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## INTRODUCTION OF 3D INFORMATION IN URBAN GIS : A CONCEPTUAL VIEW

**BILLEN ROLAND**

Aspirant FNRS (Fond National de la Recherche Scientifique – National Foundation for Scientific Research),  
Laboratory SURFACES, Department of Geomatics, University of Liege, Belgium  
Roland.Billen@ulg.ac.be

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### ABSTRACT

This article shows the basic effects of the integration of 3D information in urban GIS. It presents from a user point of view the reasons why 3D information is not widely used. This study is only conceptual and is free of any technical constraints. The underlying statement is that, in a first approach, all urban phenomena should be considered in 3D since the urban physical environment is in 3D. The reasons not to model in 3D are technical or conceptual. When no more technical limitations will remain, only conceptual justification will be put forward. It means that the third dimension should be disregarded only if it is not relevant. The lack of 3D thought due to the inheritance of the “old” 2D information structures, is reported as a major inhibition factor. Therefore, some means such as the use of well defined urban objects with strong relations, are provided to help the user to evolve from a 2D to a 3D spatial thinking. The impact of this evolution on GIS conception method is discussed. Thus, the user could design a complete conceptual model of his 3D virtual world. He would have a powerful tool in order to choose the optimal 3D data acquisition mode. Afterwards, the setting up of a global 3D urban model with different subdivisions is discussed. The underlying idea is to provide a common 3D model which can be used by different users. This follows the same goal as the actual 2D urban databases provided by public authorities.

### FOREWORD

This contribution should be seen as a first doctorate report where the basic study framework is defined. This article presents concepts that are not related to any data structure or acquisition modes. It is free of any technical contingency and must only be read at a conceptual level. The complete study is planned to tackle 3D structures and acquisition modes and will be achieved by the concrete implementation of a 3D urban GIS. In a primary approach, it seemed necessary to focus on the basic concepts. This prerequisite was more complex than expected. It took a fundamental character and is becoming the primary interest of the doctorate study.

## 1 INTRODUCTION

The 3D modeling of the urban environment is a major issue for a wide range of scientific research. This specific research focuses on the basic effects of the integration of 3D in urban GIS, or, to be more precise, on the evolution from a 2D to a 3D spatial thinking. This article tries to understand why the use of 3D information is actually so unusual. A user perspective is taken. The ultimate aim is to provide tools to ease the evolution from a 2D to a 3D thinking.

## 2 INTRODUCTION OF 3D IN URBAN GIS

The introduction of 3D in urban GIS is often view through its technical aspects. At a first glance, it deals with 3D data structures for 3D processing, especially visualization, and with 3D data acquisition modes. Even if 3D is known to have an influence on different phenomena most of urban specialists don't use 3D information, except for a few town planning applications and for pollution studies. In their survey on 3D-city models Fuchs et al. (1998) argument to explain the fact that only few institutions are using or producing data in 3D that the cost for the acquisition is still high and that the users requirements are not really known. The later reason should be investigated. Are producers ignorant of

user's needs for 3D information ? Or is it the users who don't know what 3D can give them ? Usually users don't know their 3D needs. Even if 3D needs are expressed for some applications (for example the propagation of mobile phone signal), the most urban studies are still tackled in 2D. 3D information is still considered by most users as an extension of 2D database in which 3D is added partially. The major limitation for the implementation of 3D GIS or 3D model is the inheritance of the old 2D representation model. Just as the biggest difference between 2D and 3D conception method lies in the fact that the referential framework changes drastically. The way to build 2D GIS is the often the computerisation of formalised GI such as maps. While for building a 3D GIS a thoughtful study of the phenomena is needed. This implies to enrich the descriptive study of conception methods by basic spatial concepts. Urban applications are classified in two categories : the first one includes applications already studied in 3D (few town planning studies) and new applications where 3D is a crucial parameters (mobile phone propagation signal); the second one gathers other applications. The former one allows the formalisation of 3D thinking and of 3D GIS conception methods. The later one provides the means to enrich the step of needs evaluation in a prospective way and to improve the conception methods.

While the urban physical environment is in 3D, the human perception of this environment is according to (Marr, 1982) either in 2.5D or in 3D. So, one can think that the most adequate model for any geographical event must be in 3D. The only reason not to use 3D model is either technical or conceptual. By technical we mean the availability of data, the lack of adequate data structure and process, etc. By conceptual we mean the fact that the geographical phenomena can be explained nearly completely without the third dimension. It is common to take only the principal variables of a phenomena in order to make a model of it. So, if one considers that in a close future no more technical limitations will remain, the only reason to stay in 2D world must be conceptual. The problem of the integration of 3D in the urban GIS would then need a primary study about the principal variables of the geographical phenomena to be modelled. It should be done during the step of needs evaluation advocated by all the conception methods.

