UNCERTAINTY IN ENVIRONMENTAL DATA INTEGRATION INTO 3D URBAN INFORMATION SYSTEM

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ABSTRACT

This paper introduces a 3D environmental urban information system which is to help urban designers and developers to analysing and evaluating the environmental impacts of their urban projects. Where urban data is acquired from 3D urban models and environmental data is often coming from simulation software. For realizing environmental impacts analysis, the environmental urban information must be embedded into urban information system. However, environmental data from different simulations is heterogeneous, especially in geometry. It is not easy to modelling common geometrical descriptions for all kinds of environmental data. In this case, the data of simulations can be inputted in different geo-database, but some queries basing on different environmental conditions will be not applied. Therefore, basing on regular meshes (both in 2D and in 3D), an approach for integrating environmental data in a same geo-database will be proposed. The approaches for integrating these data into one geo-database bring out some uncertainty. Looking for an approach for integrating environmental data that causes less uncertainty in the result is necessary. We discuss some uncertainty of integration process and introduce a solution for reducing the uncertainty.

1. INTRODUCTION

The quality of urban environment is central to improve urban life and sustainability which is a main challenge in urban planning (Yao *et al.*, 2006). So, designers and developers of urban projects (e.g. creation of new building blocks, renovation of housing, operation of urban renewal, etc.) need a tool for analysing and evaluating the environmental impacts of their projects. The common intention of this tool is to contribute to better understanding of environmental impacts in urban planning.

In addition, 3D visualisation and analysis is an efficient way of assessing the impact of urban project, and 3D geographical information system is important in the sustainable urban planning.

In this context, we would like develop a 3D geographical information system, called *'3D environmental urban information system'*, for inputting, storing, integrating spatial data as well as environmental properties of urban space. The development of this system leads to the research of computer-based approach for the analysis of these environmental impacts with assistance from advanced GIS capacity, further functions of queries, modelling, visualisation and spatial analysis can be carried out for making the decisions.

The work comes within the scope of urban form (e.g., urban density) and microclimate (e.g., sunshine condition, ventilation condition, sound environment and heat environment, etc.). The environmental information is related to physical phenomena. In this research, they are results of different simulation tools, or obtained by some terrain observations. The software is used for simulations provides separately results of each type of environmental data and visualise them, but they cannot gather and visualise all data. So, the role of GIS is to integrate results from environmental observations and digital simulations. However, because of different meshes coming from different simulation tools, environmental information is heterogeneous (especially in geometry). It is not easy to modelling common geometrical descriptions for all kinds of environmental data. In this case, the data of simulations can be inputted in different table of geo-database, but some queries basing on different environmental conditions will be not applied. Therefore, an approach for integrating environmental data in a same geo-database, which contains same geometry field of geo-database record, will be proposed in this paper. The process of environmental data integration contains the uncertainties. Looking for an approach for integrating environmental data that causes less uncertainty in the result is necessary.

2. ENVIRONMENTAL URBAN INFORMATION SYSTEM

2.1 Main Information Sources of System

The main data sources for embedding into environmental urban information system are information about urban objects and environmental information.
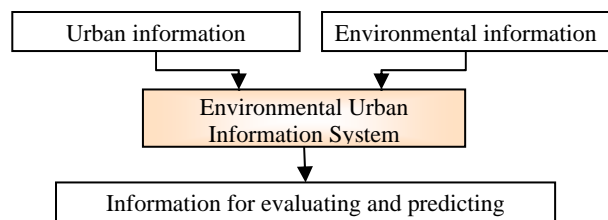

Figure 1. Main sources of environmental urban information system.

Acquisition of urban data

Urban objects are the real-world entities in cities. They are presented by means fixed and non-fixed objects (Benenson *et al.*, 2003). Because of working with urban form and microclimate, non-fixed urban objects are not taking into account in this work. Fixed urban objects (e.g. building, park, traffic ways, etc.) are located directly by coordinates (geometric) and characterized by several properties (non-geometric). Such urban object data can be associated to elementary entities like points, lines, surfaces and volumes.

Often, geometric information of urban object is foreseeable. The geometric information of external space and building footprint can be measurable and acquired from some terrain observations or existing cartography. For 3D geometric information, such geometric information of building is existed in building permit. Usually some draft of form in building permit, often in existing CAD files of urban design, can be inputted directly into the system. More generally, geometric information of urban object can be imported from some existing files (ASCII text files, CAD files).

