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Development of Mobile 3D Urban Landscape Authoring and Rendering System

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Abstract : In this study, an integrated 3D modeling and rendering system dealing with 3D urban landscape features such as terrain, building, road and user-defined geometric ones was designed and implemented using OPENGL | ES (Embedded System) API for mobile devices of PDA. In this system, the authoring functions are composed of several parts handling urban landscape features: vertex-based geometry modeling, editing and manipulating 3D landscape objects, generating geometrically complex type features with attributes for 3D objects, and texture mapping of complex types using image library. It is a kind of feature-based system, linked with 3D geo-based spatial feature attributes. As for the rendering process, some functions are provided: optimizing of integrated multiple 3D landscape objects, and rendering of texture-mapped 3D landscape objects. By the active-synchronized process among desktop system, OPENGL-based 3D visualization system, and mobile system, it is possible to transfer and disseminate 3D feature models through both systems. In this mobile 3D urban processing system, the main graphical user interface and core components is implemented under EVC 4.0 MFC and tested at PDA running on windows mobile and Pocket PC. It is expected that the mobile 3D geo-spatial information systems supporting registration, modeling, and rendering functions can be effectively utilized for real time 3D urban planning and 3D mobile mapping on the site.

Key Words : 3D authoring, 3D urban feature, Graphic rendering, OpenGL | ES, PDA.

1. Introduction

With user friendly interface, the efficient authoring and rendering system for actual 3D geo-spatial data has been required in the various domains such as ITS, LBS, Telematics, and multi-sensor urban engineering, as well as most conventional GIS applications. For this purpose, it might be implemented using GIS-based photogrammetric techniques related to 3D data acquisition and 3D computer graphics for visualization (Ranzinger and Gleixner, 1997; Pullar and Tidey, 2001; Huang and Claramunt, 2004; Takase *et al.*, 2004; Varshosaz, 2004; Kwan and Lee, 2005; Sirakov and Muge, 2005).

Furthermore, although they are still developing stage, database issues for storage and management of 3D topological geometry data and its attributes are

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related to 3D GIS (Losa and Cervella, 1999; Zlantanova *et al.*, 2004). For 3D modeling, conventional GIS data sources such as LIDAR and remotely sensed image has been studied (Suveg and Vosselman, 2004; Zhou *et al.*, 2004), and the studies related to database schema for 3D urban modeling also carried out (Coors *et al.*, 1999; Arens *et al.*, 2005).

However, these previous studies for 3D GIS modeling and rendering of geo-based spatial features has been available in the platforms of desktop or stand-alone system and web-based system. In the stand-alone platform, 3D modeling and rendering can be regarded as data production and visualization, as basic functions in a conventional GIS. While, in the case of web-based 3D graphic modeling system, Geo-VRML (Virtual Reality Modeling Language) (Honzo and Lim, 2001) or X3D (Extensible 3D) can be utilized.

Since the early 2000s, some researches have tried to test and develop 3D modeling system on mobile devices (Brachtl *et al.*, 2001; Rakkolanen and Vainio, 2001), but the main purpose of those studies was to investigate future possibilities by wide-spread uses of mobile or handheld devices such as such as mobile communicator, PDA or WAP device.

Currently, mobile devices are widely used in the GIS application domain, and practical needs regarding mobile GIS by wireless communication and various sensor systems are abruptly increasing. However, most mobile GIS-based application is limited to manipulation and processing for 2D geo-based feature, in these days. Despite lots of studies on 3D GIS and mobile GIS, it is hard to find mobile 3D GIS with authoring and rendering functions for complex types of 3D features.

Although major advantages of mobile devices are portability and mobility to users, the limited system resources such as small-sized memory, slow CPU, low power and small screen size are the main obstacles to developers who should handle a large volume of geo-based 3D model. As well, the high computation through multi-stage graphic pipeline or pixel pipeline processes has prevented the use of high-quality 3D graphics in mobile devices. In addition, database attribute schema of 3D features to be rendered in it also should be taken into account, because this aspect is discriminated 3D GIS from photo-realistic 3D graphic system such as game or entertainment fields.

In this study, we attempted design and implementation of a prototype of authoring and rendering system for multiple and complex types of 3D urban features with user interactive interface on PDA (Personal Data Assistant or Portable Display Assistant) running Pocket PC.

