Spatial Navigational Patterns Induced by Real and Virtual Architectural Environments

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Abstract. The scope of this paper is the identification of elements in architectural space that can trigger human behavior in both real and virtual environments. These elements can be either material, such as shapes and volumes or immaterial, such as light and shadow. Our research depends on a series of experiments taking place in an existing architectural environment (a high-school) and its virtual counterpart, focusing mainly on the spatial perception and cognition by the subjects through real-time navigational means. The aspect that survey knowledge (spatio-exploratory or exocentric perception) is “primary” in virtual environments seems to be confirmed. It is indicative that in the virtual environment the movement of subjects (primarily visitors) is related and defined strongly by specific architectural elements, such as a stoa and the staircases, while being strongly exploratory.

Keywords. Virtual environment; 3D simulation; immersive environment; navigational pattern.

Introduction

One of the aims of architectural education is to develop the ability to visualize space. A major component of this visualization is the ability to view the environment from different perspectives. These perspectives include exploration of the environment in an egocentric (self to object) manner, in an exocentric (object to object) viewpoint, or combining the exocentric view with the egocentric view (Gluck, 1990; Darken, 1998).

The media chosen for representation can have a significant impact on the creative process. 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 of as a tool for intuitively conceptualizing 3D space (Kuo and Levis, 2002). Virtual environments have proved efficient for training and skills in three-dimensional spaces 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.

This research investigates the difference of spatial perception and cognition between virtual and real architectural environments. Specifically, two different aspects have been studied, concerning the live perception and cognition of a complex actual building and the perception and cognition of a high quality rendered virtual space. To study the differences between these two types a series of experiments were prepared, in which students of architecture (visitor subjects) as well as high-school students (resident subjects) participated and statistical results were drawn. Earlier studies have investigated the desirability of key simulation attributes for architectural design visualization (Kalisperis et al., 2002 and Pehlivanidou et al., 2005), but extensive research on what contributes to a better spatial comprehension is still missing.

**Experiments - Methodology**

**Experiment I**
The identification of the parameters that influence human perception and movement behavior was initiated through the development of two discrete experimental fields, the first focusing on the real world, while the second on its virtual counterpart. Moreover, for this study a specific building was chosen which offered not commonly found interior and exterior spaces, and was three-dimensionally modeled so that it could be used as a basis for virtual navigation research. Furthermore, the real building navigation should offer several different possible routes, so that subjects navigating through the building are not constrained by the buildings’ configuration. The building chosen for the experiment is a high school, designed by the well-known Greek architect, Takis Zenetos, in 1969, shown in Figure 1. The innovative, at the time that it was constructed, building has a very simple circular outline dominated by the internal courtyard, which is surrounded by the classrooms and the school’s administration offices. For practical reasons, the study area was confined within the circular courtyard of the school.

With the building as a starting point, two distinct experiments were developed, the first concerned with the study of navigational patterns inside the real building, while the second concerned with the study of real-time navigational patterns within a three-dimensional model of the same building. The first experiment focuses on recording the movement and the behavior of the building users – mainly the students – which are by default used to the functional, configurational and morphological structure of the school, and thus, decision making for orientation and direction is subconsciously processed (Wickens, CD, 1992). The means that were used for recording were 3 digital still cameras, fastened on tripods at the circumference of the roof of the building, programmed to shoot every 5 seconds (Figure 2), as well as two human observers, taking notes, to correlate the data with the cameras, and recording additional data, such as gender, number of people in groups, starting and ending points and weather conditions (Figure 3). The route details were transferred to a CAD file, which provided the basis for the

*Figure 1*
The high-school designed in 1969.
Figure 2
Sample photograph sequence of the movement in the courtyard with a time-lapse of 5 seconds

Figure 3
Schematic plans of the courtyard with descriptive movement routes representing two different school breaks

