Perception and Cognition in Real and Virtual Computer Generated Architectural Space

An Experimental Approach

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This paper investigates the difference of spatial perception and cognition between virtual and real architectural environments. Specifically, three different aspects have been studied, concerning the live perception and cognition of a complex actual building, the perception and cognition of a high quality rendered virtual space, as well as the perception and cognition of a non-photorealistic virtual environment. To study the differences between these three types a series of experiments were prepared, in which students of architecture participated and statistical results were drawn. Earlier studies have investigated the desirability of key simulation attributes for architectural design visualization, but extensive research on what contributes to a better spatial comprehension is still missing. This experiment is part of a series of experiments mainly focused on the perception and cognition in virtual spaces. The results of these experiments were correlated with each other, each one leading to new ideas of experimentation. Preliminary results confirm earlier findings from previous similar experiments. It was found that there was a statistically significant tendency of the students towards larger scatter in more luminous virtual space as well as a tendency to visit the lit part of virtual space. Visitors of the photorealistic spaces also seem to have better knowledge of the depth of space in comparison to those navigating in the non photorealistic space.

Keywords: *Perception; Cognition; Virtual Architectural Space; Real-time Navigation.*

Introduction

One of the aims of architectural education is to develop the ability to visualize space. The media chosen for representation can have a significant impact on the creative process (Rice, 2003). The primary goal of architectural education is to develop the ability to accurately perceive scale and spatial character through design representations and therefore an appropriate form of representation has always been important for architects and designers. In architecture, 3D simulation is thought as a tool for intuitively conceptualizing 3D space (Kuo & Levis, 2002). Virtual environments have proven to be efficient for training and developing skills in three-dimensional spaces (Seidel and Chatelier, 1997; Winn, 1998) and thus constitute a necessity in every architectural practice. These applications require students and professionals to become familiar with the characteristics of computer-generated environments and to apply their knowledge to the real world. The differences of real and virtual environments have been the topic of several studies that have focused on distance perception, navigational awareness, landmark recognition, spatial ability, interface expertise, way finding and the individual differences of users in prior experience towards computers (Leach, 2002).

This paper investigates the difference of spatial perception and cognition between virtual and real architectural environments through the use of experiments. Specifically, three different aspects have been studied, concerning the live perception and cognition of a complex existing building and the perception and cognition of its virtual counterpart concerning photorealistic and non-photorealistic rendering techniques, which can be customized according to visualization and interactivity parameters. To study the differences between these three types a series of experiments were prepared, in which students of architecture participated and statistical results were drawn. Earlier studies have investigated the desirability of key simulation attributes for architectural design visualization (Kalisperis et al., 2002), but extensive research on what contributes to a better spatial comprehension is still missing. This experiment is part of a series of experiments mainly focused on the perception and cognition in virtual spaces (Liakata - Pehlivanidou et al., 2005). The results of these experiments were correlated with each other, each one leading to new ideas of experimentation.

Perception and cognition in real time interactive navigation

The complete navigational knowledge of an environment is known by the term navigational awareness. There are two types of navigational awareness: the first is procedural, which is ego-referenced and is usually acquired by the exploration of a new area, and the second is survey knowledge, which is acquired after multiple exploration of an environment using multiple routes. The differences between the procedural and survey knowledge is that the person who has procedural knowledge can move successfully from one landmark to another but does not know alternative routes. Survey knowledge characteristic is that it is world referenced. Therefore, although the trainee who acquires procedural knowledge can navigate through the 3D model successfully, it is the survey knowledge which is referred as a "primary" experience in a virtual space (Presson and Hazelrigg, 1984). The reason for better judgment of distance for a specific route traveled is because learning is formed by sequential travel. Knowledge of relationships of places along this route is unidimensional, thus a student will be better at recalling when it is in the direction they learned the route (Allen and Kirasic, 1985).

To reach the level of navigational awareness by exploring a 3D model in a VE, the trainee must go through a process called dynamic process or "Sequential and Hierarchical" model, as described in Siegel & White (1975). To achieve this, four steps are required. The first and second steps are necessary for the procedural knowledge and the third and fourth for the survey knowledge. The first step is landmark recognition, where objects become landmarks for their distinctiveness and their personal meaning (Lynch, 1960). The second step is characterized by the routes and links formed as the trainee is traveling between two landmarks. The third step is the primary knowledge acquired by the significant traveling through the routes in the VE. The fourth step is the secondary knowledge which involves the use of maps in order that the trainee learns more about the VE. The above process, which is subliminal in real space navigation, can be represented in real-time virtual environments using customizable visualization engines that can depict representations of reality, as well as schematic non photorealistic representations.

