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The Visualisation of Urban "Ambients" Parameters

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Abstract

For many years architectural and urban ambience, a topic included in environmental design studies, has been the focus of extensive interdisciplinary research in physical and social science laboratories. Urban and architectural spaces, in interaction with environmental parameters such as light and sound, generate environmental entities called “ambients”. This notion places the human being back in the centre of space analyses. With regard to classical models of ambience representation, the rule of scale and human interaction allows us to define this notion of ambients through the immersion principle, integrating relevant perceptive parameters in the architectural and urban ambience research fields. This approach aims to integrate the main subjective aspects of perception into the scientific knowledge of physical processes of urban environment. We place this approach in the context of emerging virtual technologies, where formal solutions can be tested in a multidimensional data set. This opens up the possibility of a global characterisation system, including space (urban data), process (environmental physics), and players (humans). The main goal of our work is to provide designers with tools in order to include thermal, aerodynamic, acoustic and lighting data in the urban design process.

1. Introduction

The development of data-processing tools has permitted ongoing development of numerical simulation methods. It is now established practice to use a predictive approach to urban space through models describing environmental phenomena. This may involve the use of solar, luminous or aerodynamic simulations during architecture and urban planning design phases. Furthermore, this analytical approach to urban and architectural space can be also used in diagnosis and assessment spots in order to gain a better understanding of environmental impact of built forms. Generally, these numerical simulations provide local and rough information applied to every point of the urban space defined through an informed mesh. This practice does not really take into account the global perception of a pedestrian placed in this space: environmental analysis results are very interesting from the viewpoint of city

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physics, but do not give a realistic image of the atmosphere of the place in we are immersed.

2. Models for urban ambience representation

2.1 Specified space representation methods

Urban shape representation includes visualisation of built urban entities, green spaces and urban installations. Any visualisation can be obtained by different methods: data acquisition, primitive assembly (graphical interactive renders), intelligent systems (automatic generation) with certain constraints (Peroche/Argence 1988). The geometrical model can also incorporate the material and physical properties of each surface or volume of the scene.

An important part of urban ambient phenomena (aerodynamics, thermal, acoustical) lies in the atmosphere. Its principal constituent, air, is represented by the unoccupied points of the urban scene. Mainly, it is modelled with finite element 3D-meshes. Computational fluid-mechanic methods are then applied on this type of representation, notably in aerodynamics and thermal studies. The main problems posed by these visualisation methods are contiguous representation techniques. A number of interactions between environmental shapes and physical phenomenon are situated in the neighbourhood of empty / full interfaces of the urban environment. Those interfaces are modelled by specific methods, such as 2-D/3-D meshing, analytical physical behaviour or roughness characterisation (statistical or fractal).

2.2 Physical phenomenon modelling and visualisation

The description of urban interactive physical phenomena uses different types of models. A distinction can be drawn between physical models able to render the system's variables in a particular scene, phenomenological models which allow ambience prediction by using previous observations, and scale models providing dynamic ambience control.

A physical model is constituted of an equation system expressing mathematical relationships between the physical parameters describing the phenomenon. Within the urban field, physical modelling implies a knowledge of two main parameters: properties of the building's wall surfaces (thermo-physical, acoustic properties, for instance), and properties of the fluid area, the ambient air, which constitutes the propagation space in acoustics, or the convection and conduction area on a thermal level. A number of classical models are based on predictive numerical 3-D techniques, which provide parameters related to the environmental physical factors. The data structure obtained by associating 3-D geometrical elements and physical or textual data is similar to GIS 3-D structure. Numerical simulation consists in solving a discrete equation system, possibly coupled. This implies dividing the problem into spatial and temporal elements.

Empirical models are produced by a modelling procedure called *phenomenological*, which consists in correlating an experimental dataflow to an *a priori* physical parameter system. They are used both in place of non-adapted physical models for complex multi-phenomenal reality descriptions which involve a number of interdependent parameters, and to obtain direct solutions for applications under complex constraints. They include the well-known expert tools, or artificial intelligence models, used to drive decision flows, and are affordable by non-expert users.

Scale models traduce a physical scale reduction of the environmental phenomenon, generally precise and not far from the physical reality, but they are complex and difficult to design and handle (Neirac 1988). Their results are often interesting, but their computation doesn't linearly follow the laws of the real physical phenomenon. Those black-boxes are useful for mastering the process, and they also allow real-time environmental control.

