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Applying level-of-detail and perceptive effects to 3D urban semantics visualization

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Abstract

Urban environment consists of various types of data, both geometric ones and non-geometric ones, among which urban semantics are important sources for non-geometric data. The modelling and visualization of urban semantics is one type of information visualization (InfoVis). In both 2D and 3D environment, a lot of work has been done, which use different kinds of representation forms to illustrate knowledge and information stored in the original abstract dataset. This paper aims to apply the idea of information level-of-detail (LoD) to urban semantics visualization and a text-based semantic database is built to illustrate how the idea works. Then in the implementation process, four perceptive factors for text visualization are chosen, while we mainly test, compare and analyse text size, aiming to better aid users find new knowledge and make decisions.

Categories and Subject Descriptors (according to ACM CCS): I.2.4 [Computer Graphics]: Knowledge Representation Formalisms and Methods—Frames and scripts

1. Introduction

As computer science develops rapidly and user demands grow daily, huge amount of urban environment based applications appear to aid urban planning, transportation control, disaster management, navigation and decision-making support. In these applications, data can be divided into two types: geometric features and non-geometric features. Geometric features provide users with direct information about the urban environment, to help user establish the knowledge of where he is and what the surrounding looks like. So the user can *see* geometric features. As for the non-geometric features, which are always abstract dataset that users can not directly *see* through their eyes, a translation process is needed. This translation process, from abstract data to a result that users can easily understand and find new knowledge, is information visualization (InfoVis), which includes urban semantics visualization [KHG03].

In this paper *urban semantics* stands for the non-geometric features in urban environment. The visualization results of urban semantics differ themselves through numbers, tables, charts, symbols, colours, figures, texts, links or even 3D objects. Since its creation, text is one effective way to transmit information to human beings. This paper chooses text as the visualization form for urban semantics, to study information management and promote user interaction.

An information level-of-detail model in [ZTM13] is firstly used to create an event semantics database with different LoDs, which is later implemented in a case study. Four perceptive factors are chosen, three parameters are used as inputs. Results are screen-shots of different parameters applying to perceptive factors from the same camera position. Discussions and future work are given in the last part.

2. Related work

This work is built on the basis of semantics visualization, level-of-detail for semantics and perception in visualization. A lot of work has been done respectively, but few of these works combine them together.

2.1. Semantics visualization

Semantics enriched visualization would dramatically enhance the usability of urban models and would open the door to the use of complex models in more sophisticated applications [PCS12]. Semantics visualization develops rapidly in both 2D and 3D environment. A lot of on-line tools are available for InfoVis, which deal with data topics firmly related

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to our daily life, such as economy, health, energy, education, politics, population and environment.[1 2] Most of these visualization results are represented in 2D and through graphs.

In 3D environments, [CWK*07] introduces a highly interactive way to provide user with intuitive understandings of urban semantics, population census information to in his case. They aggregate buildings and city blocks within urban environment into some legible clusters, which can give the user an mental impression of the city, even if level-of-abstraction is applied to the city model. Population census information is superimposed onto the city model in form of colour, along with a detailed information table aside explaining the 3D visualization result. *Invisible city*[3] uses social network datasets to describe a city of the mind, such as how a topic moves in a city. It combines time into the visualization result, and lines are drawn to illustrate the moving trends of topics.

Few of above works use texts as the representation form for semantics. However, our work is different from the pure 3D text visualization problem, which mostly focuses on the performance of a single text or a small group of texts, such as where to place it, how to improve its visibility, how to highlight it out of the environment or how to avoid occlusions among themselves. While we emphasize more on the overall performance of all the information/texts visualized in the 3D urban environment.

2.2. Level-of-detail for semantics

Levels-of-detail (LoD) were firstly introduced in computer graphics to describe the detail degree or complexity of an object, which mainly dealt with geometric features [Jam76]. Starting from *21st* century, LoD for semantics was proposed to enable accurate information management and knowledge sharing, and to improve the reliability and performance of visualization result. The five LoDs defined in CityGML by OGC are geometric-semantic combined standards to construct an urban environment [KN12]. But one drawback is that the LoD for semantics is always linked with that of urban environment, which is not independent.

