Feeling the urban project: the use of virtual reality for a perceptual approach of the urban climatic environment

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Abstract Virtual reality thanks to immersion and interaction is a good tool to assess urban environments. Allowing users to freely navigate in the virtual environment, virtual reality permits to take into account the influence of dynamic elements and the observers' actions in the perception of urban spaces. However, previous works have shown that virtual assessments of urban projects are mainly based on visual experience. Thus, the multisensory perception of the actual environment is biased.

In order to tackle this issue, we propose to focus on climatic ambiances, which are dynamic and multisensory. Moreover some studies have shown the importance of these factors in the appropriation of an urban space whereas they are very seldom integrated in virtual evaluations.

This paper presents a new methodolgy to delineate urban climatic ambiances in virtual environments which respects the following points: understanding and perception of climatic ambiances by non-experts, sensitive evaluation of the urban space, presence in the virtual scene and perceptual fidelity of the virtual environment. Then we apply this methodology to design ten virtual scenes with climatic effects. These scenes have been assessed in a perceptual experiment involving 42 particpants (Fig. 1). This experiment helps to improve our knowledge of perception in virtual environments in order to improve or propose new cues for sensitive climatic suggestion in VR.

Fig. 1 The perceptual experiment in the virtual room

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Introduction

Urban ambiances are at the crossroad of the built spatial structure with the physical signals (light, sound, heat, wind, smells…) interacting with human beings through actions, perception and social and cultural representations (Augoyard, 1998). The study of urban ambiances puts the human being and sensorial and sensitive perception into the heart of urban programming.

In this paper, we discuss the ability of virtual reality (VR) to delineate urban climatic ambiances. Thanks to multisensory immersion and interaction, VR permits a physical and cognitive presence in a virtual environment (Fuchs et al., 2011). Thus VR offers an alternative to a purely scientific visualization of urban physical phenomena for non-expert users and makes it possible to consider the spatiotemporal and multisensory features of ambiances.

The study is focused on climatic ambiances for a few reasons. The field of urban ambiances includes a multitude of sensory effects and interactions and we need to focus on a few of them to accurately study their multisensory perception in VR. Moreover, even though several *in situ* studies have shown that climatic ambiances are significant in perception and use of urban spaces (Nikolopoulou & Steemers, 2003), they are very seldom integrated in virtual urban environments.

From a review of the usage of VR for urban landscape and ambiances assessment, we raise the issue of sensory perceptions and microclimatic representations in VR modeling. Then we develop the adopted methodology and present the results of our first experiment. Finally from the discussion of these results we propose some orientations for future works.

Previous works and research question

Bishop (Bishop et al., 2001) (Bishop & Rohrmann, 2003) is one of the firsts to use computer animations and VR to communicate about urban landscape. He shows that, contrary to photomontages or movies, VR permits to take into account the movement function in urban perception. Indeed perception is very dependent on observer’s action (Gibson, 1986) and several previous works have highlighted the influence of walking in the evaluation of cities (Lynch, 1960) (Gordon, 1976).

According to Bishop et al. (Bishop et al., 2001), VR can be used to communicate qualities of urban design, to interact with design features and make experimentations about human perception. Thus, Tahrani & Moreau 2008) studied light perception in an urban walkthrough and Drettakis (Drettakis, Roussou, Reche, & Tsingos, 2007) proposed to use VR to compare different scenarios of the rehabilitation of a public square.

Besides, in a political context where public participation is more and more present, VR makes it possible a non-expert representation of urban projects.

