Analyzing urban daylighting ambiences by walking in a virtual city

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ABSTRACT

The urban environment is defined by the interaction between the city morphological characteristics and its physical behavior based on the human interpretation. Contemporary psychology emphasizes the relation between perception and action and shows that perception can be enhanced by the receptor's motion. Basing our work on these principles, we assume that virtual reality techniques, bringing both immersion and interaction to static computer generated images can be of use to study solar effects and therefore daylight ambience. In this paper, we show the methodology for solar effects analysis in both real and virtual world and build demonstrators to compare the emergence of solar effects.

Keywords: solar effects, urban planning, navigation in virtual environment, methodology, visual perception.

Index Terms: J.5 [Arts and humanities]: Architecture H.5.1 [Multimedia Information Systems]: Artificial, augmented and virtual realities

1 INTRODUCTION

The urban environment is defined by the interaction between the city morphological characteristics and its physical behavior (lighting phenomenon) based on the human interpretation (cognition). Contemporary psychology emphasizes the relation between perception and action and confirms that perception can be enhanced by the receptor's motion [6]. Psychophysical interaction creates a complex urban space that might be fully understood by over-layering the perceived information we gather while walking and moving. In the architectural and urban field, several studies analyze the urban space with visual dynamic perception. These studies prove that walking can be a tool for reading and evaluating public space [7, 3]. Most of these studies however ignore the physical impact on that evaluation, and especially the impact of light on visual perception. They are limited to existing built environment and therefore impossible to apply at design phase.

Virtual Reality techniques allow virtually changing space, time and interaction type. Thus, the use of virtual environments has become an opportunity to realize series of "controlled" experiments, disconnected from the real world in which it might be particularly difficult to reproduce the same situation.

Our goal is to develop an immersive tool that uses dynamic visual perception to determine the impact of the solar effects on space acknowledgement, i.e. we try to evaluate urban daylighting by using VR techniques: we attempt to compare solar effects visual perception in a real urban path with its representation in a virtual one in order to extract the characteristics of those effects. As our first experiments lacked of free motion for the observer, we have built a new demonstrator introducing the virtual guide metaphor [2] in order to get better interaction and thus immersion.

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We will introduce daylighting ambiences and solar effects and try to summarize works related to visual perception of urban spaces. We will then describe our methodology for evaluating daylighting ambiences in order to build a future ambience design tool. At last, we will present our demonstrators and the results of our enquiries.

2 BACKGROUND

2.1 Daylighting ambiences

The concept of the "Ambience" has been present in the fields of architecture and urbanism for the last 10 years. The definition of the term "Ambience" implies the character of a place and its qualities. It takes into consideration the environment, the atmosphere, the feeling, the surroundings, the character and the mood of the observers and the way they express it. All of these factors make the ambience a difficult and complicated concept. Six fundamental dimensions of "ambiental phenomena" are defined: Environment, social interactions, actions, physical signals, perception and cultural representations. We are trying to simplify the study of these relations and consider the Architectural and Urban Ambience as the interaction between the built environment (the mixture of volumes, shapes and materials that form the cities), the physical signals (wind, light, sound, pollution etc.) and their physical and cognitive representation by the human sense (Figure 1).

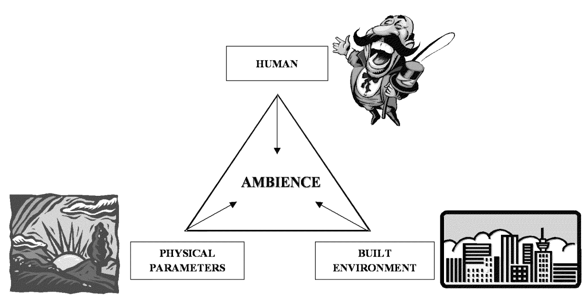

Figure 1: The architectural and urban ambience.