2.3 Environmental predictive systems

Furthermore, our interest for environmental studies, solar luminance and acoustics, has a twin motivation. Firstly, sun and lighting are constantly modelling built spaces. In this way, they noticeably influence our practice of urban space. Elsewhere, fundamental principles of architecture touch on the relationship between shape and light. Secondly, the importance of sound in urban spaces is reflected in growing noise pollution. This makes acoustic parameters factors of prime significance for our urban environment and explains how architects, urban designers and planners have become interested in sound propagation phenomena in built spaces.

In order to estimate physical phenomena linked to these environmental parameters, we can use numerical simulation tools that allow us to predict their intensity and location (figure 1): the lighting software application *Solène* developed by the Cerma laboratory (Groleau/Marenne/Gadhile 1993) and the acoustics software *Orphea* (Woloszyn 1998) created jointly by the Cerma (Research Centre for Architectural Methodology) , the Cresson (Research Centre for Sonic Spaces) , the Laum (Acoustics Laboratory of the Maine University) and the Lcpc (*Ponts et Chaussées* Central Laboratory).

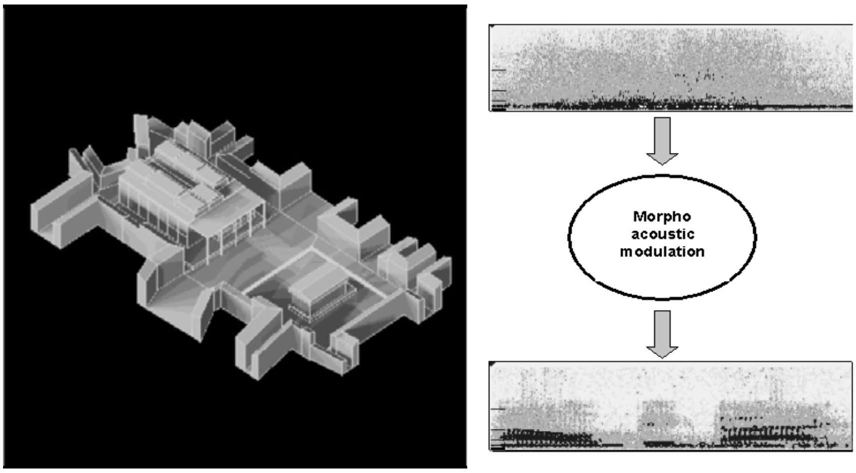

Figure 1
Lighting simulation by *Solène* and *Orphea's* principle of modulation by an urban street (time-frequency visualization of sound)

2.4 Space and physics : the rule of scale interactions

Considering the interaction between space and environmental phenomena, it is useful, as a first step, to segregate them into elementary physical manifestations, which involves specific parameters. Each parameter describes, during its manifestation, a particular spectrum, which is a function of each phenomenon's particular scale, called *characteristic scale* (Woloszyn 1998)

The example of the sound wavelength, which corresponds to architectural and urban scales (from millimetre to metre), opposed to the light wavelength (micrometre) and to the microclimatic phenomenon (kilometre), is, at this aim, absolutely eloquent. In addition, those *spatial characteristic scales* are complemented with the phenomenon *temporal scales*, which have to be taken into account in order to implement the physical parameters in the urban built geometry.

Therefore, it will be necessary to refer to various system analyses. The most currently used method, direct measurement of phenomenon parameters, implies a physical model for process evaluation (Péneau 1991). This multidimensional and multi-factorial characterisation leads us to organise urban space as a field of data relying on physical parameters.

2.5 Virtual Reality: Human Interaction for Ambience Analysis

Considering the implementation of the subject of perception in the virtual simulation process, we are aiming a hybrid environmental representation model rooted in our research in the domains both of spatial analysis and perception. The final model we propose would be able to render the environmental parameters at each step of the pedestrian's displacement (Follut/Groleau 2000), and, simultaneously, to preview their configuration for the whole spatial displacement system. To achieve this aim, we will use Virtual Reality as a powerful and flexible 3-D visualisation tool for the complex geometrical-physical data (figure 2).

Figure 2
Integration of the perceptive dimension in a structural multi-phenomena scheme

This cumulative approach doesn't distinguish between phenomena, but considers perception as a single object. The scalar physical phenomena involved are perceived with specific *human sensors*, which lead to sensorial disparities between environmental phenomena. In fact, the laws of human perception, considered as a sensorial filter of reality, are specific for each physical domain, relative to their spatial and temporal scaling. Moreover, psychological perception studies point out a noticeable difference between individual perception, in which the ambience sensitivity depends both on the local context of perception situation and on the inner disposition of the human being (Augoyard 1995).