However, in these examples, the perception in cities is oversimplified: evaluations are often based only on the visual quality of the project to the expense of other sensory effects. This issue has been also developed by Lange (Lange, 2011) in a recent paper. According to him, *“focusing only on the visual aspect of landscape design provides us with only a partial “view”, literally, of our environment.”* He also underlines the lack of knowledge in the representation of a multisensory environment and *“how such representations might influence landscape assessments, or how they could influence decision-making in planning and designing our environment”*. Moreover, we can notice that VR applications represent urban environments in ideal situations: the sky is blue, there are a few white clouds, vegetation is lush, trees are leafy or flowered and the sun is shining. Except in (Bishop & Rohrmann, 2003) in which the environment is simulated by night, participants can never experiment various seasons, times of day or weathers and, compare and evaluate the urban design under different climate or lighting situations.

However in order to settle the virtual urban project into a climatic atmosphere, we have to know how to suggest multisensory climatic ambiances and how they are perceived in VR.

The most intuitive approach consists in reproducing the physical stimuli of climatic ambiances. Thus, Moon & Kim (2004) proposed a WindCube to reproduce wind with fans. Kulkarni et al. (Kulkarni et al., 2009) designed a complete wind tunnel based on fluid dynamics and able to simulate wind very precisely. Nevertheless, these devices are at a prototype state only and they are not validated yet in a perceptive way. They are also too expensive and unpractical to use. Therefore we propose to focus on immersive audio-visual virtual environments to delineate climatic effects.

The next question that remains is: how to suggest multisensory climatic ambiances and how are they perceived in audio-visual virtual environments?

Methodology for the suggestion of urban climatic ambiances

Climatic effects are multisensory whereas here we are restricted to two sensory inputs: visual and audio inputs. Therefore we have to identify some means of suggestion to overcome this lack. We use a concept based on high-level perceptual fidelity elaborated in a previous paper (Vigier et al., 2012) and we apply the following methodology. Each step permits to identify some ways of suggestion and/or eliminating non-feasible means identified in an earlier step.

1. Listing of climatic situations and/or microclimatic effects.
2. Study of the perception and identification of helpful mechanisms (sensory interactions, cognitive metaphors, memory mechanisms, etc.).
3. Study of artistic representations of cities and climatic conditions (Fig. 2).
4. VR feasibility: real-time rendering; software capabilities and restrictions; avoiding perceptual biases; reaching a good degree of immersion, interaction and presence.
5. Implementation of audio-visual effects on a VR platform and realization of virtual urban walkthroughs augmented with climatic effects
6. Perceptual studies from virtual walkthroughs.
7. Discussion and return to step 4.

These different steps can be repeated until obtaining “good” perceptual results. For the moment the studied effects are present all along the virtual scenes but we can apply this method to delineate localized microclimatic effects like glare, gust of wind, temperature or lighting transition. Then we can compare them under various conditions (seasons, weather, time of day, building orientation, presence of vegetation…).

Fig. 2 From left to right: (a) The Corneille Bridge in Rouen, rainy weather[1] (Lemaître, 1891); (b) Spring day in Karl Johan street[2] (Munch, 1890)

A first visual experiment

We conducted our first perceptual environment based on the above methodology.

First, we constructed an urban street model in 3DS MAX and imported it on the OpenSpace3D[3] VR platform. Then we implemented climatic effects and designed ten different scenes. Each scene consisted of a combination of visual and dynamic effects. The objective of the experiment is to determine how this combination is perceived in terms of climate. Transitions

[1] Original title: Le Pont Corneille à Rouen, temps de pluie

[2] Original title: Journée de printemps sur la rue Karl Johan

[3] http://www.openspace3d.com/

were not taken into account in this first experiment and only visual means of suggestion are studied. All computer graphic effects are compatible with real-time rendering and an interactive virtual walkthrough. However, because of issues of performance when several effects are superposed and to simplify this first experiment, perceptual evaluation was held on videos only.

Videos were accompanied by a soundtrack (footsteps and cars sounds) to increase immersion but there were not climatic sound effects. Each video lasted 25 seconds and contained a subjective walkthrough in the street at constant speed (Fig. 3a). Each one began with 4 seconds of white model (without textures and effects, Fig. 3b) to condition the participants and avoid interferences between the different scenes.

