

Editorial: Interoperation of 3D Urban Geoinformation

LIQIU MENG, München; CHRISTIAN HEIPKE, Hannover; HELMUT MAYER, Neubiberg & JUN CHEN, Beijing, China

1 Background

3D city models have grown in popularity during recent years, especially since the Google Earth revolution. They offer an intuitive organization of spatial objects from the real world, thus allowing a natural perception and understanding of urban information. Indeed, there is a huge potential to use 3D city models as communication language and working tools in a large number of fields, e. g., architectural construction, urban planning, virtual tourism, civil engineering, mobile telecommunication, navigation, facility management, disaster simulation, and mission rehearsal. In spite of the considerably different requirements with regard to spatial coverage, currentness, semantic information, and spatio-temporal accuracy these applications share the common demand for an easy access to detailed 3D urban information.

However, due to insufficient geometric and semantic granularity as well as the lack of interoperability, the available 3D city models are primarily treated as individual show pieces instead of urban information systems. More specifically, the state-of-the-art is characterized by

- separate and partly redundant acquisition of urban information and 3D city models mostly at a rather coarse granularity level,
- inconsistent modeling and updating of urban objects based on ad-hoc specifications for levels of detail,
- limited re-use of existing urban-related datasets due to incompatibility of data models,
- limited updating schemes that account for the rapid changes in the urban environment,
- incomplete, heterogeneous, and partly inaccurate coverage of 3D city models in large regions,
- little semantic information integrated with the geometries of individual 3D urban objects,
- visualization limited to the representation of the appearance of urban objects, and
- few analytical functions available in 3D urban information systems.

With the rapid development of high resolution sensors and multimedia technologies as well as the increasing computing performance, it is now possible to devise and implement methods spanning over the whole process from modeling, acquisition, visualization to analysis of highly detailed and current 3D urban information. Being aware of the potential of high-end techniques and the importance of establishing national and international geodata infrastructures, scientists from Germany and China in the field of photogrammetry, remote sensing, cartography, and geoinformatics jointly launched a bilateral bundle research project on the topic of “Interoperation of 3D Urban Geoinformation” in 2006. 14 research teams from the following institutions of both countries have been playing an active role in the joint bundle:

- Institute of Computer Engineering and Microelectronics, Technical University of Berlin
- Institute of Geodesy and Geoinformation, University of Bonn
- Institute of Cartography and Geoinformatics, Leibniz University of Hanover
- Institute of Photogrammetry and Geoinformation, Leibniz University of Hanover
- Institute of Photogrammetry and Cartography, Technical University of Munich

- Institute of Photogrammetry and Cartography, Bundeswehr University Munich
- China University of Information Engineering, Zhengzhou
- China University of Mining Technology, Beijing
- Hong Kong Polytechnic University
- Hong Kong Baptist University
- National Geomatics Center of China, Beijing
- Wuhan University

Being supported by the Deutsche Forschungsgemeinschaft (DFG) and the National Natural Science Foundation of China (NNSFC), the bundle project aims at promoting the seamless availability and accessibility of up-to-date 3D urban information with the finest possible geometric and semantic details. Trees, roads, land use areas and buildings of urban or suburban areas have been selected as test data. This special journal issue is devoted to the methods, techniques, case studies and the first results of six involved subprojects of the German side.

2 Research Challenges

The goal of making 3D urban geoinformation interoperable is associated with a number of research challenges. At first, the existing methods and techniques applied in two-dimensional GIS need a substantial extension to deal with the inherently complex 3D scenes in both, the geometric and the semantic sense. Second, urban information is of a highly dynamic nature and is related to densely populated areas. It is therefore by no means a trivial task to model the fine-grained 3D structures along with their temporal aspects and to develop efficient strategies for 3D data acquisition, updating, and retrieval. Finally, the realization of an interoperable GIS requires to (1) integrate data sets of different origins, scales, resolutions, formats, spatio-temporal scopes and semantic contents, (2) define quality measures for the integration, and (3) determine the quality of the integrated data.

As a whole, it is far more intricate to reconstruct, describe and render interoperable

3D urban objects than 2D footprints. Taking the object type “building” as an example, a 2D building is represented by its cadastral ground plan, while a 3D building model is characterized by a large number of surface elements. The meaning of a 2D building is usually expressed by a number of semantic attributes attached to its ground plan. In 3D space, however, every surface element of a building could be assigned a number of special semantic attributes.

The larger amount of information necessary to characterize a 3D building implies more effort for reliable data acquisition and maintenance. The relationship between two individual 2D buildings can be described by location, form, size, orientation, proximity, horizontal alignment, and semantic attributes of their ground plans, whereas two individual 3D buildings are additionally related by the vertical alignment, roof structures, wall elements, building heights, surface textures etc.

The visualization of a 2D building is conventionally confined to a plan view, while 3D rendering is determined by more parameters in terms of viewing distance, viewing angle, eye level, vision field etc. Similar arguments hold for other urban objects. Moreover, thematic overlay on a 3D presentation is difficult. Although many GIS vendors tend to expand their toolkits to include 3D interactions, users are often only allowed to change the visualization parameters such as camera position, illumination, color and texture, or conduct some simple calculations on visible objects. The individual 3D objects or object parts and their associated attributes are largely inaccessible, especially when they are occluded.

With regard to the above mentioned challenges, this special journal issue touches basic research questions on

- how to model and capture highly detailed geometric and semantic information of 3D urban objects,
- how to ensure the geometric, topological, attributive, and temporal quality of the available urban or sub-urban information,
- how to re-use existing 3D city models,

- how to harmonize 3D urban information from different sources,
- how to enrich 3D geometric models with additional semantic attributes, and
- how to communicate 3D urban geoinformation to diverse end users.

