Introduction

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Large-scale 3D models are the cutting edge of the use of computer technology to understand and plan our urban environments and infrastructures. These models have emerged from two modelling structures – Systems for Architecture, Engineering and Construction (AEC) and Geographic Information Systems (GIS). Developed for different purposes, the problems and challenges facing today's modellers focus almost exclusively on data integration – the ability to use data originally developed in one modelling system in the other and vice versa.

This need for data transportability is not new, as evidenced by several authors in this volume. What is new is the desire to go beyond various conversion programs into an environment where data is truly integrated, where the modelling framework is more universal, where data standards cut across software programs and vendor-specific platforms. This book captures the excitement of researchers, organizations, and vendors in this quest.

The border between data structures used within GIS and AEC continues to diminish. As these two principal forms of modelling continue to merge, as the result of increased interest in large-scale 3D models, the need for data structures capable of supporting both types of modelling efforts, as well as new types of modelling efforts that combine the best features of both simple efforts, is manifest.

In its original concept, computer aided design (CAD) software was designed to deal with large-scale (complex) but small in size (in terms of area) models. Its fundamental feature was providing tools for design. There was no need to maintain attributes and/or geographic coordinate systems. GIS software, almost in direct contrast, was designed to manage small-scale (simple) models but very often large in size. Its fundamental feature was the maintenance of attributes and a variety of different geographic coordinate systems. The first were used to create new objects (buildings, roads, landscapers); the second were used to represent existing phenomena and analyse it. CAD software provided extended 3D tools; GIS was mostly 2D

As CAD has developed into AEC solutions and GIS has developed into 3D solutions, there is a renewed interest in large-scale geo-information among the diverse set of AEC and GIS end-users. AEC designers are frequently challenged with requests to provide the means to link small-scale models to construction representations. The aim of AEC engineers is no longer designing in a local environment. The local environments are now part of a wider world, where project(ed) coordinates are needed. Since the same information is reused and updated, a system is needed to maintain the integrity and consistency of geo-data. GIS users are using tools available in AEC to reconstruct and edit large-scale, realistic 3D models. Since the same information is reused and updated, a system is needed to maintain the integrity and consistency of geo-data. This developments have given impulse to database management systems (DBMS) to develop into integrated systems managing administrative and spatial data. CAD and AEC/GIS use in large extends the spatial data types offered by DBMS.

But many fundamental issues are still to be addressed. Most of these issues can be captured by the need for better integration. Two stand out: data integration issues and modelling integration issues. On the data side, the major questions include: how and where to maintain topology?; how and where to maintain attribute information?; how and where to maintain geographic coordinate systems?; and what kind of functionality would be offered where? Similar questions exist on the modelling side. 3D GIS modellers are struggling to incorporate several AEC tools – such as the notion of primitives (such as 3D parametric primitives, splines, etc.) to design and visualize objects – that are currently not supported in most GIS software.

Within this research and application environment, the need for an Open GIS compliant environment, capable of sharing data across platforms, programs, and policy areas, is obvious. How can Open GIS primitives be used in combination with AEC functionalities (textures, shading etc.) to represent a model close to reality? While 2D GIS have quite advanced tools to edit/update geometry, 3D GIS users are only provided with visualization/navigation environments. AEC designers may become major providers of large-scale 3D geo-data with the ability to edit/update in 3D.

These and related questions were explored at a Geospatial Research Seminar held in Orlando, Florida in May 2003, supported by the software vendor Bentley systems. The current book arose from the papers and discussion at that seminar. Many of the papers were re-written as a result of the collaboration and review of and by the seminar participants and other selected reviewers.

The book is organized into four parts. Part one, titled Nature of the Problem, presents an historical overview of the issues involved integrating GIS and AEC as well as pointing to the issues that still need to be addressed. Simply put, these issues are data integration and semantics, ontology and standardisation. Part two, titled Data Handling and Modelling, consequently focuses on the data issue from a number of viewpoints: data collection, database structures and representation, database management, and visualization. Part three, titled Interoperability, covers the areas of semantics, ontology, and standardisation, from both a theoretical (language theory) perspective as well as detailing some of the best thinking in the world of practice. The book concludes in part four, titled Alternatives, with contributions that focus on recent advances in Virtual Geographic Environments as well as alternative modelling schemes for the potential AEC/GIS interface.

Part one consists of a single chapter. In highly accessible language, Peter Van Oosterom, Jantien Stoter, and Erik Jansen review the question of integrating data between CAD and GIS, provide examples from plan development, visualization, data collection and location-based services, and discuss existing (theoretically and practically inferior) existing conversion capabilities. These parts of the chapter are extremely well illustrated and provide a firm foundation of well-known similarities and differences (e.g., CAD systems are design based, AEC and GIS are more linked to data collection – survey, remote sensing, photogrammetry – and analysis; CAD systems maintain minimal or no attribute information on geometric objects, while AEC/GIS have theoretically unlimited means; AEC systems have 2D/3D geometry with topology, while GIS has 2D/2.5D geometry with 2D topology, etc.; AEC/CAD software clearly provides elaborate tools for editing and visualization of 3D data while GIS software offers more extended tools for analysis of 2D data) .

Moving to the future, the authors suggest, based on their earlier assessment of common applications, that a framework needs to be developed that can incorporate both real-world and designed objects. They suggest a view based on two principles: formal semantics and integrated data management. These themes are picked up throughout the book, forming the essential components of parts two and three.

The second part of the book consists of four chapters focusing on data acquisition, data representation and data structures, database structures and operations, and the issue of transmitting and receiving geo-database information on mobile devices.