Photorealistic vs. non-photorealistic rendering techniques

In the present experiment, apart from the live navigation in a real building, two different aspects of real-time navigation have been studied, the first being a photorealistic representation of the real building with lighting, materials and shadows, while the second being a non-photorealistic representation of the same building. Foley et al. (1990) argue that realistic images can support designers in evaluating new products (e.g. car designs) by replacing model building with computer generated images. This is certainly true in some cases, as for instance for special effects in movies, where the aim is to seamlessly fuse computer-generated elements with filmed material, but in general it only considers part of the imagery traditionally used in the cited areas. For instance, it may be useful for architects to be able to generate photorealistic images of the finished building, but during the design process they prefer to work with sketches and conceptual drawings that are better suited for explaining the basic concept of a new product or showing its inner structure.

On the other hand, non photorealistic rendering techniques offer a way to exclude all the above information of colour, materials and lighting and concentrate on the perception of shapes and patterns. By using the Gestalt theory (Solso, 1979) the perception of a non photorealistic virtual environment can be studied through the following principles:

Simplicity: A visual pattern is always perceived in the way that leads to the simplest possible structure. For instance a form is normally perceived as a rectangle in 3D space, because a rectangle is simpler (due to its regularity) than a form with unequal lengths and angles.

Proximity: Visual patterns that lie close together are grouped together.

Similarity: Visual patterns that share some properties are grouped together. These properties can for instance include form, colour, orientation and size.

Direction: Elements that are arranged along a continuous, smooth direction tend to be seen together.

Common Fate: Elements from a larger group that behave in a similar manner tend to be grouped (e.g. dancers moving in the same direction)

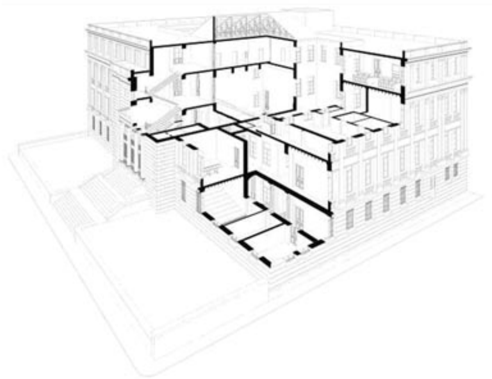
Objective Set: An organisation that is seen in one setup tends to be propagated to a similar setup if it is presented immediately afterwards.

Critics of the Gestalt theory reproach it for only being able to explain visual phenomena, but not to predict them, because in complex situations more than one principle could be applied to the same setup, leading to different results. In computer graphics, these principles could be useful for deriving better depiction methods for applications where it is important to emphasise the relationships between different elements. Therefore, to study which is the optimum way to perceive and navigate through a virtual space, the experiments in this paper focus on both photorealistic and non photorealistic virtual environments, as well as navigation in real environments.

Methodology

A basic requirement for the experiment was the objectivity of the results. For this reason the navigation was proposed to take place in a building that was not familiar to the students which would take part in the experiment. The building chosen was the Chimion building on Solonos Street in Athens, which is now closed to the general public. The Chimion is a 19th century edifice originally built to house the Departments of Chemistry and Physics of the University of Athens. Founded in 1887 and completed by 1890 according to the drawings made by Ernst Ziller (University of Athens, 1923), the building has suffered a major conflagration shortly after its completion and has been renovated twice. Each time a new floor has been added, so that the initially two-storey building is actually a four storey one with totally altered proportions and aspect.

Figure 1
Cutaway perspective of the Chimion Building model.



The study of the Chimio, including on site surveys and archival research together with a proposal for its restoration, has been the subject of a Thesis for the Master's degree in Conservation of Historical Towns and Buildings at Raymond Lemaire International Center for Conservation in Leuven, Belgium (Mikrou, 2003). To facilitate this study a 3D Computer Model has been generated.

The model was produced from a survey by hand-taped measurement and was meant to serve as a data base in which, as much of the accumulated information as possible could be stored and thereafter easily retrieved. The constitutive elements of the historical building, its structural and morphological characteristics, its past, its phases and its actual state of conservation have been incorporated in the model.

The building has been modelled in ArchiCad 8.1, while the exterior moulding profiles, the cornices, the entablature, the pilasters and all other decorative elements have been modelled in Archiforma. The drawing of any non-easily accessible exterior or interior decorative element has been based on photographs processed and rectified in ArchiFacade. All of the windows, internal and external doors have also been separately modelled since they were of rather particular designs and therefore not available in existing libraries. The same applied for the cast iron balustrades and posts of the main internal staircase and the railings of the front fence of the building. The permanent equipment of the Chimio, including workbenches for experiments, three different types of cast iron seats, each in one of the three different lecture rooms, books and display cases has also been separately modelled. In this way, it has been possible to generate thereafter all necessary drawings for the documentation of the building, including orthogonal views, plans, sections and elevations but also hidden line external and internal axonometrics and perspectives (Figure 1).