This special issue does not intend to cover all these questions in a balanced way. It rather tries to highlight some essential problems that are frequently encountered in the efforts toward the interoperation of 3D urban information system.

3 Contents Overview

Six papers are included in the special issue. They introduce a number of multidisciplinary methods and techniques that are rooted in mathematics, physics, computer science, and a number of engineering sciences such as electronic engineering, geodetic engineering, and geoinformatics. The contents reflect the following three focuses:

- modeling and reconstruction of highly detailed 3D urban objects such as facade elements, stairways, and structures of tree branches,
- updating and quality assurance of existing urban or suburban database, e.g., 3D building models and road databases, and
- geometric and semantic enrichment of 2D datasets (e.g., topographic objects of different resolutions) and 3D city models (e.g., facade textures in the infrared domain).

The work of HEINRICHS et al. deals with a generic strategy for reconstructing architectural models using multiple mobile terrestrial video sequences from a trifocal sensor. In a prototype system, triangulation of spatial stereo is combined with tracking of temporal stereo. The trinocular rectification of uncalibrated images is solved in closed form with six degrees of freedom. An algorithm for image matching on the basis of trinocularly rectified images and semi-global optimization is elucidated and evaluated. The motion of the video sensor is estimated using temporal feature tracking and

it is possible to generate dense point clouds. First experiments with image sequences from a real scene resulted in a highly detailed metric model of the scene, clearly demonstrating the feasibility of the proposed strategy.

SCHMITTWILKEN et al. report over a semantic model for the transition areas from building facades to the surrounding terrain which is termed “building collar”. Their experiment is focused on stairways – one of the most frequently occurring features within a building collar. Stairways of different geometric complexities together with their semantic constraints and functional aspects are represented by Unified Modeling Language (UML) and Object Constraint Language (OCL) notation. It is then possible to derive an attribute grammar consisting of productions and semantic rules from UML/OCL. The paper introduces a procedure for mapping UML/OCL to an attribute grammar which is then used to specify a subset of stairs observed in reality. Further, a generic method to solve the constraints and to generate stair models is described. Although the currently implemented prototype is dedicated to instantiate a limited number of simple 3D stair models only, it opens up the way to formalize and reconstruct more complicated stair models and other 3D features in high resolution building models.

HUANG & MAYER address the extraction of the 3D branching structure of unfoliated deciduous trees from wide-baseline urban image sequences. By combining the descriptive power of Lindemeyer-Systems (L-Systems) for trees with statistical sampling based on Markov Chain Monte Carlo (MCMC) and cross correlation, individual 3D trees are generatively modeled and extracted. The approach allows the reconstruction of realistic branch structures even when they are partly occluded or mixed up with noisy background. This potential has been confirmed by the results of first experiments. The statistical analysis of tree parameters could provide useful information for ecological applications and the detailed 3D branching structure allows for animated visualizations, e.g., for windy days. The authors have started to extend the current

work to open L-systems that will make it possible to recognize different types of trees.

A two-stage strategy of using high resolution aerial orthoimages to verify road databases for suburban areas is described by GROTE et al. In the first stage, the Normalized Cuts algorithm, a graph-based approach, is applied to segment the image on the basis of pixel similarities reflected by colour and edge properties. After grouping the segments containing road parts are then separated from the non-road segments by means of shape criteria. The second stage is devoted to the verification of the road database by comparing the road parts in the image segments with their counterparts in the database. The preliminary experiments have proved the suitability of the segmentation approach. Further, an iterative approach is introduced which should overcome the existing shortcomings of the Normalized Cuts algorithm concerned with the necessity of indicating the number of segments a priori. As to the implementation of the verification approach, an available platform developed for the quality assurance of rural road information is in the process of being adapted for road information in suburban areas.

KIELER et al. attempt to improve the interoperability between different geospatial datasets on the basis of semantic integration with data matching as one of the core techniques. Starting from simple cases with known semantic relationships between the datasets to be matched, they use the semantic correspondences to enrich similar objects or object classes. For the case of unknown semantic relationships, they first establish the geometric correspondences between two different datasets and subsequently infer the semantic correspondences. For this latter task, the possible differences with respect to geometric and semantic granularity are considered. The experience gained so far reveals good matching results for data sets with different granularity levels and similar currentness. The matching process will be refined and extended with additional attribute information. Meanwhile, the authors strive for an automatic analysis of object corre-

spondences with the help of spatial data mining techniques.

Methods of extracting textures of building facades from low resolution infrared (IR) image sequences and integrating the results with a 3D database are demonstrated in HOEGNER et al. This work aims at enriching the currently available 3D building models with the information from non-visible domains such as thermal textures. The images and the given 3D model are first matched with two alternative strategies. One is based on the correction of the camera parameters using three corresponding points, while the other relies on the estimation of planes in the image sequence using homographies. According to the principles of ray casting, partial textures can subsequently be generated for every visible surface in each single image of a sequence. Different partial textures belonging to the same facade are then combined. The resulting textures are finally integrated with a 3D database in a format conformal to CityGML which will likely become an open source standard. The enriched 3D building models serve as the starting point for the subsequent multi-purpose visualization and interactive analysis.

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Prof. Dr.-Ing. LIQU MENG, Prof. Dr.-Ing. CHRISTIAN HEIPKE, Prof. Dr.-Ing. HELMUT MAYER, Prof. Jun CHEN, e-mail: meng@bv.tum.de, Heipke@ipi.uni-hannover.de, Helmut.Mayer@unibw.de, Chen-Jun@nsdi.gov.cn