3. Notion of Ambients

3.1 Physics, Space and Human

Physical models allow us to describe and to manipulate phenomena in space. Models of suggestive representation allow us to place the individual perception in the centre of the phenomenon design process. Consequently, Virtual Reality tools can help us to achieve the synthesis necessary for the creation of a new tool of knowledge and conception. In addition to those spatially and physically interacting parameters, the human being, identified both as a modifier of the environment and as a subject of ambience perception, is also interacting with these ambience constituents. This leads us to re-formulate all the ambience parameters from an anthropocentric point of view, producing the notion of *ambients*.

Considering the interaction between space and environmental phenomena, it is useful to segregate them into elementary physical manifestations, which involves specific parameters. The sensitive aspect of phenomenal perception leads us to consider this aspect as a sensation vector from the subject (human being) to the ambience complex. The corresponding psychophysical representation of space supposes the construction of an homoeomorphism between temporal and spatial figures of the phenomenon, and their correspondence with perceptual space-time feedback.

3.2 A New Visualisation System

This ultimately permits a visualisation system including the urban space, the physical process, and the human actor. The powerful multidimensional toolbox offered by Virtual Reality can thus be applied to the main classical physical topics of our laboratory research work on the architectural and urban environment, related to three main interacting parameters (figure 3), which are :

- The specified built form, whose shape and material characteristics are able to generate specific environmental conditions. The main examples to illustrate this type of interaction are the aerodynamic urban flow, the acoustic diffusion or the *albedo* factor of the built surfaces, which influences the reflection of heat and light.
- The various specific urban physical factors, which cover a large spectrum of environmental phenomena, such as wind, temperature, sun exposure, acoustic propagation and pollution dispersion.
- Finally, the human being who can be seen both as a receptor of the environment and as an observer of ambients.

From these three fundamental building, physical and human poles, we can flesh out our notion of ambients (figure 3), identifying :

- an aesthetic field that induces a representation of the urban environment to range of players, residents and cultures.
- a physical domain where the impact of the signal represents the specific interaction between physical parameters and building shapes. The urban built forms act as a filter for the physical parameters.
- a sensitive approach in which users perceive the urban environment across the breadth of their multi-sensitive perception.

As shown by this definition, the notion of ambients includes the environmental immersion of the human being. This allows sensations to be synthesised by modelling discrete scalable and measurable objects whose systemic organisation constitutes the ambient entity, situated in space and time.

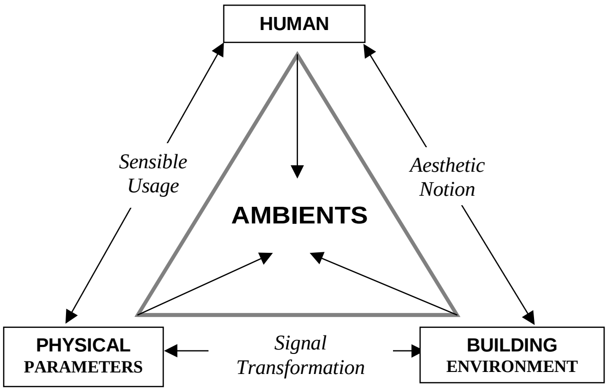

Figure 3
The *ambients* scheme

3.3 The Immersion Visualisation Method

The immersion principle (Burdea/Coiffet 1993) places humans in an equivalent position to an urban pedestrian, with a height situated between 0 and 2 metres (life layout). The effect of this positioning is that the simulation of physical and spatial interaction occurs very close to reality. This realistic interaction principle conditions the user's degree of freedom in the system. Technically, our methodology consists in generating feedback between a 3-D geometrical model of the town and the associated physical data. After the simulation process, the geometrical model is informed with the physical data in order to allow an interrogation of the so-constituted database with the techniques of Virtual Reality. The generic method is shown on figure 4 .

