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Learning View-Model Joint Relevance for 3D Object Retrieval

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Abstract:

In the last decades, 3D city models appear to have been predominantly used for visualisation; however, today they are being increasingly employed in a number of domains and for a large range of tasks beyond visualisation. In this paper, we seek to understand and document the state of the art regarding the utilisation of 3D city models across multiple domains based on a comprehensive literature study including hundreds of research papers, technical reports and online resources. A challenge in a study such as ours is that the ways in which 3D city models are used cannot be readily listed due to fuzziness, terminological ambiguity, unclear added-value of 3D geoinformation in some instances, and absence of technical information. To address this challenge, we delineate a hierarchical terminology (spatial operations, use cases, applications), and develop a theoretical reasoning to segment and categorise the diverse uses of 3D city models. Following this framework, we provide a list of identified use cases of 3D city models (with a description of each), and their applications. Our study demonstrates that 3D city models are employed in at least 29 use cases that are a part of more than 100 applications.

Keywords: 3D Information, Fuzziness, Visualisation, Spatial.

1. INTRODUCTION

A larger set of 3D information (e.g., terrain, abstract 3D plots, etc.); however, in the context of this paper, our narrow focus is on 3D city models and these terms also refer to software or data environments in which one finds 3D city models. An important challenge in deriving an inventory of how 3D city models are utilised is the fuzziness in the segmentation and terminology (e.g., use cases, applications; or 3D city model, 3D geoinformation, 3D GIS, etc.). Many terms appear to be used often interchangeably in literature. We attempt to solve this terminology issue in this paper by proposing a hierarchical framework and criteria we developed based on our subjective reasoning. Demand driven growth of construction activities in the rapidly expanding urban areas has become a global phenomenon. With the advancement of technologies, expectations are increased where valid 3D volumes can be calculated with least errors. Can 3D topology and topological data structures help in achieving better accuracy and facilitate the maintenance of 3D models? Complex constructions get immense support if the data structures are 3D compatible and thus can be visualized in a 3D environment. It is important to have accurate alignments of the adjoining objects in 3 dimensions since errors will not only affect the horizontally adjacent objects but also the objects on the surface below or above it. Demand driven growth of construction activities in the rapidly expanding urban areas has become a global phenomenon (Urbanization and Global Change, 2006; Lu et al, 2007). The fact is we are doing construction activities at an unprecedented rate in all spatial dimensions which can be below, on and above surface. With high technology involved, humans are

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successful in constructions of complex nature on a large scale. Our city space is shrinking not only in horizontal terms but also vertical extents (Godard, 2004). The competing demands for the vertical and horizontal space by different types of objects is throwing new challenges to the professionals involved in such activities (Pearlman et al, 2004). Expectations have increased where valid 3D volumes can be calculated with least errors.

2. RELATED WORK

To achieve this goal, it is important to understand the elements involved in such types of processes and their interaction in the limited space available. Indeed the subsurface information should be matched with what is on the surface. So these surfaces representing underground objects cannot intersect with the terrain or with the 3D Buildings on the terrain. All these issues can be regarded as topological inconsistency. Therefore it is important to understand the necessity of 3D topologically correct models for all the objects above, on and below the surface. Currently, the research on 3D topology is disperse and domain-oriented. Therefore, often 3D topologically correct data created for different domains appear to be inconsistent when integrated in one environment.

The paper aims to highlight the significance of 3D topology for all objects above and below the ground. The applications where we need to work with spatially valid datasets are increasing and 2D topology or even domain 3D topology is insufficient to validate their objects consistency. The paper is organised as follows. The next section (Section 2) elaborates on the complexity of construction works in large projects and motivates the need for topologically valid 3D data. Section 3 provides an overview on 3D topological data structures developed for above and below surface objects. Section 4 highlights the common characteristics of the models in order to allow match between The paper aims to highlight the significance of 3D topology for the applications where we need to work with spatial datasets of above and under surface. We illustrate with a small example that current practice of creating 3D models is insufficient to validate their objects consistency. 3D data visualisation and information consistency is critical for large civil projects. Such projects have time span of 5-10 years. In this period huge amounts of data are exchanged between companies involved in the project. Within the Dutch program Ruimte voor GeoInformation, 2004- 2009 (RGI, Space for Geographical Information) several projects have dealt with 3D data modelling (www.rgi.nl) and many of them investigated this problem. For example the study performed within the project GeoInformation management for civil infrastructure works (GIMCIW) in the period 2006-2007 has clearly revealed low efficiency in data management and data exchange. The interviewed large companies have acknowledged numerous challenges: much of the design information is 2D CAD drawings (although 3D features are presented), much of the subsurface information is given as measurements (Excel sheets) and not as 3D models, various different files formats, limited re-use of data, difficulties in obtaining a general overview of the project, etc. (Tegtmeier et al 2009). The companies have recognised the importance of 3D information partially due to increased complexity of construction works and partially due to technology developments. An increasing number of 3D City Models are becoming offered freely by municipalities and other data providers. Various BIM models are progressively produced by designers, architects and constructors (Stoter et al 2011). However, the integration of 3D data sets exhibits even large problems compare to 2D. The available 3D data sets are either not validated or validated within a given domain.