From that logic, the sun envelops the city morphology and consequently creates a various nuance of shades and contrasts. It reaches surfaces and forms with two phenomena, an objective one, which is the lighting, and a subjective one, which is the light. The association of sunlight (level and distribution of the luminance, form and color of the lighting) with the space (shape and color) from an observer point of view creates a physiological and psychological environment. As a result, the daylighting ambience concept is defined by the position of a human being in a specified space and his visual perception of environmental daylight.

2.2 Solar effects

The notion of *effect* in architecture is not new, this notion has been well discussed especially in spatial studies to improve and understand the aesthetics of a city [11, 13, 3]. The notion of *ambiental effect* has been proposed by Augoyard and Torgue [1] in their work on the "sonic/sound effects". As an analogue step concerning the *solar effect*, some studies attend the notion of *effect of light* leading to *visual and luminous effect* [12]. Although this work is not yet complete, there are several experiments that are based on this double-sided concept *visual and luminous effects* [5].

Human vision is conditioned by the existence of light, producing physical and psychological effects. *Solar effects* are generated by combining the three following factors: the daylight ”light sources”, the space (architectural and urban morphology), and the observer (visual perception, mental image). In other words, visual perception of solar effects process is carried out in two steps (Figure 2):

Physical step The interaction between the light and morphology gives visual configurations interpreted by the Gestalt theory according to two components Figure/Ground.

Subjective step It is the passage from a physical phenomenon that is filtered by the observer towards a subjective (perceptual) phenomena interpreted by cognition. That allows the observer to build a mental image and is the cause of the emergence of the *solar effects*.

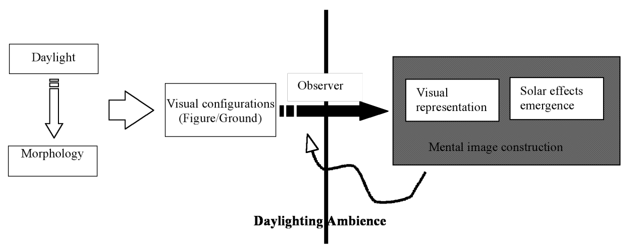

Figure 2: Visual perception of solar effects.

In our work, we approach the *solar effect* as a perceptual tool for phenomenal interpretation of the public space. It is an essential component in building and understanding the urban scene. For example, Figure 3 shows our observation of a street where we have denoted several effects, such as *Opening* which highlights the opening of space, related to the position of the observer, *Imprint* that emphasizes urban and architectural forms and make it possible to disregard the notion of scale, and *Silhouette* effect which gives a vision on the morphology of the city and urban framework.

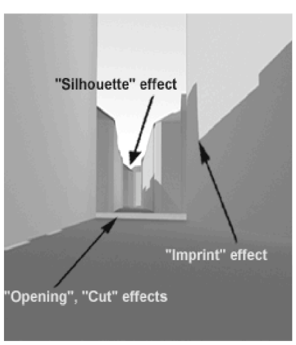

Figure 3: Solar effects examples in a street.

3 URBAN SPACE ANALYSIS

We will here lay the stress on space evaluation from the architectural and urban point of view basing by focusing on its visual aspect and on the assets of perception while in motion. As mentioned in the introduction we are interested in the space effects related to human-space interaction. Moles and Rohmer [8] define space psychology by the following statement: pure space does not exist, and space only exists through the reference to a subject, a group, a content or a viewpoint. Two perception modes are proposed:

- A Cartesian vision of space as the vision of an exterior observer which examines an extended and unlimited world where no viewpoint can be privileged and all of them are thus equivalent.

- A centralized perception that is in fact the viewpoint of an individual immersed into space at a given instant. In that way, Man is the center of the world that surrounds him. This mode is best adapted to the sensitive dimension of the human being and relies on three fundamental elements (the individual, space and time) that allow taking into account subjectivity.

This notion of immersion is central to our study because it is the main asset of Virtual Reality techniques. Beyond this, ”urban paths” have been extensively studied in the literature as an interesting approach to the dynamic aspect of perception because they are fully taking into account the temporal dimension (i.e. the fourth dimension of space). Traditionally, time is translated into motion in the 3D space hence the notion of circuit.