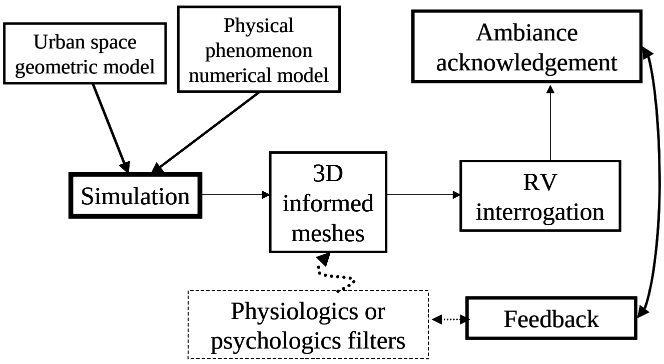

Figure 4
The ambianscape principles

During the computation of the descriptors, we were able to consider the results by psychological and physiological parameters. It is obvious that human doesn't attach the same importance to what he sees according to its relative position or psychological situation (e.g. difference in environment perception between a hurrying and a strolling situation).

3.4 Towards a global integration methodology

In order to structure our analysis method on this virtual meshed space, we defined a new notion we call *Ambientscape*. This notion relates to the different studies about landscape, notably on the Murray Schäfer neologism *Soundscape* [SCH81]. This notion is guided by a method which analyses results of simulation through the descriptors, linked to the spatial position of the observer. This allows us to map the urban void, informed by the physical and building data and reviewed by a virtual observer. This new representation introduces a new vision of the objective environmental conditions of the analysed space, and is to be considered as a workshop for the designer, testing *in silico* different spatial hypotheses to the breadth of the physical parameter filter of ambients during planning phases of the project.

As these descriptors will be directly linked to the perceived space, or to the urban geometry, they provide information by drawing on the integrative effect of the raw data of the simulations applied to a specific position of the pedestrian. Therefore, a new triangular scheme, synthesising the methodological convergence between Virtual Reality area and ambients restitution, is able to define the ambientscape method through three new reference points (see figure 5):

- the human factor, relative to the immersion process, corresponds to a realistic positioning in the space, associated with a phenomenon perceptive situation.
- psycho-physical parameters directly linked with the imagination principle used in the virtual world through perception's specific descriptors.
- the interaction principle, acting on the built environment through a displacement permitting its discovery.

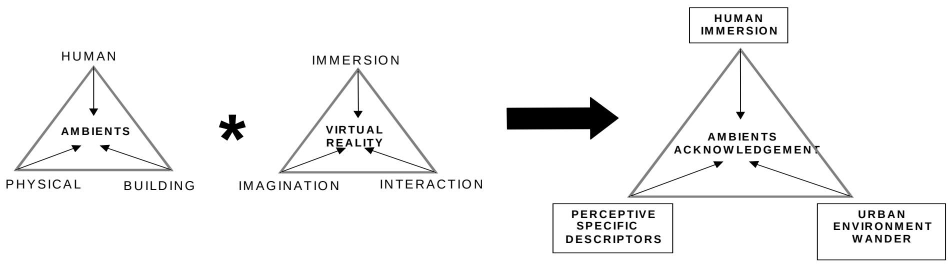

Figure 5
Ambients acknowledgement scheme

4. The "Ambientscape" Methodology

4.1 Data Processing

Through physical information resulting from the different simulations applied to the urban meshed model, we can define the Ambientscape as the totality of phenomena distributed around a place, creating a perceptible atmosphere for any pedestrian situated in this space. This ambients landscape reveals a new geometry of the city, modifying its shape through its dynamic evolution at different levels:

- when freezing time to an instant t, walking in the new perspective city reveals new phenomena that punctuate space (global data integration).
- during the pedestrian's displacement, we can observe the continuously changing Ambientscape in time, sun evolution and usage modifications. This induces a constant new distribution of phenomena, interacting with the urban frameworks (directional data integration).

The global data integration concerns the whole environment that surrounds the viewer position. It corresponds to an analysis that takes into account a solid angle of 4π steradians (Dupagne 1997), considering that each visible patch in the 3D scene has an impact on the viewer, concerning the ambient descriptor we have to define (figure 6-1). A practical example might be the analysis of the radiative comfort for the pedestrian standing in a place.

The directional data integration analyses a portion of the space according to a solid angle in relation with the human being's field of vision (figure 6-2).