Currently the LoD for semantics are normally illustrated in 2D environment, with figures or tables at different views, such as [ZHRT08], which uses a tree map to represent different LoD patient information, which can be used for analysis and comparison between patients who have similar diagnoses. This type of LoD is in fact a multi-view visualization method. This work will extend the LoD for semantics into 3D environment.

2.3. Perception effects for visualization

Visualization is the technology which makes data *visible* to users to enhance communication or understanding [RL95], hence we should take human perception into consideration. The research on human perception conducted by psychologists and neuroscientists has advanced enormously during the past years. In the book of *Information Visualization - Perception for Design*, C. Ware details how human perception and cognition work and why perception is important for information visualization [War04]. This book gives comprehensive suggestions on how to take advantage of perceptive factors such as color, lightness, contrast and constancy to design an information visualization.

Besides, [PKB05] works to evaluate the influence of layout, screen size and field of view on user performance in visualization. [EF10] gives an overview on visualization and introduces techniques and design guidelines from the viewpoint of perception. [MTW*12] works to analyse the effect of styles in visualization. For a long time, Shneiderman's famous mantra is wildly accepted: *Overview first, zoom and filter, then details on demand* [Shn96], based on which a lot of information visualization are designed. Here are also typical visualization techniques concerning perception: *Fisheye effect*, one kind of *Focus + Context* technique, uses geometric distortions to guarantee geometry continuity while information at the distorted part is always hard to read for users [Fur86]. *Overview + Detail* integrates details and the global view in one visualization result but lose the continuity of geometries [SWRG02].

3. Urban semantics LoD dataset

3.1. Semantics LoD model

A general strategy for semantic LoD is proposed by [ZTM13]. The main idea is that a more detailed semantic level enriches part of the semantics from its upper level. *S-LoD* is used to stand for semantic level-of-detail. Suppose here are three semantic levels, then *S-LoD0* consists the overall information of semantics to be visualized. In *S-LoD1*, two or more topics are to be integrated into S-LoD0. And there are zero or more topics which can not be further enriched. Semantic element at this level may have zero or more internal relationships with each other. Then at *S-LoD2*, similarly there are two or more sub-topics and zero or more un-enrichable semantic elements. Zero or more internal relationships are possible. And semantic element at this level can be aggregated into one or more upper elements. Then for following levels, mechanism is the same as that for S-LoD2.

3.2. Case study

This work chooses the annual summer music festival in the city of Nantes, France, as a study object to create an urban semantics dataset with LoDs. The festival, "Aux heures

1 http://www.visualcomplexity.com
2 http://outils.expoviz.fr
3 http://christianmarcschmidt.com/invisiblecities/

d'été" in French, is dedicated to give the people in Nantes a chance to enjoy the cultures from both local and abroad.[4]

The semantics dataset is built on the basis of texts, because semantics about this festival are mostly textual information. So we will mainly use text to represent the semantics. As for the 3D urban environment, datasets from [HMM12], which models Nantes in five different geometric LoDs are used.

Each year during the festival, there are various types of activities in the program list, which are named as *event* in this work. Based on the theory above, along with the program information for "Aux heures d'été", a dataset with three LoDs is created as illustrated below in Figure 1 [Bri13], in which *E-LoD* is the level-of-detail of an event in this festival.

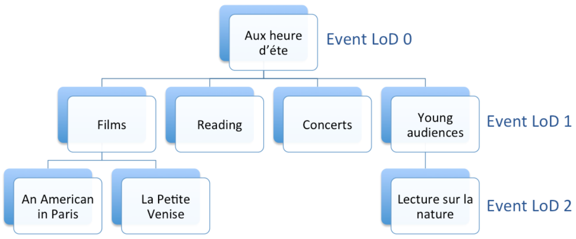

Figure 1: *Event semantics with three LoDs.*

- E-LoD0 lies on top, at this level, semantics are data about the "Aux heures d'été" general information.
- At E-LoD1, there are four topics: Films, Readings, Concerts and Young audiences. Semantics of each topic are information concerning this topic.
- At E-LoD2, here are 32 items in all, separately enriches contents for one item in E-LoD1.