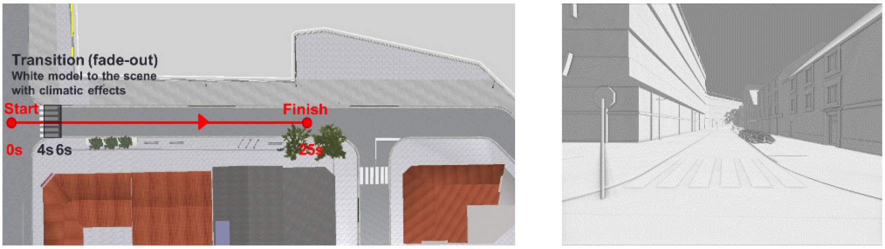

Fig. 3 From left to right: (a) The walkthrough; (b) The white model

The test was done in a VR room equipped with a 2.4 x 2 meters screen and a 5.1 surround sound system. The videos were projected at 1:1 scale and in a subjective view (Fig. 1).

42 persons participated in the experiment, 22 male and 20 female. The average age was 28.5 years (minimum 18, maximum 61, SD 9.91). Most of participants were students but only 4 were specialists in virtual reality or computer graphics and 4 in architecture or city planning.

During the experiment, each participant watched and evaluated 10 scenes in a random order. The evaluation of each scene was made up of two steps. First, temperature, light, wind and humidity were assessed on numeric scales (Fig. 4a). Numeric scales did not represent physical but subjective values (e.g. for temperature, -2 is cold, -1 is quite cold or cool, 0 is mild or no special thermal feeling, +1 is quite hot and +2 is hot even very hot). Participants could give only one response per feature or could choose to not answer (NSP). Then they had to pick the most adequate terms to describe the climatic atmosphere of the scene. Terms were arranged in three columns: time of day, season and climatic impression (Fig. 4b). Participants had to choose at least one term by column but they also could choose several terms in a same column if they all matched the scene.

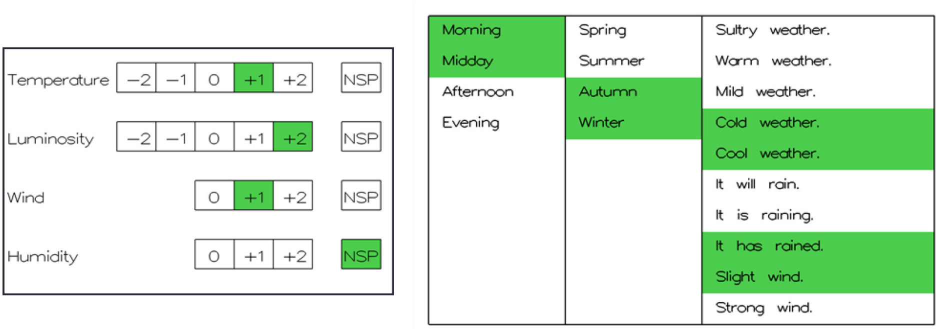

Fig. 4 Interfaces (experiment was led in French so terms have been translated here). From left to right: (a) Numeric scales; (b) Climatic impressions

Results

Participants more or less felt the climatic effects as expected. However, this study is really rewarding because it permits to improve our knowledge of perception of climatic ambiances in virtual environments and to draw conclusions about the means of suggestion. For a concision effort we only detail the results for four scenes. For each scene we present an image of the video (colors on the paper can differ from colors on the overhead projector screen) and some interesting charts. Finally, we sum up the results in a general discussion.