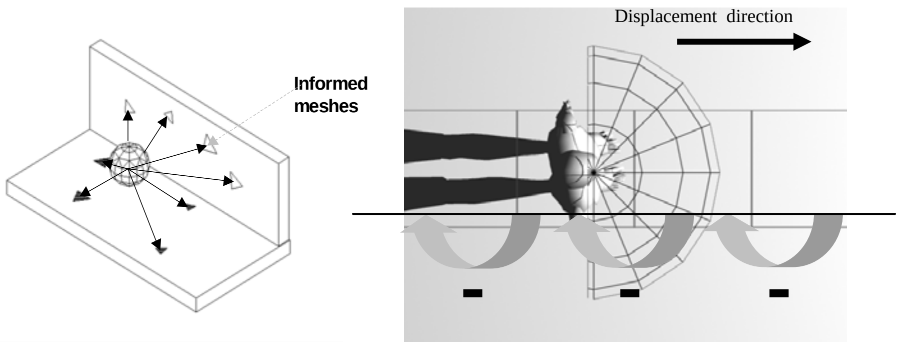

Figure 6
Data integration methods (global and directional)

The results obtained can be represented in cartographic form where information is associated with point in space (centre of gravity of a mesh), or in the form of a graph with two axes: the first using the intensity of the studied descriptor, the second the discreet time of the course (successive instants), in order to study the temporality of ambient events (continuity, simultaneity, contrast,…). A differential representation can also be used to evaluate what is perceived by a pedestrian, underlying the differential perception between two successive positions in a displacement. As presented, the use of ambientscape method permits firstly calculation of the local accessibility for perception by the user, and secondly evaluation of high level information (the descriptors) which influences his behaviour.

4.2 Specific Descriptors of the Solar Factors

The descriptors are presented here in relation to two complementary description fields: urban space geometry and sunlighting process. Geometrically, spatial morphology description is analysed from a specific point of view, relative to a viewer, through the following descriptors:

- *The sky view factor,* which reflects the importance of sky visibility from a viewing point; it indicates also the importance of the urban built mask.
- The *viewed built surface / total viewed surfaces* ratio indicator reflects the importance of urban built structures in a place.
- The *confinement* descriptor is a combination of the two previous descriptors and gives a notion of closeness or openness of space in which the observer is immersed.

The sunlighting analysis describes the perceived solar radiation for a viewer placed in this space through the percentage of visible sunlit faces of buildings.

This sunlit space description is defined by two questions:

- Is the viewer exposed to the sun?
- How is the visible space around the viewer sunlit?

If the answer of the first question is obtained directly from the simulation, the second one needs to define specific descriptors such as following :

- *Area of sunlit facets / total area of facets* evaluated in the viewer's field of vision*:* it implies determination of the sunlit facets among the totality of visible facets of the 3D urban scene. This indicator allows us to quantify the sunlight perception for a viewer according to his spatial location in the urban framework.
- *Number and visual distribution of solar spots:* these indicators are derived from the previous one, but it is more concerned with the sunlit dispersion quality,

rather than the dispersion quantity. Perception of one large solar spot is very different to that perception of a multitude of small spots.

- *Redistribution of solar spots according to the urban elements:* this indicator provides information on the distribution of spots between ground and buildings through effects in the urban scene between frontages and roofs.
- *Spots' centre of gravity:* this descriptor calculates the position of the centre of gravity of sunlit patches in the field of vision. It provides information about the density of the framework and the relative situation of the sunlit zone in relation to the viewer's location.

5. An Application: Comparison of the Sun Impact on Three Streets

5.1 The Experimental Sites

Rue des Petites Ecuries — *Medieval typology*

Rue Boileau — *18th typology*

Rue de Strasbourg — *19th typology*

Figure 7
Maps of experiment sites

The three streets in which the experiments were performed (figure 7) are located in Nantes (France), with approximately the same orientation (S-N).

5.2 Analyse of the Solarscape

The *Solarscape* can be defined as the totality of phenomena distributed around a place, creating a perceptible solar ambient for users of those urban spaces. According to this method, some different specific descriptors are calculated, including the *percentage of visible sunlit facets.* This indicator evolves according to the hour of day in the same direction for each sample (from South to North), giving the following time series presented in figure 8 :

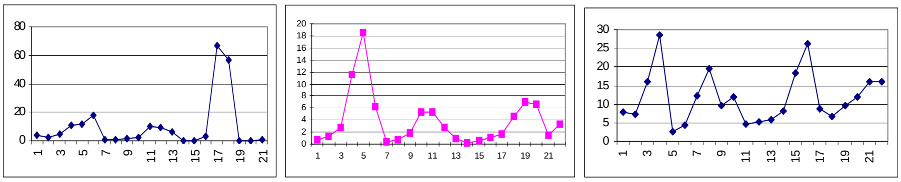

Figure 8
Solarscape for Rues Petites Ecuries, Boileau and Strasbourg

Two important elements can be seen in the graphs:

- For the same global orientation and the same time of observation, there are significant differences due to the typology of the frameworks.
- The values show strong variation, revealing the local morphology of the street as a crossroad or an urban place.