Based on this dataset, the *event* is structured with attributes as listed in table 1, in which *LoI* is the importance degree of this event compared with other events at the same level. On the basis of this data structure, the data for "Aux heures d'été" is organized and stored in a XML file. In reality, the place where an event takes place might be inside a building or in a park. In our case, *Place* is stored as a 3D point when creating the XML file. And for the LoI of event, it is set as three levels, from 1 to 3 separately, among which 3 represents the most important level.

Attribute name	Descriptions
Name	Event name
LoI	Level-of-importance
Content	Detailed information of event
Place	Where will this event take place

Table 1: *Data structure for event.*

[4] http://www.auxheuresete.com

4. Perceptive effects for urban semantics

4.1. Work-flow

For different representation forms of semantics, different perceptive factors can be chosen, such as [PZG*13] chooses different rendering styles for buildings to generate different perceptive effects. We choose texts as the representation form, four perceptive factors concerning texts are chosen: size, color, transparency and resolution. Input datasets are urban semantics and the 3D urban environment, from which we can acquire the *object space distance* and *screen space distance* based on camera position and user interactions:

- Screen space distance: users perceive the visualization results through either computer screens or other display equipment, which are in 2D environment, hence the *screen space distance* can be computed. In this work it means the distance from the screen position of a semantic item center to a screen focus point, written as *Ds*.
- Object space distance: the results of 3D visualization are 3D scenes, objects still maintain their spatial relationships due to their spatial locations, from which the *object space distance* can be calculated. In our case it means the distance from the semantic item to the current camera position in 3D scene, written as *Do*.

Besides *Ds* and *Do*, *LoI* of the event is also considered as an input which is pre-tagged in the dataset. Figure 2 illustrates the work-flow:

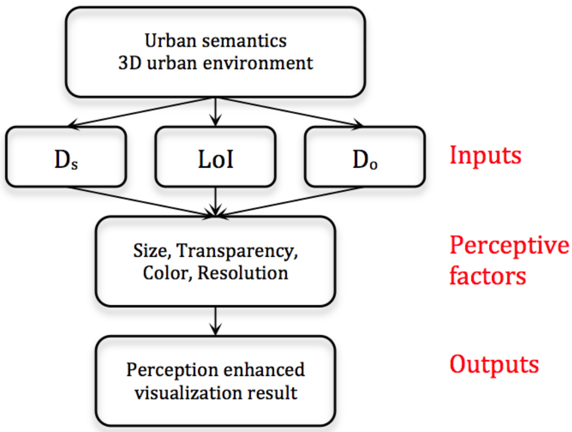

Figure 2: *Work-flow of applying perceptive effects.*

4.2. Processing functions

The inputs are determined, then it is time to use these inputs to *process* perceptive factors. We decide to construct different processing functions using inputs as variables to generate the *output*. Currently we have 8 processing functions, in both screen space and object space. The results of all functions are normalized between [0, 1]. For each perceptive factor, they separately have a *base*. Output is generated by multiplying the base with function results as showed in equation (1):

$$Output(s,t,c,r) = func(D_s, D_o, LoI) * base(s,t,c,r) \quad (1)$$

This equation illustrates that the matching between perceptive factors and processing functions is a multi-mapping relationship. For a perceptive factor, one or more processing functions can be applied. And for a processing function, it can work on one or more perceptive factors at the same time. So the final output is the result of all the processing functions used multiplying all the perceptive factors chosen.