1. The “standard” scene (Fig. 5)

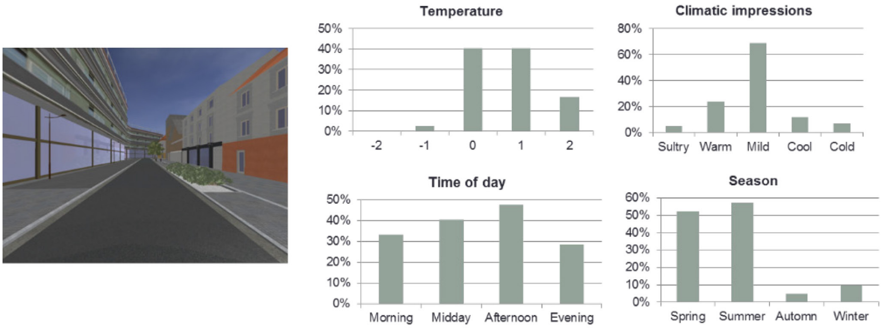

Fig. 5 Results for scene 1

This scene is the standard scene we can see in virtual environment for urban assessment. The sky is blue, the vegetation is quite lush and the scene is well lighted without particular ambient colour but there are no shadows. This scene was felt as mild or quite warm without wind and humidity. For the participants, it can be whatever time of day but inevitably in summer or spring. These results show that the standard scene of the virtual urban environment is really poor in a climatic point of view and clearly depicts ideal conditions.

2. A warm summer scene (Fig. 6)

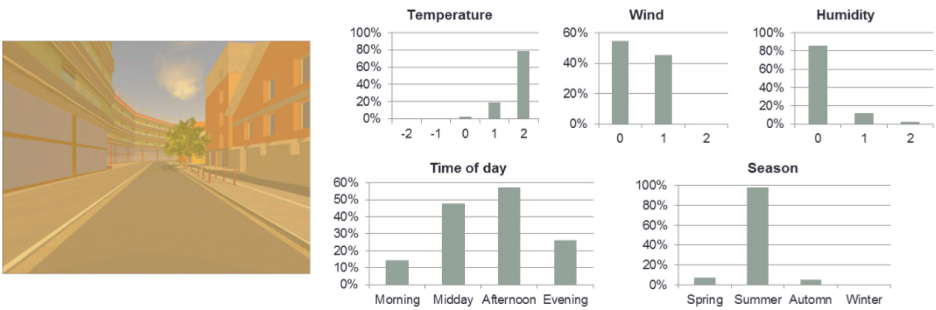

Fig. 6 Results for scene 2

This scene was designed with a yellow ambient color and a strong luminance. It was felt as a dry hot even sultry summer day. Participants said that it sure couldn’t be the morning because of a sensation of heat accumulation. Because clouds slightly moved, about 40% reported a slight wind: if we completely freeze them maybe the weather would appear even heavier.

3. A cold and wet morning (Fig. 7)

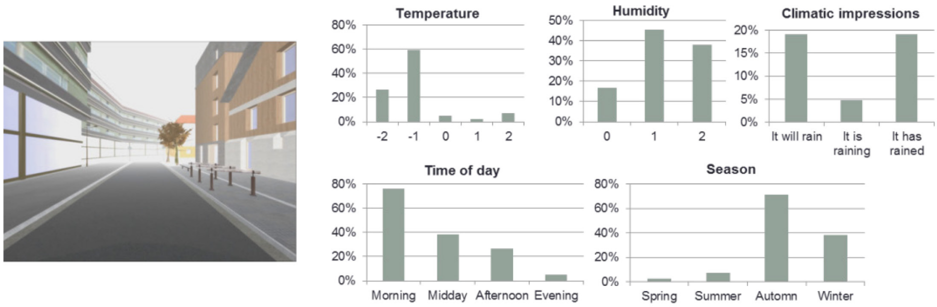

Fig. 7 Results for scene 3

The expected effect was the arrival of sun during a foggy day in autumn. We used a uniform grey sky with diffuse lighting. We added a slight yellow fog and a subtle effect of glow. The temperature was felt colder than we expected. Around 75% of participants answered that it could be the morning since they identified the scene as the sunrise. 83% of people perceived humidity in the scene but they could not really say if it had rained or if it was going to rain.