### 3 EFFECTS ON THE GIS CONCEPTION METHODS

There are several conception methods for Information System (MERISE, etc.), but not so many especially for GIS (MECOSIG, etc.). It seems reasonable to say that the 3D nature of the information must be taken into account in GIS conception methods. But what is the influence of the introduction of 3D in these methods ? A way to answer is to look at a simplified scheme (Figure 1) of the process of a GIS Conception method, MECOSIG (Pantazis, 1996). Note that other methods could be used and would not present big difference in this descriptive study.

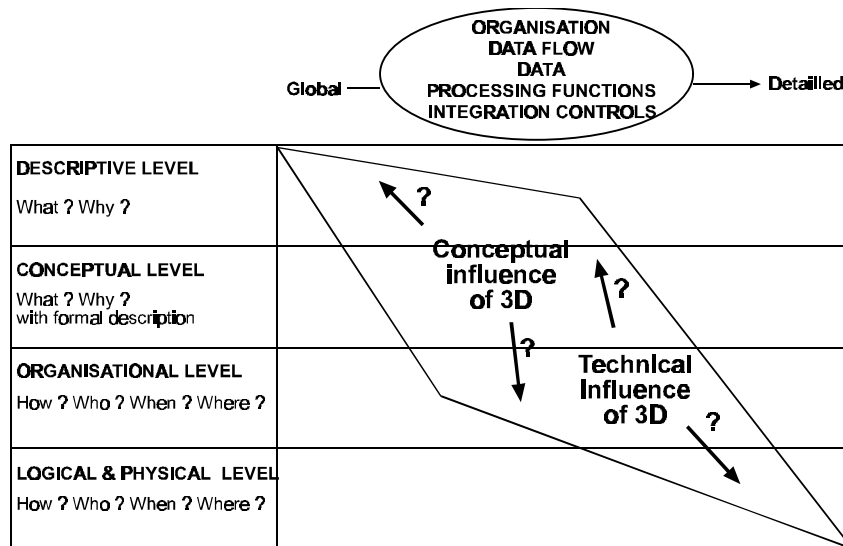


Figure 1. Possible technical and conceptual influences of 3D in the GIS conception progress

In MECOSIG, four abstraction levels are considered : - the descriptive level; - the conceptual level; - the organisational level; - the logical & physical level. All the preoccupation classes (the organisation, the data, the data flow, the processing function and the integration controls) must be considered at the different abstraction levels. The process of the conception method begin with a global consideration of the preoccupation classes and goes to a more detailed study. Usually, the conception is more descriptive and conceptual at the beginning and becomes more organisational and

logico - physical at the end. These explanations are very simplified, more information can be found in Pantazis (1996). Our opinion is that the influence of the 3D introduction is either conceptual or technical.

The technical influence can be considered as the adaptation of tools and techniques to 3D referential, e.g. : - 3D formalisms; - 3D data structures; - 3D processing; - 3D acquisition modes; - 3D visualisation modes; - etc. This influence is more related to the physical implementation and conceptual model of data and process. But it is also important for the descriptive level, for example a 3D visualisation can help the user to think in 3D. All these tools and techniques are widely studied, for example in Breunig (1996) and Flick (1996).

The conceptual influence is the core of our thought. It is directly related to the descriptive and the conceptual levels. It can be viewed as all the means which can help the user to spatialise his urban interests in 3D. These means can be derived from cognition models of urban environment (by to specialist or layman). Note that the other abstraction levels are influenced. Indeed, this new 3D way of thinking must be taught to the users at the end of the conception method in order to insure a complete 3D use of the GIS.

The rest of the article is dedicated to a primary mean to handle the 3D thinking in urban studies.

#### 4 URBAN OBJECT SPECIFICATIONS

A way to help the user to express his needs is to provide him a basic 3D object framework. This basic framework is conceptual and is not related to any data structures. The experience acquired in the field of 2D GIS, show that a complete definition of the object and of its metadata is the necessary basis for a proper GIS conception. These concepts are extended to the 3D urban GIS, and stand in a user perspective, i.e. define object specification. The fact that the proposed 3D data fit on the specification is not taken into account in this primary study. Indeed, the needs of the users would be expressed in an ideal virtual 3D model without any technical constraint. From then on, the user would create a definitive conceptual model, and would use it to evaluate the new technologies (structure or acquisition modes) which could appear in the future.

The idea is to fix some basic 3D urban objects. At an upper level, other objects can be defined and are related to the lower ones by a generalisation relationship. Conversely, it should be possible to go from an upper level object to a lower one (figure 2).