It is hard to find references on how researchers construct processing functions, so we firstly conducted a parameter study. In brief, the goal is to find a [u, v] pair where u value is used to control the maximum value of the function and v is to control the changing speed of the function. Finally we found that [1.0, 0.31] is the best pair and a table for [x, function value] is gained. This value pair is used for the construction of all the functions. In implementation, this value pair can be modified easily by users if they want.

Typical functions in object space:

- Object space linear function: the aim is to change the function value with a continuous linear effect.

$$OL(x,u,v) = \begin{cases} \frac{u}{v}x & : x > 0, x \leq v \\ u & : x > v \end{cases} \quad (2)$$

- Object space sinusoid function: a sinusoid curve with the value pair is established by equation (3).

$$OS(x,u,v) = \begin{cases} 1 - \frac{u}{2}(\sin(\frac{\pi x}{v} - \frac{\pi}{2}) - 1) & : x > 0, x \leq v \\ 1 - u & : x > v \end{cases} \quad (3)$$

As x grows in *X-axis*, the user gets closer to the object in 3D environment. The purpose of these two functions is to decrease the function value as x grows.

Typical functions in screen space:

- Screen space linear function: the default focus is the screen center and *Sw* is the screen width. Users can click a point on screen to set it as the current focus. Semantics near the focus point will get a bigger function value.

$$SL(D_s, S_w) = 1 - \frac{2 * D_s}{S_w} \quad (4)$$

- Screen space fisheye function: a function that ensures semantics in the center part of screen is amplified and the other part is decreased so as to achieve a fisheye effect.

$$SFE(D_s, S_w) = \begin{cases} 1 & : D_s \leq \frac{S_w}{4} \\ 0.9 & : \frac{S_w}{4} < D_s, D_s \leq \frac{3*S_w}{8} \\ 0.6 & : D_s > \frac{3*S_w}{8} \end{cases} \quad (5)$$

Besides these four functions, we have *LoI function*, *Object space constant piecewise function*, *Object space continuous piecewise function* and *Object space ordering function*, which are difficult to put in an equation as those illustrated. There can be more functions for special purposes.

4.3. Result

The implementation is achieved on an Apple MacBook Pro with a screen resolution of 1440*900 and with the open source 3D graphics toolkit-OpenSceneGraph 3.2.1.

LoD for urban semantics:

The distance from the urban model center to current camera position (*CameraModelDistance*) can be calculated, which is used to control the transition of semantic LoDs. There are three semantic levels, hence we get three scopes in the same parameter study, which are *far*, *near*, *very near*. During the *far* scope, semantics at E-LoD0 are displayed. Similarly E-LoD1 contents are visualized in *near* scope and semantics at E-LoD2 are displayed in *very near* scope.

In Figure 3, the left part is the visualization result for E-LoD0. Detailed information is displayed as *HUD* (Head-up display) texts on screen. In the middle is the visualization for E-LoD1. On the right is the visualization for E-LoD2 semantics, which is the original camera position for later comparisons. The default information visualized for each semantic level is the event name. Detailed information can be gained through clicking on the name as showed in the middle part.

Perceptive effects for urban semantics:

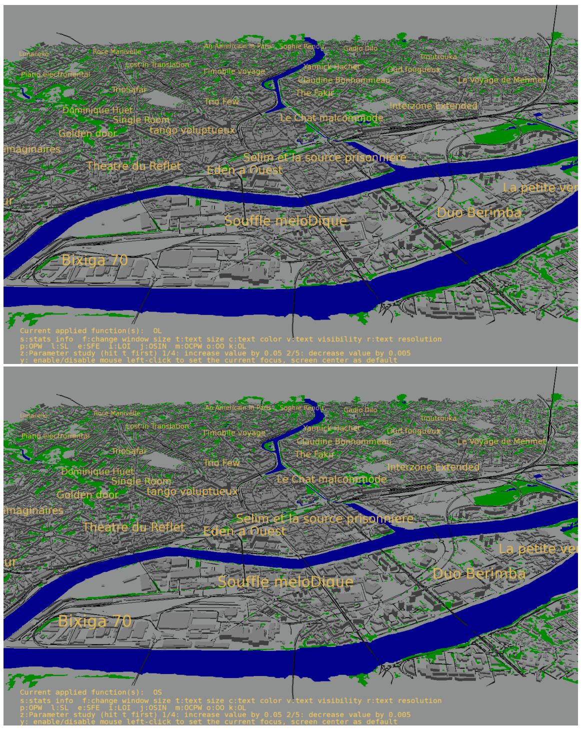

Figure 4: *OL & OS functions applied at original position.*

Here we choose text size to compare the performances of processing functions based on E-LoD2 semantics. In Figure 4, the upper part is the result of applying *OL* function, at the

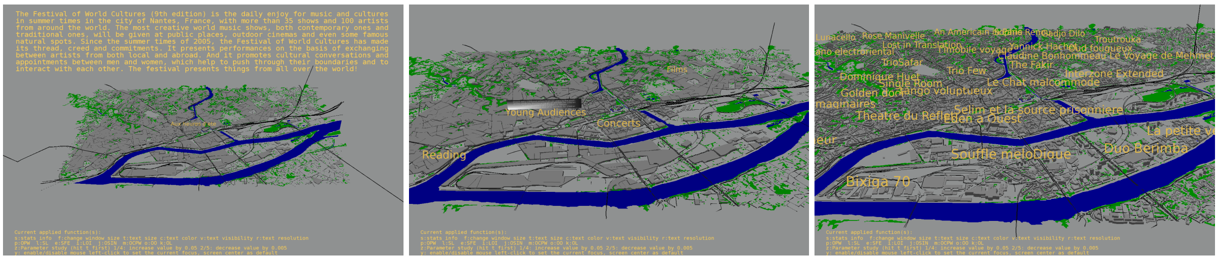

Figure 3: *Visualization of semantics E-LoDs in 3D urban environment.*

same camera position as the original one. We can see from the original picture that there are some occlusions among texts with default size (size base).

While after applying the *OL* function, occlusions decrease. The lower one is the result of applying *OS* function. Since these two functions have the same [u, v] value, there is no big visual difference between them at this camera position. However, as we approach nearer into the scene in Figure 5, it is obvious in the result that from this camera position, the text size in front of the scene with *OS* function is bigger than those with *OL* function (e.g. *Eden a Ouest*).

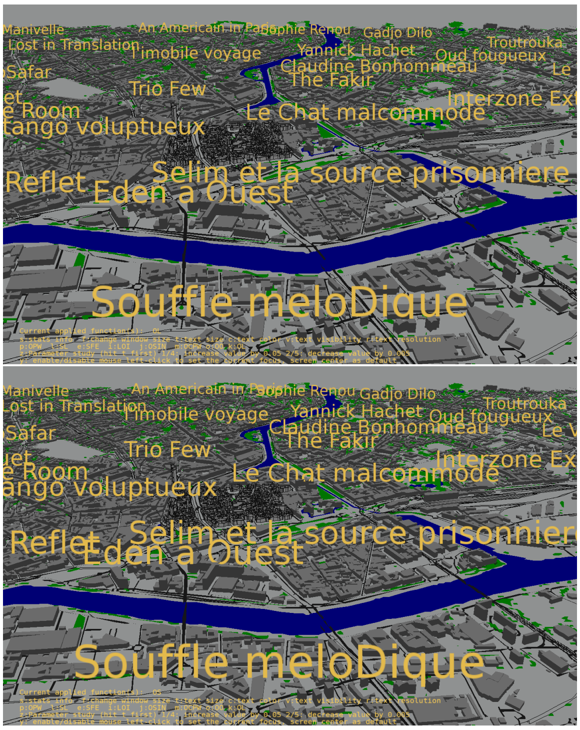

Figure 5: *OL & OS functions applied at a near position.*

Then in Figure 6 is the *SFE* function result. It clearly illustrates the *fisheye* effect as semantics in the *eye* zone is enlarged while the urban environment remains the same, which will not distract user's attention from semantics.