3. PROPOSED SYSTEM

Although 3D models are getting used increasingly in many areas, they mostly have been used without using topological structure or semantic information (Jun et al, 2010). 3D entity-based data models for geospatial representation are based on the concepts used in 2D vector GISs (Lee et al, 2008). In 3D, to provide a comprehensive overview of relationships, frameworks need to examine relationships not only between 3D objects but also between the primitives constructing the 3D objects (3D, 2D, 1D or 0D). This may require 2D and 1D topological requirement to be accomplished first. Many visualisation engines require the presence of topological primitives (nodes, edges and faces) to support the display of 3D objects (represented as meshed closed surfaces), with the data currently being stored primarily in proprietary file formats for efficiency. It may therefore be possible to provide support for visualisation in 3D as part of the implementation of topology, by modifying and enhancing the topological structure to support visualization. Presently many 3D topological models have been presented as data structures (schema's) with the purpose of storing and maintaining topologically correct data and little attention has been paid on processing and 'cleaning' the data sets according to the rules of the topological models or for performing spatial (topological) analysis. 3D topological models have been developed as individual models (Molenaar, 1989; Pilouk et al, 1994) or as an addition to geometrical models supported by present Database Management Systems (DBMS) such as Oracle Spatial and PostGIS (Penninga et al, 2006; Brugman 2010). An overview of 3D Topological models has been made in many studies (Ellul et al, 2006; Zalatanova, 2004). Early 3D topological models differ significantly in number of primitives, explicitly managed relationships (also related to the allowed singularities) and subdivision of space. The primitives managed can be 0D (node, which contains the coordinates), 1D (arc, composed of two nodes), 2D (face, which can have 3 and more nodes) and 3D (body, which can be polyhedron or tetrahedron). The explicitly maintained relationships and singularities are closely related to the type of the allowed primitives. For example, if only triangles and tetrahedrons are allowed, the model commonly does not maintain explicit relationships. Most of the models are based on a full subdivision of space, which means that an extra object 'air' should be defined. To illustrate the differences, few of the models will be described here with their main characteristics.

4. ANALYSIS

All the models listed above have been developed with the idea of managing 3D objects above the ground. Topology has been considered of great importance also for geological objects (Wahl, 2004). The 3D topological models for subsurface (geological) objects have been created separately and focused on objects with indiscernible, continuous boundaries. In these models the subdivision of space is by definition complete. The objects of interest are predominantly bodies and 3D surfaces although line (breaklines, boreholes) and points are also included in the models. Spatial relationships like neighborhood and containment are of specific interest. Another critical characteristic of geological objects is uncertainty of objects. As described by Tegetmeier et al, 2009, the uncertainties could be spatial (unclarity about boundaries), temporal (changes in time) and semantic (unclarity in classifications or values). To represent best the objects and to provide the most suitable operations to perform certain operations different data models have been investigated. Lattuada, 2006 and Breuning and Zlatanova 2011 discuss the differences of geological models compared to on and above surface objects. In all models however, the spatial topology description on subsurface objects as well as on the spatial relations between subsurface

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engineering and surface spatial objects is semantics dependant. Surface features: To show the surface features, we have used a 2D high resolution satellite imagery which is basically a non-interactive raster image. A Triangulated Irregular Network (TIN) depicts the surface variations (0 – 1.07 m). The TIN is created from the point geometry elevation spots which store the height (NAP) values in a separate column in an attribute table. These elevation spots are used to interpolate surface as TIN using 3D analyst extension of ArcGIS. This TIN also serves as base height for the satellite imagery of the area in the 3D environment. The image shows clearly the different landcover/landuses in the area covered. Majority of the area is covered by building complexes. Railway track could be seen dividing the area covered broadly in two parts. Trees and some green patches are also visible on the surface.

CONCLUSION

Much more efforts are need for the implementation and use of data model that maintains 3D topology for above and under surface objects. The reviewed 3D topological models for above surface and under surface confirm that such datasets can be created, but the most appropriate 3D topological data structures still have to be investigated and agreed upon. 3D topological data structures that are based on tetrahedrons such as TEN are very promising start and need to be further studied for their applicability for an integrate data model. Another approach is use of polyhedron data type. A polyhedron data type has some advantages since it will not require subdivision of solid objects into tetrahedrons, but the topological data structure will be more complex to maintain. The topological model then can be linked to the semantic classes of CityGML and the geo-technical ADE. Concluding, we firmly believe that the research on integrated above/under surface 3D models have to be dealt together with 3D topological models. Maintenance of topology in any stage, i.e., creating, storage and analysis of 3D models will ensure their validity and consistency.

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