Figure 4(left)
The 3x3 meter grid placed on the plan of the courtyard

Figure 5(right)
The grid perspectively superimposed on observational photographs.
final transfer of all data to a GIS system. The accuracy of the transformation of the data was controlled by a 3x3 meter grid placed on the courtyard (Figure 4) that was perspectively distorted to fit the observational camera angles as shown in Figure 5. The GIS system provided the means to accurately visualize the data, through a pre-defined time-lapse of 5 seconds, as with the actual recording, thus providing with a tool for analyzing each route according to the following factors:

- Date, time and weather conditions
- Gender
- Starting and ending location
- Time necessary to cross the courtyard
- Shading on the courtyard
- Geometry of the building
- Exits

Experiment II

The second experiment involved the creation of a virtual counterpart of the first experiment. The method, that was used, was real-time navigation of a photorealistic three-dimensional representation, using large stereoscopic projection screens (6m wide x 2m tall) as shown in Figure 6.

The three-dimensional model was reprocessed extensively to be used with real-time navigation software. More specifically, all polygons of the original model had to be optimized and reduced to an absolute minimum, so that any conventional high-end pc could cope with the advanced real-time rendering required. This technique started by using polygon-reducing software, but no real-time visualization package could withstand the size of the model. The final reduced polygon model is shown in Figure 7.

The second stage involved the synthesis of the materials and their application to the three-dimensional model. For this, several pictures of the real building were shot at certain lighting conditions and were later processed in image editing software to produce image results that could be applied to the model. The model was then texture-baked and all materials were applied to the geometry of the building, thus, including more realistic materials for the final model. Lighting control was applied directly to the real-time navigation software Zermatt (www.zermatt.se). The software produced a final executable file, in which one could navigate in a photorealistically rendered three-dimensional environment (Figure 8), while being able to control natural lighting conditions by specifying the azimuth and angle of the lighting source.

The properties for navigation were defined as follows:

- Navigational controls were keyboard and mouse
- Navigation length was 2 minutes
- Entry point was the main entrance of the school
- There were no limits as to where one could go
- Data recording was done by screen video capture software

The experiment was completed into two phases, in order to study navigational relationships between two different target groups. The first phase involved students of architecture, who had knowledge of the building from photographs and drawings, while the second phase involved resident students of the school, who had a real life navigational experience. The results of all experiments were compared to each other as follows:

- The navigation patterns in the real building by the resident students were compared to the
navigation patterns by the same students in the virtual counterpart.

- The navigation patterns of the architecture students were compared to the navigation patterns of the school students.

**Results**

According to the experiments that took place both in the real and virtual space, the results can be grouped into two comparative observation clusters (*real vs. virtual* and *virtual vs. virtual*). In the first case, the school students were observed in the actual environment of the school as well as in the virtual environment of the school. Moreover, the second case included both groups of architecture students and resident school students who navigated in the same virtual environment (Figure 9). The following observations derived from the juxtaposition of corresponding diagrams, photographs, questionnaires, GIS videos etc. that represented the subjects’ movement either in the physical school or in the virtual model of the school.

**Real vs Virtual**

In the real school environment the following have been observed:

- Students’ movements during short breaks are mostly located at the perimeter of the circular yard, whereas during long breaks, their movements are spreading towards the centre.
- Movements whose track crosses the centre of
the circle from one peripheral point to another are usually targeted to specific places such as the administration offices, the canteen etc.

- Movements that include traffic points e.g. the staircases and more particularly the canteen are very common.
- The stoa, which surrounds the yard, constitutes an architectural element of great impact on the way that the students move, either during periods of significant sunlight or shadow (Figure 10).
- Because of the harsh lighting conditions the highly lit and reflective centre of the yard is rarely used as a standing area, in contrast to the stoa, which accommodates circulation of the students.

In the virtual model of the school, the high-school students, while navigating one by one, presented the following behavioral characteristics:

- Students tend to navigate as if they were in the actual space of the school, without evaluating the virtual characteristics of the school’s model. Moreover, the navigational speed matches their movement in real space (Figure 9).
- Additionally, as the students directly perceive the characteristics of space, they avoid the centre of the circle and maintain a straightforward movement (Figure 11).
- The stoa still constitutes an architectural element that determines the course of the students’ movement (Figure 11).