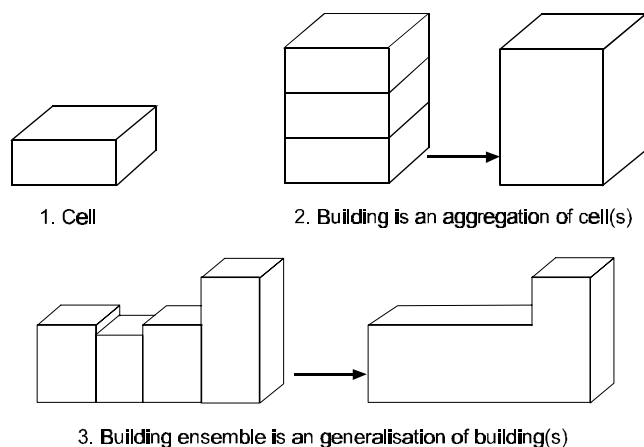


Figure 2. Some potential urban objects

For example, a cell (ex: an apartment) is a basic 3D urban object which composes an other object, the building. The generalisation relationship between these objects is only an aggregation, so the 3D geometry of the building is directly derived from the geometry of the cell. An upper object, the building ensemble, is composed by buildings but its geometry is the generalisation of the geometry of the building. The aim of these subdivisions is to conceptualise a part of the urban environment, and to identify the object of interest. For example, for a price analysis of flats in connection with the height and their view, the cell object is of primary interest. On the other hand, a study on the propagation of GPS signal in urban area would need the building ensemble object.

There are several ways to obtain the 3D geometry of an object. : - measurement; - estimation; - generalisation; - desaggregation;

*Measurement*

It is the most common way. The measurement provides the 3D geometry. It could be done with classical survey material, GPS, photogrammetry, laserometry, radar interferometry.

*Estimation*

This mode is based on the estimation of the third dimension from the 2D footprint and from a specific information like the density, the number of roof and their height, the context, etc.

*Generalisation*

The 3D geometry can be found by some generalisation techniques. These techniques must be fixed for each object and be part of the metadata.

*Desaggregation*

The 3D geometry of a lower object can be derived from the geometry of a upper object. In this case also, the techniques used must be fixed and become a metadata.

This conceptual subdivision is not useless even if the user needs are well known. For the object attributes, similar reasoning must be done. This object approach is then directly linked with the data acquisition. The link between conceptual model and 3D processing is not yet established.

**5 PRIMARY APPROACH OF A GLOBAL 3D URBAN MODEL**

Actually, 2D reference urban database are nearly exclusively produced by public authorities. Their goal is often to provide information to the maximum number of users. Because of the high cost of the 3D data, this kind of solution, i.e. production by public authorities is a good solution for a lot of users. The problem lies in the nature of the 3D information. To be useful for a large number of users, the 3D model must contain a common information base like in 2D databases. Thus, a global 3D urban model must present different subdivisions. This 3D subdivisions should correspond to the 2D subdivision usually used by public producers. This approach meets our will of global spatial thinking and then is not linked to a specific application. It is build on the generalisation of the actual 2D urban subdivision and of 3D city information (already) collected. The following figures are only schemes. They are not designed with a specific formalism and their interpretation is not strict. According to OEEPE study (Fuchs, 1998), 3D city information model should include : - buildings; - vegetation; - traffic networks; - public utilities; - telecommunication; - others. These are linked with potential urban objects.

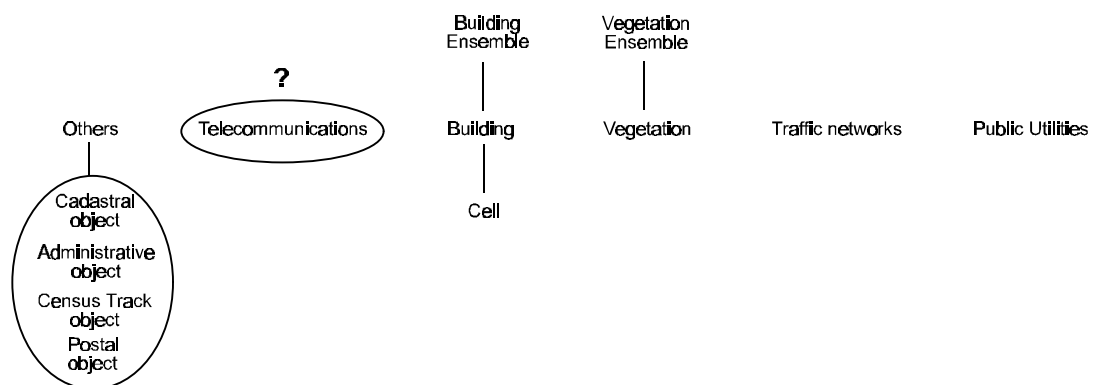


Figure 3. Starting point of the categorisation of 3D city information

In figure 3, 3 objects were added : - the cell; - the building ensemble; - the vegetation ensemble. The cell is introduced because it corresponds to the basic human division of his built environment. It could be a level of a building, above or below the ground. Cell could be composed by n-ary cells corresponding to more specific criteria (architecture, social, etc.). A building is composed at least by one cell. The building ensemble is a set of building grouped by neighbourhood and / or similarity criterions. The vegetation ensemble is a set of vegetation unit also grouped by neighbourhood and / or similarity criterions. Telecommunication objects such as antenna or call box can be basic elements but products such as digital surface model are in fact objects derived from other urban objects. Administrative objects, cadastral, postal and census track are other potential 3D objects. These are 3D extension of the classical 2D subdivisions of urban space (Rouet, 1993)