In Chapter 2, C. Vincent Tao provides descriptions and analysis of the three major approaches to data acquisition: image-based, point cloud-based and hybrid. Each of these approaches are first illustrated and then compared using the criteria (advantages/disadvantages) of resolution, accuracy, turn around time and cost. Emphasis throughout this discussion is on how improvements in technology for data collection (aerial and close range photogrammetry, airborne or ground based laser scanning, surveying and GPS) and in the automation of 3D object reconstruction is revolutionizing the field. While significant time and non-automation costs remain, and the nature of a good system for 3D management, and the difficulty of modelling 3D within GIS remain issues, the message here is that the technology for collecting accurate, high resolution 3D data progresses over time. Detailed large-scale real-world 3D models will be available in large amounts soon, waiting for good tools for editing, management and analysis.

Roberto Lattuada, after a brief but compelling metaphor on the need to integrate AEC and GIS, provides an extensive literature review of data representations and corresponding structures used for both AEC systems and 3D GIS. Included are discussions about object types, spatial representations, and surface and volume modelling. The author then takes the reader through the problems associated with converting or extending 2D systems into true 3D systems. Attempting to integrate AEC and GIS "problems", he offers the Extended Simplex Model (ESM) as a solution and concludes the chapter with a critical, but forward looking, evaluation of the model.

Chapter Four focuses on the management of data. Martin Breunig and Sisi Zlatanova describe how database management systems (DMBS) are currently used to manage spatial data, including a cogent discussion of needed improvements. They argue for a wider utilization of geo-database management systems, discuss the historical "top down" and "bottom-up" approach and argue cogently for the latter. 3D geo-DMBS is discussed in terms of geometry, topology, 3D spatial access methods, (predicates, functions, and operations), and extensions for spatial query language. The last two sections provide several examples of 3D representations in object-oriented DBMS and object-relational DBMS as well as two case studies – one for man-made objects and the other for natural environments to illustrate the possibilities of geo-DBMS in maintaining 3D spatial data .

In the last chapter in this section, Heiko Blechschmied, Volker Coors and Markus Etz, Coors explore the state of the art in using mobile devices to query and retrieve geodatabase information "on the fly." The authors review the staus of augmenting reality for location based services through such existing mobile systems as ACRHEOGUIDE, GIEST, TellMaris, and LoVEUS. Design features, such as the inclusion of multimedia databases, representation, connecting multimedia and GIS information and the handling of visualizations, are discussed in terms of the LoVEUS model. The chapter provides extensive exploration into system architecture requirements and, various ways to generate and transmit 3D information to mobile devices. The chapter concludes with several operational examples from ongoing research projects.

The third part of the book focuses on one of the major challenges facing data integration in large-scale 3D, or any in fact, modelling efforts. This is the problem of interoperability, perhaps more appropriately described in terms of problems of language and standards. This section has three papers. The first is a theoretical discussion of the issues; the second two describe organizational and vendor perspectives.

Thomas Bittner, Maureen Donnelly, and Stephan Winter place the problems and challenges of data integration on language. Semantic difficulties arise when different modelling approaches term the same domain differently. After briefly describing both syntax and semantic heterogeneity, the authors present a discussion of various ontologies (terminology systems) including: logic based ontologies, non-logic-based ontologies, meta-standards v. reference ontologies, logic-based reasoning, and interoperability. They then discuss potential uses of standards and reference ontologies for spatial information systems and conclude with a discussion of reference, domain and top-level ontologies. The message is that ontologies have to be developed for AEC and GIS integration

While Bittner, Donnelly and Winter present the theoretical argument, the next two papers in this part represent the best of the thinking in practice. The first contribution is by Carl Reed, executive director of the specification program of the Open GeoSpatial Consortium Inc. (OGC). The OGC is a global, voluntary, and consensus-seeking standards organization that envisions seamless geographic information across networks, applications, and platforms. Reed describes a number of OGC initiatives – mostly associated with the Abstract Specification Model – that have resulted in numerous adopted standards recognized by the ISO. After describing more fully the Abstract Specification Model, the author directs his attention specifically to the AEC/GIS integration issue by focusing on the ability of the Web to facilitate integration and then by providing an extended discussion of how the Land XML model used by civil engineers and transportation planners is being developed into an interoperable Land GML model.

The second chapter in this part is by Oscar Custers, business management director of GeoSpatial, Bentley Systems, one of the leading vendors exploring the synthesis of GIS and AEC applications. The chapter focuses on the nature of the workflow – first in terms of the separate AEC and GIS environments, and then concludes with a description of a solution that allows for improved interoperability between these modelling perspectives. The value of this chapter is the clear definition of the workflow requirements, from the point of view of the software and application designers, in large-scale 3D models.

The final section of the book consists of two chapters that represent important cutting edges of research, not discussed above, in areas related to the AEC/GIS integration problem.

Rod Thompson presents an alternative model for topological management in spatial databases. Based on identifying conceptual gaps within an extensive literature review, Thompson introduces the concept of the *regular polytope*. The remainder of the chapter examines the potential usefulness of the concept and identifies possible future lines of research.

In the final chapter, Hui Lin and Qing Zhu present an overview of *virtual geographic environments* (VGE). Here, the authors review general theoretical issues, based mostly on the work of behavioural geographers, involved in designing and using such a system including detailed discussions of: such as how people process spatial data; attributes of multidimensional representation; and modes of interacting with a VGE systems including speech, hand, sketch, and geocollaboration.

In conclusion, large-scale 3D models are clearly the present and future in the design of tools to assist policy makers (who need better and better information to make choices), designers and engineers (working in the entire range of both the natural and built environments), and individuals (who make daily decisions regarding their own personal welfare). The chapters in this book address all three types of constituents for 3D modelling efforts. Problems and challenges in the integration of modelling perspectives and data will never go away, but the contributions in this book take a major step in both ameliorating some of the current problems and showing the way the better models and modelling strategies.