4. Evening, before the storm (Fig. 8)

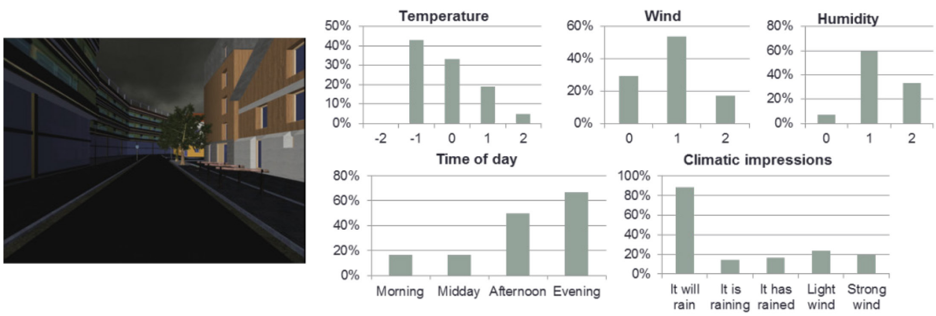

Fig. 8 Results for scene 4

The global scene and the clouds were very dark but there were some clearer façades. Colors were a little bit more saturated and contrasts were amplified. We wanted to suggest a moment just before storm at the end of summer. The temperature and the season were hardly assessed. On the other hand the scene was felt as very humid and almost 90% of participants said it was going to rain. It took place in the afternoon or in the evening for a large part of the population. 70% of people said there was wind or strong wind whereas the only visual indication was a quite slight clouds movement. We think that it is the global ambiance of the scene which leads to this result in a perceptual effect of memorization.

General analysis and discussion

1. Temperature

The choice of ambient light, saturation of colors and depth of field are predominant in the feeling of temperature. In more neutral representations (in a light and color point of view) we can see that the presence of clouds, humidity or wind seems to induce a slight decrease of temperature (average around -0.15 in the experimental scale). About the experimental procedure, we think that the temperature should have been asked before the season. Indeed, some participants focused on the appearance of trees to infer the season and the temperature. Yet a temperature feeling according to a pre-identified season could be more interesting to analyze (a cool summer day; a dry cold autumn day; a rainy and mild winter day; etc.).

2. Light
   The strong dispersion of responses show that light was very hardly evaluated. We think that the term used in French – *luminosité* – is too imprecise. Moreover there is often a mix-up between luminosity and saturation. Perhaps the evaluation of sunlighting could be more appropriate.
3. Wind
   Results about wind are mitigated. We can notice that wind speed is a determinant factor whereas in reality clouds movement is not significant in urban scenes. Increased cloud speed – even in a nonrealistic way – seems to be a good way of inducing wind effect. Nevertheless it must be verified in free navigation because the effect can be perceived differently than in videos. Because of constant camera speed, videos and animations quality, participants hardly detected variations in movement of leaves. This effect must be tested in a next experiment. Moreover radial blur effect did not work because of the constant navigation speed and the localization of blur on the screen (only on the sides, Fig. 9a). Use of blur to suggest wind could be tested again but for rather a wind gust or transition. Here we decided to focus on visual effects but we can see that sounds are clearly missing for wind suggestion.
4. Humidity
   Humidity assessment depends on floor reflections, clouds color and ratio, fog and saturation of colors. Some people also said that blur could accentuate the sensation of humidity (Fig. 9b). Because of fog and saturation of colors are significant both for temperature and humidity evaluation, it is difficult to represent a cold and dry scene for instance.