5.3 Application to Solar Ambients

Superposition of a data map and a framework map clearly shows the specific evolution of the previous descriptor.

This map of the visible sunlit facets is a new visualisation of the urban sunlighting. It describes the perceptible conditions of displacement rather than classical crude physical factors. This representation shows the relationship of this factor to the urban typology on figure 9.

Rue des Petites Ecuries	Rue Boileau	Rue de Strasbourg

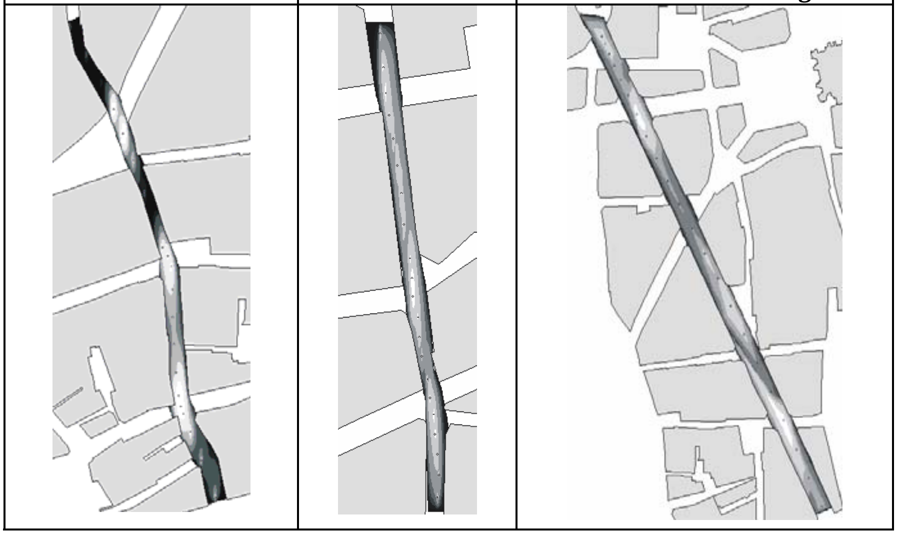

Figure 9
Solar Maps of the three streets

5.4 A Synthetic Representation of Solar Ambients

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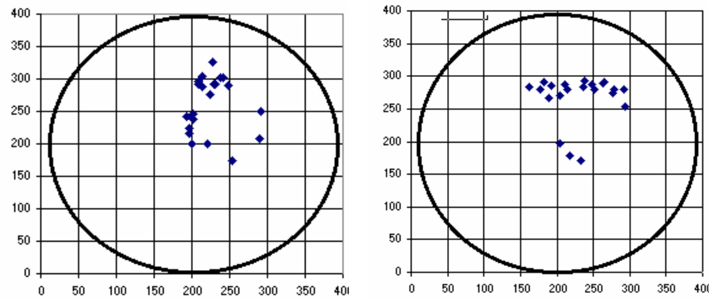

Figure 10
Centre of gravity positions for Rues Petites Ecuries and Strasbourg

As seen on figure 10, the sunspot centre of gravity is used to integrate the changes with the hour of day through a synthetic representation of the urban landscape.

During an analytical day we can evaluate the position of G point defined as the centre of gravity of the solar spot weighted by the size of this spot for each measurement position. The G trajectory provides a suitable approach. As shown by this analysis, the G position evolves differently according to the framework.

6. Conclusion

This report constitutes an overview of existing methods for visualisation, simulation and/or measurement data analysis of urban environmental parameters. The possibilities offered by the immersion method allow the evaluation of interaction between urban built environment, physical conditions and human perception *in silico*. The use of Virtual Reality as a rendering tool offers an alternative to methods based on surveys performed in real cities. By taking into account scaling and human factors, this method would be able to compare different urban frameworks, in order to identify the characteristics of their solar, thermal and acoustic ambients. This leads to a new urban built typology in relationship to the human perception parameters.

The method can be also applied to non-existing cities, past or future, and further studies are needed for the interpretation of the human reaction in the virtual city in order to render them through a multi-sensorial rendering module.

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