Virtual vs. Virtual

In the case of university students navigating in the same virtual environment, the following remarks were made:

- The students are navigating freely in the circular area, as they are temporarily staying and crossing the centre of the circle (Figure 12).
- The stoa significantly contributes to the students’ navigational paths along with the staircases.
- Some of the students visited the interior space of the classrooms; nonetheless the majority was not interested in repeating this step.
- The speed of their navigation was rather slow as they were probably not accustomed in using input device for such purposes.

An on-going comparative research is still taking place concerning the movement behavior within the physical environment between groups of students of the respective high-school and visiting students from the School of Architecture NTUA.

Unfortunately, the sample of the university students is at the moment very small; however, some indications allow us to induce that the circular shape of the school yard; that is its geometry, influences the navigational pattern. It is characteristic that movement along the perimeter is very common as well as standing at the centre or crossing it in an exploratory disposition.
Conclusions

In the real building navigation is related to the parameter of physical light. More specifically, shaded areas seem to play an important role in selection of paths as well as standing spots. In the virtual experiment light and shading seem to have a minor effect being surpassed by the subjects’ strong navigational-exploratory disposition.

In the real environment mobility is associated to the duration of school-breaks. During short breaks movements are more targeted and the yard is only traversed. During long breaks the courtyard is used by groups whose movement is more dispersed. The centre of the circle is avoided while movements are mainly targeted towards staircases and openings that lead to the open yard. On the contrary, within the virtual environment the subjects avoid standing and movement is more exploratory.

The comparative studies of the results between the two experiments lead to the following conclusions:

Movement and daylight
The results show that movements are closely connected to the preference of shaded areas (like the stoa) in spite of the mild and clear weather.

In the case of the navigation in the virtual environment, lighting conditions were stable and did not affect the users’ behavior of both groups, especially because of the strong exploratory disposition of the university students, as well as the disposition of the school students to identify known spaces. For these reasons, it can be deducted that lighting had low

Figure 11
Buffer of 90cm recorded on break 08:00-06.05.08 and 08:45-06.05.08 respectively

Figure 12
Buffers (90cm) of the students navigating in the virtual environment
influence for this case.

**Choice of direction based on space geometry**
It is noteworthy that the center of the circle in the real space has been avoided whereas the main direction of most movements was towards the staircase that led to spaces with diverse uses (canteen, sport courts etc). In contrast, in the virtual space virtual users navigated without making any stops, while in several cases they traversed the circle in order to reach points of interest such as staircases and corridors in the perimeter of the courtyard. Therefore, it can be noted that exploratory movement was predominant in the choice of direction instead of other parameters such as light or spatial geometry.

**In relation to current kinetic behavior and visual perception theories**
In the case of high school students the exploratory interest did not prevail, thus their navigation was driven by the verification of spatial characteristics and uses. This group inquired a more detailed representation similar to a 3D video-game environment. Subsequently, their mental maps were developed and rigid. On the contrary, the university students behaved in a more exploratory way while navigating in a building whose spaces are only familiar by floor plans and pictures from academic sources.

In general the experiments can confirm that in virtual space the spatio-exploratory (exocentric perception) is the primary experience, as implied by Presson and Hazelrigg (1984). The characteristic of spatio-exploratory knowledge is that space is based on references, experience is obtained after multiple exploration using diverse routes. In particular, movement and orientation are judged by parameters not related to the body, but instead on parameters, which are defined by the characteristics of objects. This is revealed by several elements such as:
1. The fact that navigators’ movement in virtual space is exploratory.
2. The fact that movement seems to depend on architectural elements such as the stoa and the staircases.
3. The fact that spatial geometry is not taken into account as strongly at the virtual space as in the real space.

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