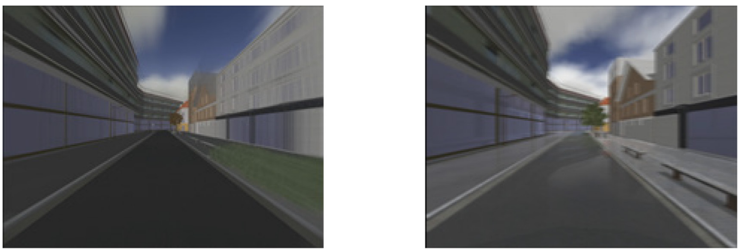

Fig. 9 From left to right: (a) Radial blur effect for wind; (b) Suggestion of humidity (reflections, clouds and blur effect)

Conclusion and future works

This paper shows the relevance of the study the perception of urban climatic ambiances in VR and presents a first perceptual experiment on videos. This experiment permits to better understand perception in virtual environments in order to improve or propose new cues for sensitive climatic suggestion in VR. For performance and practical reasons the test was done on pre-calculated images but we can already notice that videos are limited both about climatic suggestion and immersion. Moreover visual means of suggestion are numerous but, particularly for the wind, it is necessary to add sound effects. Thus new experiments with real-time interaction, free navigation and sound effects will be done in the next months. Besides, it would be interesting to assess the perception of localized effects or transitions, as well as the interaction between climatic features by modifying only one factor in a scene (e.g. intensifying wind indicators, darkening ambient light) and then studying the effect on other features (e.g. does the temperature decrease?). A final experiment will consist in a complete walkthrough in a virtual urban environment augmented with climatic effects in order to study the perception along it, as we can do *in situ* with the method of *commented routes* (Thibaud, 1998) which has been successfully used in virtual environments (Tahrani & Moreau, 2008).

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References

Augoyard, J.F. (1998). Eléments pour une théorie des ambiances architecturales et urbaines. *Les cahiers de la recherche architecturale*, *42-43*.

Bishop, I., Rohrmann, B. (2003). Subjective responses to simulated and real environments: a comparison. *Landscape and Urban Planning*, *65*(4), 261–277.

Bishop, I., Ye, W., Karadaglis, C. (2001). Experiential approaches to perception response in virtual worlds. *Landscape and Urban Planning*, *54*, 115–123.

Drettakis, G., Roussou, M., Reche, A., Tsingos, N. (2007). Design and Evaluation of a Real-World Virtual Environment for Architecture and Urban Planning. *Presence: Teleoperators and Virtual Environments*, *16*(3), 249–332.

Fuchs, P., Moreau, G., Guitton, P. (2011). *Virtual Reality: Concepts and Technologies*. CRC Press.

Gibson, J. J. (1986). *The ecological approach to visual perception*. Lawrence Eribaum Associates, Publishers.

Gordon, C. (1976). *The Concise Townscape*. London: Architectural Press.

Kulkarni, S., Fisher, C., Pardyjak, E., Minor, M., Hollerbach, J. (2009). Wind Display Device for Locomotion Interface in a Virtual Environment. *World Haptic Conference 09,* 184–189. IEEE.

Lange, E. (2011). 99 volumes later: We can visualise. Now what? *Landscape and Urban Planning*, *100*(4), 403–406.

Lynch, K. (1960). *The image of the city*. MIT Press.

Moon, T., & Kim, G. J. (2004). Design and Evaluation of a Wind Display for Virtual Reality. *ACM VRST Conference* (pp. 122–128). ACM.

Nikolopoulou, M., Steemers, K. (2003). Thermal comfort and psychological adaptation as a guide for designing urban spaces. *Energy and Buildings*, *35*(1), 95–101.

Tahrani, S., Moreau, G. (2008). Integration of Immersive Walking to Analyse Urban Daylighting Ambiences. *Journal of Urban Design*, *13*(1), 99–123.

Thibaud, J.P. (1998). Comment observer une ambiance ? *Les cahiers de la recherche architecturale*, *42-43*, 77–89.

Vigier, T., Moreau, G., Siret, D., Lescop, L. (2012). A new concept of perceptual fidelity to augment virtual urban environments with microclimatic ambiances. *3U3D2012: Usage, Usability, and Utility of 3D City Models.*