Other than the initial use of the model as a database meant to serve both the documentation and the restoration project, the idea was that this should also be possible to serve as a virtual environment where real time navigations could take place. The basic obstacle for this aim would be the level of detail. The documentation and restoration project required a very high degree of detail whereas such detail not only was unnecessary for a virtual environment but, most important, resulted in a high polygon model that could not be used for VRML exports. Thus, such elements as doors and windows, railings and floors, usually rich in ornamentation but flat or almost flat in geometry, were individually rendered -in both photorealistic and hidden line representations. Then the saved images served as textures to be applied on plane surfaces that would replace the respective complex objects. In this way –using the adequate layer combinations- several of the components of the building could be represented by either the original 3D object or the respective plane surface.

In the present experiment two groups of students were formed (statistically equivalent) and asked to make a real-time navigation through the Chimion building, while their actions were being recorded. The first group navigated in real time through the virtual building, which was rendered photo realistically, while the second group navigated also in real time but was shown an abstraction of the visual information shown in the previous group (Non-photorealistic representation). The method of non-photorealistic representation (NPR) was included in order to identify parameters that are used for movement through a virtual space without the interference of lighting, shadows, colours and textures because NPR methods allow us to emphasize or omit detail in order to communicate information more effectively. The visualization engine that was used in this experiment was able to be configured as far as the shaders were concerned, while it provided a realistic real-time output that could be navigated through an html browser (Figure 2 and Figure 3).

Both groups were monitored during the navigation process and their actions were recorded in real time, both for the virtual camera movement and the point of interest movement so as to determine possible distractions of the intended movement, such as detours to identify possible objects in a room, vertical movement to understand vertical access points and others. Therefore, a simulation of each navigation was available for evaluation along with a questionnaire completed by each participant to determine previous experience of navigating in three dimensional space, as well as her/his impressions of the navigation.

The goal of this experiment was to distinguish the differences between the two groups in the routes they chose, the places that where disorienting and how the representation of the model influenced their decision according to their perceptual field, which corresponds to their perception of form, order, succession and variation. Additionally, their depth and distance perception was noted, along with how many objects they remembered finding during their navigation in the 3D model.

The next step of the experiment, which has not yet been completed, involves the use of interactive features in the walkthrough (such as operable switches, animated objects, controllable illumination etc.), as well as taking the students on site at the actual building in order to perform the live walkthrough of the real environment and compare the results of the three different navigations. In this last navigation each student will be recorded by a digital camera while she/he is performing the live walkthrough. These recordings will be analysed and individually compared for every student with the respective recording from their previous navigation in virtual space. This comparison will provide statistical results on the orientation, the perception, the cognition and the preferences of the students concerning their navigation.

Figure 2
Photorealistic example of the Chimion building front façade.

Figure 3
Non-photorealistic example of the Chimion building

Conclusions

Preliminary results from completed walkthroughs reveal that the students that navigated in a photorealistic representation (PR) environment got a better understanding of depth in the VE than those that were given the NPR environment. An additional proof of that is that those students did not feel the need to travel close to an object which was far, but visible, from their position. More specifically, any object in their line of sight could be identified from a distance and therefore the students considered that they did not need to view it any closer. The opposite was true in the majority of the NPR cases, in which the understanding of depth was ranked lower than in the case of PR.

Another interesting result which emerged from this study was the finding of a general tendency of students that participated in the PR part of this experiment to visit spaces with higher luminosities. This can be attributed to the fact that humans are attracted to light and brightness. Therefore, apart from circulation areas, the ones that were visited more often were those with high contrast between shadows and direct sunlight. A general rule of thumb can be made that visitors tended to scatter more in high luminosities. NPRs have higher brightness in comparison to PRs, under the same conditions, because lighting conditions, shading and colours are not shown and thus the scattering in the NPR walkthroughs was higher. As a result, if someone is asked to explore a VE thoroughly a NPR is most probably a better choice of representation than a PR.

These preliminary results confirm earlier findings of a similar experiment that used an image based navigation system (Liakata – Pechlivanidou et. al., 2005) for a smaller scale virtual model. As the experiment continues, more results will be available concerning the effect of interactivity in the perception and cognition of virtual spaces, which will be compared to the results expected from the live walkthrough of the real building.

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