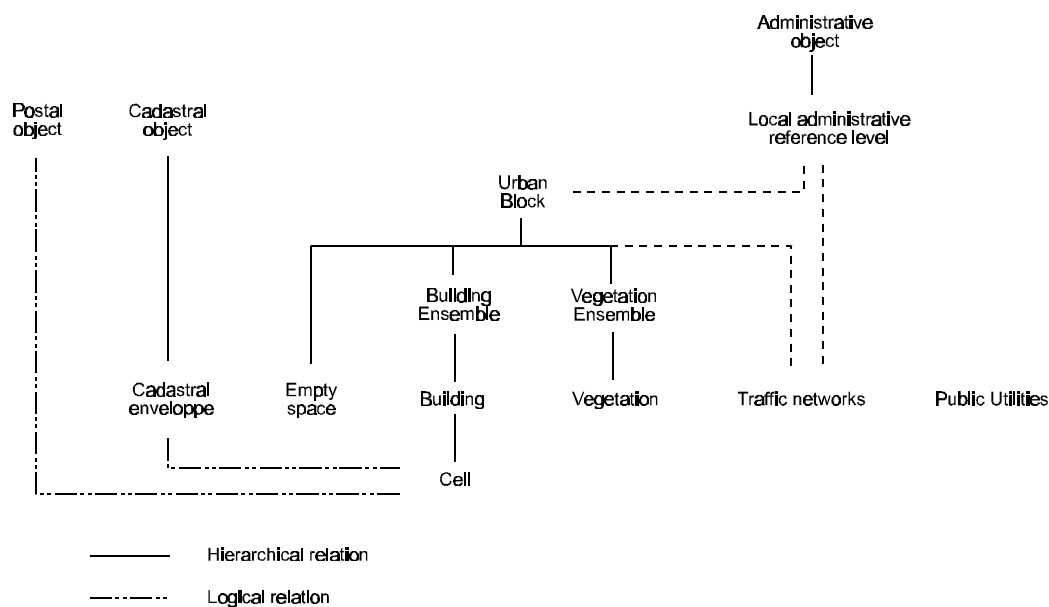


Figure 4. First step in the categorisation of 3D city information

In the figure 4, the following new objects are included: - empty space; - urban block; - cadastral envelop; - cadastral object; - postal object; - local administrative reference level; - administrative object. A 3D urban block is composed by building ensemble, vegetation ensemble, empty space and potentially a part of the traffic network. Urban block, traffic network and public utilities represent the entire 3D physical urban space. The cadastral subdivision represents a set of object where the third dimension is only potentially acquired from their component objects. In this model, some subdivisions are directly included : - 3D politic and administrative; - 3D real estate (cadastral). The 3D “land” use (or better space use) can be linked to the physical object. The 2D land cover information can be, if needed, derived from the physical object. The 3D address information must be combined with the traffic network objects and the cells or buildings objects. The introduction of some abstract urban objects (Postal, Cadastral, Administrative, etc.) implies a big work of redefinition of actual 2D subdivisions of urban space. Note that in few cities, 3D cadastral object and some 3D concept of urban rules are already taken into account. But this is certainly a major challenge for the use of 3D urban model.

## 6 CONCLUSIONS

This primary conceptual approach of the problem of the 3D integration in urban GIS provides some interesting thought. A major limitation of the use of 3D model is certainly the lack of user 3D thinking. This is due to the inheritance of the old 2D information reasoning and structuring. The GIS conception method must integrate this technical and conceptual evolution. It seems that a more descriptive definition of urban objects and of their relationships is a prerequisite to an efficient and useful 3D GIS. Like it is (or must be) for 2D GIS, the data acquisition must correspond to specifications drawn up during the conceptual step of the conception method. The challenge of the use of 3D model needs a complete revolution of spatial thinking. The users and the specialist must redefine their spatial referential to the real one, i.e. a 3D world. The cost of 3D data is still high, and inaccessible for a large number of user. Therefore, public authorities should undertake the creation of global 3D urban databases, like it is already the case in 2D. These 3D databases should contain physical but also abstract urban objects. This implies a big work of redefinition of the actual 2D subdivisions of urban space. But it is certainly a major issue for the use of 3D urban model. Further work will formalize the common 3D city model in order to implement a real 3D GIS.

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