Acquisition of environmental data

The environmental data are coming from the result of simulation tools or terrain observations. Remarks that urban climate maybe vary considerably within cities and being thus both complex and dynamic. So these simulations constitute information that always has to be referred to the hypotheses made to obtain them. To describing heterogeneity in semantics and above all in geometry of environmental data, a part of the environmental data presented by (Musy *et al.*, 2004) is illustrate.

- *Solar and luminous data* is coming from the simulation software SOLENE[*] (developed by CERMA laboratory). SOLENE performs solar, energetic and luminous simulations over 3D geometrical objects. The computation of the solar data in SOLENE is realised on the façades (walls). Each façade is meshed by triangulation and results are computed for each element of meshing (triangular patch).

- *Wind data* coming from simulations of airflow around buildings. To simulate wind, we carry out FLUENT[†] simulations, modelling a wind tunnel in which we dip the studied quarter. For computing the wind data, the outdoor areas are often meshed by tetrahedron. Each tetrahedron is assigned a wind speed and a direction.

Moreover, another important data concerning environmental impacts is *visibility data* (based on the visibility of façades from public spaces), *sonic data* (noise pollution), and *energetic data* (energy necessary for heating and cooling the building) etc. Generally, environmental data is applied on building envelopes (e.g., solar data), interior of building (e.g., energetic data) or 3D external space (e.g. wind data). Another data concerning urban morphology are computed within the system such as orientation of frontage, density (ratio between total floor area and plot area), the mean surface area to volume ratio, directional porosity, etc.

In addition, the output files (result or extract of result) of these simulations are based on ASCII text format. This ASCII data

type is helpful for 3D GIS to ensure the communication process between geo-database and the simulations. Nevertheless, environmental data are heterogeneous and it is difficult to foresee the common geometrical forms for all the environmental data. Each of these data may be presented in other ways such as averages, minimum, maximum, percentage, direction frequency of extreme values, etc.

2.2 Data Structure and Model

Firstly, land parcel and building footprint can be imported from 2D cartography or available 2D data layers or digital terrain model. Based on the basic layers, related data for third dimension will be manipulated. It is so necessary the 3D models for modelling environmental urban data.

The most important spatial fixed objects in urban environments are buildings (Zhou *et al.*, 2004). A building is described by its cadastral footprint, its frontages, its various levels, the walls of these levels and eventually elements affixed on the walls.

Because of the need for integrating the environmental data into buildings blocks (e.g. density), building envelope and inferior entities of buildings, the buildings are decomposed into levels, walls and roof. To each interior volume, that represents a level, is associated environmental information of the interior of level or building (e.g., interior energetic information). Each wall can be characterized by its surface, its orientation, the materials which it is made with, etc. The façades have to represent the walls. They are associated the semantic ones as the materials which make it up, and of environmental information (e.g. solar information).
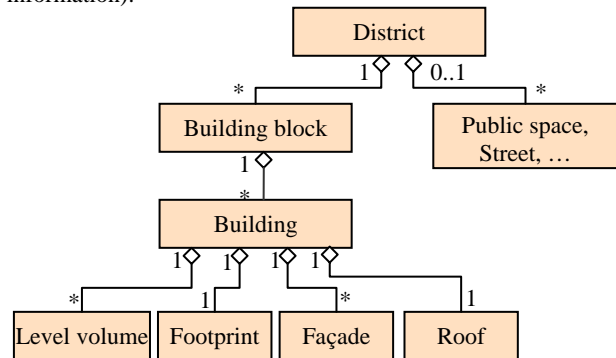
Figure 2. Hierarchical urban entities

The environmental data model is adopted data model of simulations tools. It means that surface model is used for modeling environmental data over envelope of urban objects (e.g. for solar data, visibility data), and volume model is used for modeling wind data and energetic data.

Most 3D urban model available in literature: *3D FDS* ('Formal Data Structure') (Molenaar, 1990), *TEN* ('Tetrahedral Network') (Pilouk, 1996), Modèle Orienté-Objet 3D (De la Losa and Cervelle, 1999), *SSM* ('Simplified Spatial Model') (Zlatanova, 2000), *UDM* ('Urban Data Model') (Coors, 2003). The 3D data model used in the system is similar to UDM which is proposed in (Coors, 2003). In the system, the faces are planar.

