we have to underline the importance of exactly defining the scope and the level of detail which are deemed necessary for our modelling. Indeed, since the models are simplifications and schematizations of reality, there is always a gap between reality and the level of detail in the actual model. If the level of detail is not sufficient, we run the risk of losing the main interactions and so the model will turn out to be incomprehensible and useless. On the contrary, if the level of detail is excessive, the model will become much too complicated and will end up being just as indecipherable as in the previous case. Therefore, the definition of the level of detail is one of the most important planning steps that have to be undertaken when these models are utilised.

The fundamental characteristic of digital models, apart from the photo-realistic simulation of reality, is that they are able to act as true virtual prototypes endowed with behavioural and performance similarities. They make us observe, simulate and analyse the design project (as well as its behaviour) in a much better way than offered by similar technologies, both from visualization and database point of view.

The further shift from the hyper-realistic model to the systems of virtual reality enables the planner to validate the planning decisions in relation to urban re-organization (including new forms of intervention in the pre-existing urban landscape) by using sophisticated equipments and the aid of stereoscopic visualisation (Ceconello, 2003). The models created in the previous phase are imported in suitable software that has been studied for the digital visualization of re-constructed environments on a large screen in a virtual theatre. At this stage, an interactive real-time navigation through the virtual re-construction clearly indicates all the potential problems that a planning operation may bring about in any particular urban area while offering the best type of solution in the most suitable context. It is easy to visualize the different proposals in their natural sequence and to single out the most appropriate. A further merit stems from the fact that results and planning activities are now provided for the benefit of a non-specialized public. In addition, because the outcome can be export in many formats, a variety of packages and applications can be utilised and link; for instance with GIS databases.

In order to verify the aforementioned process, we have decided to create a model of Piazza Cordusio which is situated in the historical centre of Milan. The basic idea was to use the virtual reconstruction in order to evaluate the re-design of the site without doing drastic intervention by trying to understand if colour could help to improve the appearance and the perception of the site. Elements such as traffic lights, benches, lampposts, just to mention a few, can generate visual noise. For this reason, a purposive sampling of all the objects and a study of the colour map of the area was carried out.

Starting from digital cartography, the model was created adding more accurate information from drawings and plans of the buildings: the simple process begins from the extrusion of the buildings plant according to their height obtaining the square appearance by volumes. In order to add details on the façades, a lot of pictures were acquired with a digital camera in order to improve a better definition of balconies, ornaments, and complex shape, rendered with textures.

While creating the model, it was decided not to use laser scanners and photogrammetric techniques because, at that stage of the project, the focus was to validate the whole process from
the urban planner point of view, without excluding the use of more accurate and sophisticated methods once its applicability has been verified and demonstrated.

The model thus obtained was optimized to create photorealistic renderings of the scene and high-quality movies in order to present the project with traditional supports and without requiring sophisticated instruments.

The next step was to convert the models obtained in the previous phase in a format suitable for real-time rendering software: once the urban scene has been loaded into the virtual theatre, the user is able to navigate into the scene while visualizing the three-dimensional elements in stereo. By simply pressing a key, the user can switch between various scenarios so that the best proposal can be identified.

Since the models are in the VRML format – Virtual Reality Modeling Language - they can be easily exported into other applications for complementary results.

Finally, the textured models were integrated in the municipality GIS. In the present case, the GIS integration was completed with the ArcGis 9.1 environment. By following this approach, it is possible, in the long run, to create a digital model of the entire city.

3 Conclusions

Our approach greatly facilitates the evaluation of various scenarios of urban designs with problem solving purpose such as restoration.

Our results confirm the innovative aspect of our research. With virtual prototypes, it is possible to evaluate the most relevant scenarios in real-time on a cognitive basis. As a matter of fact, the planning action needs a support either in the analysis or in the presentation of the results. Digital tools are able to replace maps and physical models merging together shape and functions, as they allow conveying the iconic description of the real entity with its analytic definition through the use of connected databases (Batty, 2007).
The result of the presented case study is a flexible model tested mainly on two different systems: the first is a virtual reality immersive experience in a virtual theatre with a Cad wall and an active stereo equipment; the second is a portable passive stereo system made by a depolarising screen and two interconnected laptops and two DLP video projectors equipped with polarised filters. The scene can be visualised in three dimensions with the corresponding passive stereo glasses.

Virtual reality gives a great emphasis to the project but is a niche market which involves specific technical know-how, customization, dedicated hardware and software; these reveal its expensive nature and limit its applicability to fields traditionally related to the IT sector. The second approach doesn’t allow an immersive experience but is more affordable and very usable: the hardware is standard and does not need the support of a skilled technician and the interface is self-explanative and intuitive.

Our intention is to suggest an integration of these visualization techniques in the normal practice of a planning office in a City Council. In the normal course of activities, the use of GIS supports decision making is extremely useful for managing planning tasks. Virtual reconstruction and presentation of possible intervention on the fabric of a city, gives the city manager the chance to visualize its impact. The project can be considered a test bed to verify a process in which these items could be put together in order to create a “best practice” in urban planning.

Figure 3. Query of a 3D model with textures in a GIS.

The research is currently in an ongoing phase and, as we speak, this approach has been applied to the historical centre of Milan, and has been evaluated positively both by technicians and city managers employed in urban planning. From this case study, there is an opportunity to initiate more complex activities in order to evaluate various scenarios for the restoration of ancient buildings façade in the historical centre of Milan. This method has not been used with citizens, even if we think it could be very helpful as a mean for divulging and explaining all the planning activities to a non-technical audience.
4 References