3.1 Space understanding using urban paths

The easiest way to understand the city is to walk down a street and look at everything (the trees, the width of sidewalks and streets, the traffic lights, the signs, the fa cades, the benches, and the overall feeling of the area...) From this logic, several urban methods are based on the urban paths concepts in analyzing cities. The term ”path” gives a human scale to the urban space as well as continuity to public space. It has several meanings (path, itinerary, walkthrough, steps...) that show that it is both a place and an action. In our approach, we propose to go from the lived path to the planned one by adapting the *commented circuit* [12] technique to virtual reality. There are different kinds of methods that can classified in the following way:

Picturesque analysis It requires presenting the city as a sequence of views [13, 11] such paintings, sketches or even photographs. Cullen [3] develops ”space consciousness” that can be summarized as ”the city as a field of view”. According to him, the keys to urban space interpretation are motion, location and content.

Grapical notations Visual elements are drawn on behalf of emotions that form mental images of the city [7]. Lynch assumes that local residents perceive the same what they experience in similar ways. He defines 5 graphical elements and assumes that their association forms the mental image of the city.

The limit of these approaches is their discrete nature: sequences are not continuous neither in the space domain (limited constrained viewpoints) nor in the time domain (only one instant). In order to overcome those difficulties, with the help of computer graphics, researchers have created synthetic cities that look more and more plausible with the increase of computer power. Despite these improvements in photo-realistic realism, computer simulation generally still lacks both free natural motion and sensitive approach.

3.2 Environmental sensitive approaches

Environmental sensitive approaches taking care of both physical ambiantal parameters and subjective individual analysis have appeared in order to study the city at the intersection of morphology, physical parameters and personal or cultural factors. Research works try to study ambiantal parameters in an immersive context by defining the links between the analyzed place and its environment. Thibaud et al [12] have developed the commented circuit method to exhibit the relationship between the human being, the sensitive space and the physical space in its own context. It approaches ambiences with an in situ approach. Its goal is to access sensitive experience by the analysis of his perception of public space while in motion. The main steps of this method are the following:

- The subjects follow a circuit in the urban environment and describe what they see. There are here three types of activity: walk, perception and description.
- The set of subjects description is synthesized into one unique circuit which is an intermediary product of the analysis
- The phenomenons described by the users are observed in order to examine the conditions for their emergence. Descriptions are analyzed and interpreted to exhibit social, spatial and physical properties of places.

This method is considered as an interdisciplinary and dynamic way to study daylighting analysis. Their goal is to set up a sensitive lecture of space by its own users by studying their views with respect to their environment, how they perceive it, how they describe it and how they behave in it. These qualitative approaches focus on the city user who is both the actor and the public of public space. The drawback of these approaches is the presence of the researcher accompanying the subject who might influence its perception.

4 Virtual Reality: a dynamic approach to computer simulation

We would like to combine both the assets of dynamic approaches (perception in motion) and computer simulation that can be performed at design stage whereas classical immersive methods require a built environment. The key concepts of Virtual Reality (VR) are immersion and interaction. It therefore provides us with an interesting concept to integrate those two methods. In this section, we will focus on the problem of walking in virtual environments and on the way we can build a VR application fulfilling our needs.

4.1 Walking in virtual environments

The illusion of motion can be easily simulated by a fast switching between images; this is the basic principle of computer animation. But the real environment (the immersive room) in which the subject has to evolve is generally far smaller than the real environment in which he is supposed to perform the study. The motion of the subject has to be therefore limited and somehow adapted to the scale of the virtual environment. Two types of solutions can be studied:

Walking in a small place for example, the University of Warwick has designed a spherical immersive room called the "cybersphere" that rolls over itself. Unfortunately, it is still very experimental and we cannot afford one. Beyond this, the use of treadmills is quite common, at least for 1D move (following a path). The motion of the treadmill is adapted in real time to match the subject's walk. 2D treadmills are also in development but remain complex research products at the moment.