Based on the data models, database organization and data integration are introduced. In the conceptual schema, the environmental entities are related to urban entities which are affected. The relation model of entities will be represented in next subsection.

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[*] http://www.cerma.archi.fr/CERMA/Expertise/solene/
[†] http://www.fluent.com/

2.3 Environmental Data Integration

The ESRI software could import 3D features. ArcScene (ArcGIS module) can be used to manipulating en visualizing 3D environmental urban objects because this module provides the ability to create and view 3D Objects. The data integration into geo-database is based on data conversion from CAD files or 'multipatch' feature manipulation into shapfile and geo-database.

Firstly, land parcel and building footprint can be imported from 2D map or available data layers or digital terrain model. Based on the basic layers, related data for third dimension will be integrated.

The extended relational formalism of Laurini (Laurini, 2001) can be to representing the relation model. The relation for 2D map can be:

2DParcel (#Parcel_ID, Area, Landuse, (x,y)*)

Next, the 3D urban objects can be added into geo-database by using the ArcGIS editing environment for multipatch. Remark that the buildings and building blocks can be consisted a number of face (with define a boundary) which is imported as multipatch feature. Multipatch feature can be created from existing data. The input data using for creation of multipacth features is from of these ASCII text files. Often, ones create 3D CAD models during the design great infrastructure. These 3D CAD models can be exported into ASCII text file representing features as a series of extremity points (x, y, z). The relation formalisms concerning to urban data are:

3D_BuildingBlock (#Block_ID, District, Density)

BlockFace (#Face_ID, Block, (x,y,z)*)

Building (#Building_ID, Block, FootprintParcel, Compactness, Energy)

BuildingLevel (#Level_ID, Building, volume, Energy)

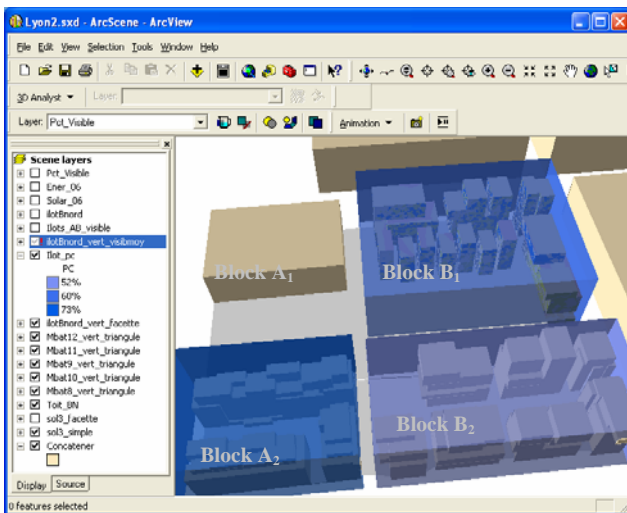BuildingFace (#Face_ID, BuildingLevel, orientation, area, env_impact_average*, (x,y,z)*)

Figure 3. Visualization of building blocks and buildings.

Lastly, by the same method with integration of building faces, the elements of meshing will be represented by multipatch feature. Each element of meshing is associated a series of extremity points (x, y, z) and a value of environmental evaluation (attribute). The relation formalism concerning to one of environmental data is:

Env_Volume (#Env_Vol_ID, value, (x,y,z)*)
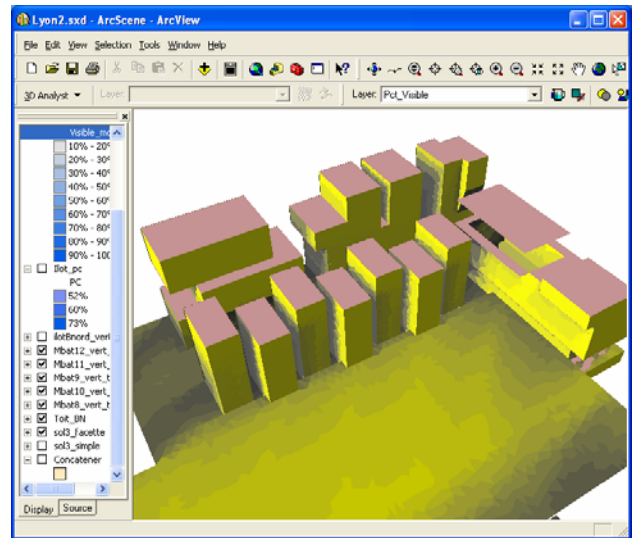
Env_Facet (#Facet_ID, Volume, Face, value, (x,y,z)*)

Figure 4. Visualization of block B_1 with solar data in June

3. APPROACH FOR INTEGRATING ENVIRONMENTAL DATA INTO SAME DATABASE

Until now, the data of simulations is inputted in different geo-database, but some queries basing on different environmental conditions will be not applied, for example, the queries such as looking for the area which have: i) more than 10 hours of sunshine by day in summer, ii) and wind speed at 1.5m more than 5m/s.