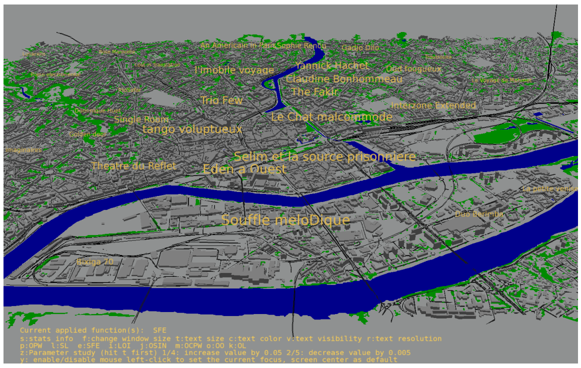

Figure 6: *SFE function applied.*

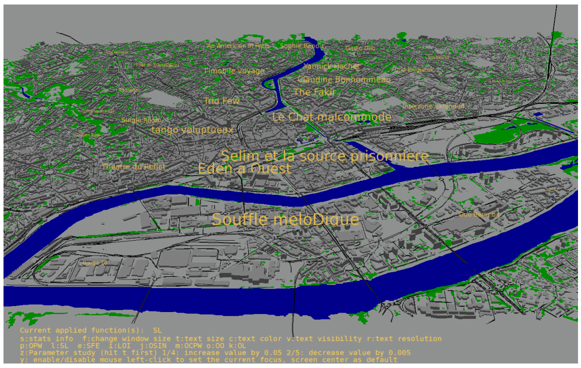

Figure 7: *SL function applied.*

Figure 7 is the result of *SL* function result. Semantics in screen center is of the biggest interest to users. The difference between it and *SFE* function is that the transition in *SL* function is smooth while *SFE* function offers an abrupt effect at the boundary of *eye* zone.

Finally in Figure 8 is the result of *LoI* function.

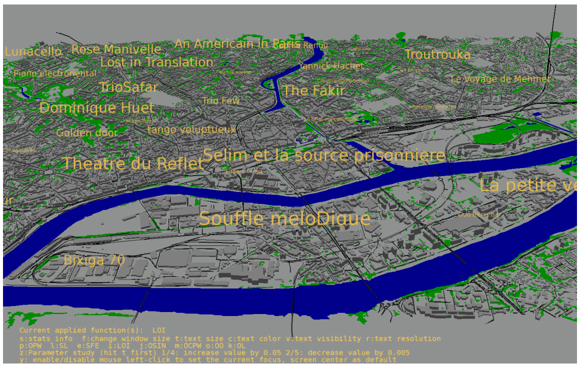

Figure 8: *LoI function applied.*

5. Discussion and future work

Currently we have not yet found any metric to measure the performances of processing functions, hence the evaluation is done by visual comparison. Two contributions are:

- Realizing information LoD in 3D urban environment. Previous works were achieved in 2D environment.
- Applying perceptive effects to 3D texts visualization at a global view, rather than just dealing with a single text. Here the perception effects are only applied to semantics without geometric deformations of urban environment, which reduces distractions for users and enables users to put their focus and interest on semantics information.

This kind of visualization result is helpful for users when the festival takes place in a city. Query equipment can be placed around the event spot and on-line query should also be available. Results put in this paper are static figures, which can not demonstrate the user interaction part. Actually the user can rotate, zoom in and room out the visualization scene to find information which interests him most. [5]

As for the implementation of this work, more perceptive factors are expected to be added, such as the text font. And we hope to have more processing functions to diversify perceptive effects. Then concerning the evaluation, it has to be finished, either with a task-given user test or with an effective metric, to prove that adding perceptive effects to semantics visualization is worth doing. Finally visualizing relationships among semantic items is another future task.

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[5] All figures and a demo are available at `ifzhang.blogspot.fr`