Walking without moving it requires a bit of learning from the subject who has to walk on a limited plane [14] equipped with sensors that try to determine what his motion would be. This is quite easy to setup and the learning curve is fast for straight walk. It is a bit more complicated as long as rotations are required.

4.2 Non-numeric evaluation with VR

In [10] the authors defined a methodology for designing and evaluating VR applications dedicated to the manufacturing industry including non-numeric evaluation such as design review that is the closest application to ours. The idea is that VR techniques allow a person to act via its muscles on a virtual environment that reacts in feedback on the user's senses. Three different levels of immersion and interaction (I^2) are distinguished: the sensori-motor I^2, the mental I^2 and the functional I^2. The design methodology starts by determining functional I^2, it then deduces the required mental I^2 and finally tries to set up the physical environment required to achieve the desired mental I^2.

Evaluation of virtual reality applications is also addressed in this paper: the three design levels easily match with three evaluation levels: the sensorimotor level tries to evaluate the immersion and interaction environment compared to human psychophysical features. The mental level is the hardest though many studies have tried to evaluate the level of presence or mental implication in the virtual scene [4]. Finally the functional level consists in comparing (when possible) the behavior of the human being at a task in both environments, i.e. the ecological validity of the simulator [6]. That will be our working principle: we will perform daylighting ambiences evaluation in a real urban path, then in the virtual environment where we will try to reproduce the same path. The results of the comparison and the potential biases will be used for further experiments aiming to evaluate daylighting ambiences before actually building the project.

5 Comparison between real and virtual sites

In order to perform the comparison required by the previous paragraphs, we have built several applications:

Still computer-generated images In order to prepare the comparison data, we have taken real photographs of several views during our walkthrough the urban path in a sequence that represent a pedestrian walk across the site.

Animated digital model The creation of this model is based on using a walkthrough camera in the model to symbolize the user's field of view during his walk through the virtual path. The camera was placed 165 cm higher than the model ground, with 61.6 degrees field of view, that corresponds to a user positioned 150 cm away from a (2.40x1.92m) screen. The fact that the digital model has been projected on a screen in full scale located in front of a standing observer makes this model more immersive than the still images. Although the user could not freely navigate in the VE, this application partially allowed him to forget experimental conditions and to concentrate on space light perception.

Immersive virtual environment In this model, to enhance perception and the feeling of immersion, we have introduced free navigation. In outdoor virtual reality applications implying pedestrians, motion is either restricted to the size of the immersive room and/or the range of the sensors, or the motion can be even determined by a metaphor. For these reasons, we have decided to use the principle of the virtual guide defined in [2] basing our choice on the fact that the commented circuit method is based on walking and that it is preferable to not change it.

5.1 Experimental site

The study site is the downtown of the city of Nantes – France; a pedestrian axis in the city with an approximate length of 500m. It is an active commercial axis that dates back to the end of 18th century. This is a varying space that contains different urban tissues from three different architectural periods. This path starts by "place du Pilori" from the Middle Ages, which has a triangular form situated at the centre of medieval districts. The path finishes at "place Royale" (19th Century), which is one of the biggest squares in Nantes, it was the entrance of the medieval city at the 19th Century. A big part of it was destroyed during World War II. What is in between those two ends is a contemporary avenue called "Cours des Cinquantes Otages" that was renovated in 1991 to install tramway lines which made it a very animated and complex zone of the downtown area (Figure 4). The choice is based on the variety of urban tissues, which might allows us to determine how historical evolution of the urban tissues may influence the perception of solar effects.