For do this, it is necessary to integrate the environmental data of outdoor space in a same database which contains same geometry field content of geo-database record. The problem is here solving of geometrical heterogeneity. One of solutions is to calculate intersection of elements of different meshing. However, the intersection in 3D is complex and is not available in most GIS software.

Therefore, basing on pixel and voxel model, we introduce a solution for solving this problem.

- For integrating surface data, each face of urban object is meshed with a structured grid (regular rectangular element). Next, for each rectangular element *p* of new mesh, if inertia center of *p* is interior of environmental facet *f*, then the environmental data of *f* is assigned to *p*.

- For integrating volume data, all volume of district is meshed by regular cubes. The same manner for integrating of environmental properties, for each cube *c* of new mesh, if inertia center of *c* is interior of environmental volume *v*, the environmental data of *v* is assigned to *c*.

After meshing and integrating environmental data, the elements of new meshes locating in indoor space can be removed because those elements are not concerning to environmental data of outdoor space.

With this solution, the environmental data can be integrated into a same geo-database (either surface environmental information or volume environmental information).

4. DISCUSSION ON UNCERTAINTY

With the proposed solution of integration, the appropriate model should not only represent the geometric information, but also implicitly or explicitly describe the topological relationship between elements of new meshes such as link relations, position relations. It is favorable to analyzing the environmental impacts such as the evaluation of environmental variation in urban environment.

However, this solution brings out some uncertainty. Meshing of simulations is different from the other. We introduce an example on surface data: facades are meshed by triangulation in SOLENE, whereas each element of horizontal/vertical plane extraction at 1.5m from FLUENT result is in rectangular form. The size of elements in a same meshing may be unlike (see Figure 5.).
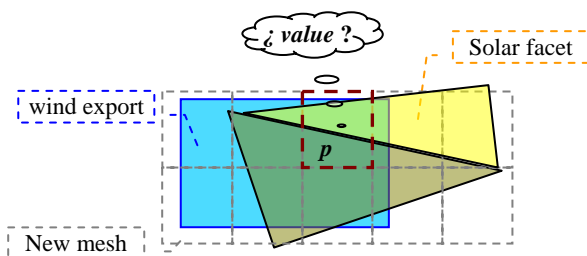

Figure 5. Different form of environmental facet.

Consider now the element p of new mesh. The inertia center of p is interior of yellow triangle. According to proposed solution, the solar information assigning to p is yellow level (9h), but a part of p is gray level (8h). So, the result of integration contains some uncertainty. This problem is existed in integration of volume data.

One of solutions for reducing uncertainties is concerning to the element size of meshes. The more the element size of new meshes is small, the more the uncertainties are reduced. However, if the element size of new meshes is small, the environmental data is voluminous.

For deducing the data voluminous, the adjacent elements having same environmental information are regrouping in same element. This stage is easy realizing because topological relationship between elements of new meshes is easy determined. The regrouping of adjacent neighbors can be realized by using quadtree structure in 2D (Finkel and Bentley, 1974) and by octree structure in 3D (Jackins and Tanimoto, 1980).

5. CONCLUSION

This paper presents an approach to modeling 3D urban environment and environmental impacts which is concerning to urban form and microclimate. Based on the data models, the environmental urban system was developed. The environmental data coming from some simulation tools is heterogeneous for integrating into the system is heterogeneous, especially in geometry. They can be inputting into the system as data layers. In this way, the users can query on some environmental conditions, but not all conditions. By using regular meshes (both 2D and 3D), a solution for integrating heterogeneous environmental data into same geo-database is proposed. The advance of this solution is easy of topology relation management. This solution brings out some uncertainty and we try to reduce uncertainty by using quadtree and octree structure.

Further research will be focused environmental impact analysis and semantic accuracy evalution.

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