5.2 VR application and experimental conditions

The 3D digital urban path was built with AutoCAD. Textures and light computation were made with 3D VIZ4 under the following

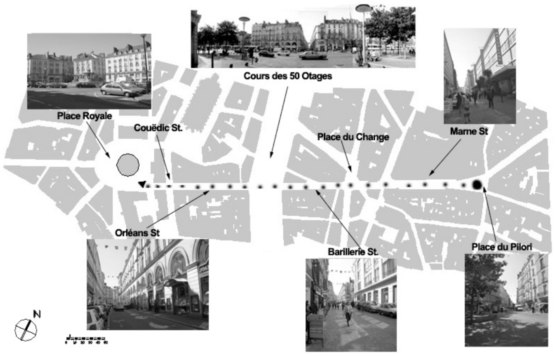

Figure 4: The chosen urban path.

conditions: Elevations textures, as photographs of real path elevations, computed for simulating light on April, 1st 2002 at 1:30pm. The computation daylight integrates sunlight, skylight, as well as radiosity, to simulate the way that light interacts in the selected environment. As radiosity only uses diffuse reflection of light, it can be pre-computed in static environments rendered in real-time provided that no more shadows are cast on the environment (we assume that our characters have no shadows which nobody noticed).

The lab is equipped with an immersive room consisting of an experimental room with a large (2.40x1.92m) rear-projected screen located 24cm above the ground. The system is stereo-enabled but we have decided not to use stereoscopic visualization yet: images computation times are doubled and stereoscopic comfort conditions [9] cannot be fulfilled. The room is also equipped for aural immersion. Though it is not an immediate goal, we are looking forward to study the inclusion of sounds in our perceptual experiments. Observer localization is performed with Flocks of Birds sensors attached to a baseball cap so that their relative position with respect to the head of the observer is quite fixed (Figure 5). The application itself has been developed with the Virtools Dev framework implementing the virtual guide metaphor [2] in the following way: the visitor follows the guide when the guide walks between the different elements of the path. Whenever the guide stops, visitors are *allowed* to wander about the guide and observe surroundings from different perspectives. Thus, we have a mean of displacing the subject automatically but he can stop whenever he wants to. Once his observations are done, he can ”restart” the guide and so on.

6 Results and discussion

In order to evaluate the part that interaction plays into visual perception, we have first investigated the comparison of way subjects' have lived the real and virtual paths: first they get acquainted with the experiment (they often have difficulties to start talking and are looking for their words). Then they start their evaluation by building some kind of mental image of the path. Finally, they become present in the environment (whether it is real of virtual).

One drawback of the virtual experiment is that subjects are often talking about the ”realism” of the environment, the lack for some urban furniture and especially for pedestrians. All subjects have a speech that is based on the lighting environment (in both environment) whereas they have not been told the goal of the experiment. This is even more noticeable in the virtual environment while in the real one, lighting is discussed when the participants are asked to cut the path into several subspaces. The decomposition into subspaces appears to depend more on individuals than on environments.

As far as solar effects are concerned, although there are objective visual differences between the two environments, effects are perceived about the same. For example, the ”cut” effect is even more noticeable in the virtual environment. We suppose it is because lighting computation has created a more contrasted environment. Attraction and repulsion are also quite more noticed in the virtual environment with the exception of reflections into store windows that are not modeled (and thus not computed) in the virtual world.

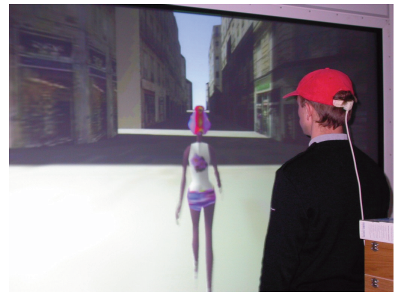

Figure 5: Observer localization and virtual guide.

7 Conclusion and further works

In this paper, we have presented a framework to compare solar effects into real and virtual environments. Results are conclusive enough to plan a second site modeling in order to validate the methodology before trying to apply it at design phase with non-built environment. There are obvious biases between perception in both worlds: people focus on the realism of the virtual world and other perception modes are lacking (especially sounds) while a few pedestrians might also be useful. But we do not know to what extent they would influence solar effects perception.

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