Geo-spatial features in this system are basically for 3D urban landscape model, composed of lots of landscape component and segment. Ervin and Hasbrouck (2001) summarized feature types and basic techniques on most landscape modeling in the real world.

Main functions for 3D graphic processing or pixel pipeline in this system are designed with OpenGL | ES standard API (Application Programming Interface) released by Khronos group in the mid 2000s. For mobile 3D graphics, M3G API for J2ME (Java 2 Micro Edition) is also available, but it is not adapted due to lower computation performance because it is designed to be implemented on top of OpenGL | ES. Besides, although 3D city modeling on VRML browser for Window CE can be used for this work, but it is not provided functions for 3D model authoring. Fig. 1 shows current three types of standard 3D graphic API.

In this paper, among lots of possible applications using mobile 3D GIS, we explain design of major components in the mobile 3D urban landscape modeling system with overview of OPENGL | ES. Then we represent implementation results.

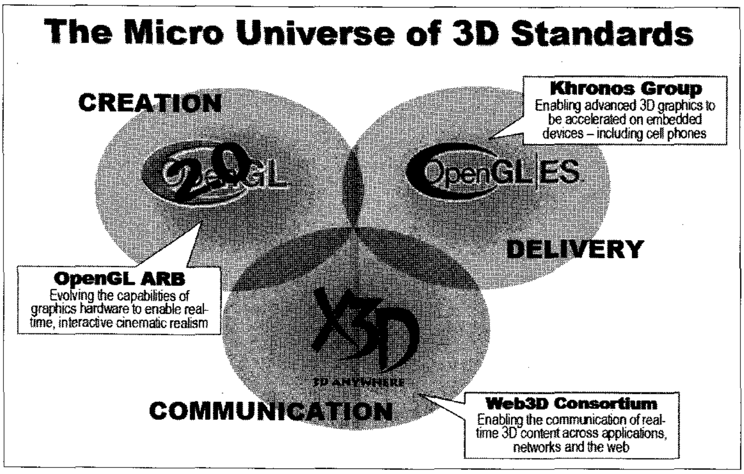


Fig. 1. 3D graphic standards from industry side, excerpted from SIGGRAPH 2005.

2. System Design and Implementation

1) Mobile Graphic API: OPENGL | ES

OPENGL which was released by OPENGL ARB (Architectural Review Board) in the early 1990 is graphic application programming interface (API) that can control graphic hardware for graphic application developers. It provides API of core pipeline functions that can process more easily complicated 3D data (Fig. 2), providing low-level rendering function that offers geometry primitive of point, line, and polygon. As well, it contains special effects functions such as a RGBA color type and lighting, shading, blending, fog, texture mapping function to help more realistic rendering process (Knaus, 2003).

OPENGL | ES which stands for OPENGL for Embedded Systems, released by the Khronos Group, is a low-level, lightweight API for advanced embedded graphics using well-defined subset profiles of full OpenGL API, the most widely adopted cross-platform 3D graphics API (Astle and Durnil, 2004). The Khronos Group members include mobile technology and graphics hardware manufacturers, operating system vendors and developers of software rendering tools. The key goal of the OPENGL | ES is to provide a well-documented, standardized API for mobile devices, designed from ground-up to scale for emerging hardware rendering solutions.

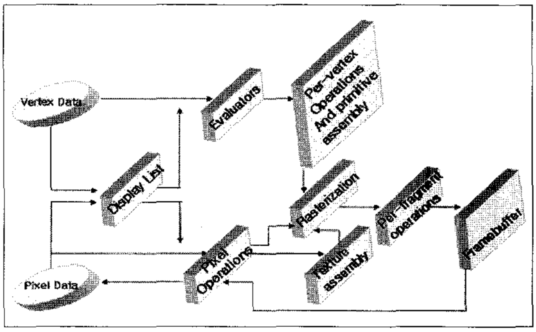


Fig. 2. OPENGL graphic pipeline, excerpted from Knaus (2003).

Furthermore, it is regarded as industry-based standard or de-facto standard from 3D mobile graphic communities including mobile phone manufacturers, mobile operating system vendors, processor manufacturers and graphics software companies. Like OPENGL on stand-alone 3D graphic application software, it provides a low-level interface between applications and hardware or software graphics engines on mobile. Therefore, this royalty-free standard makes it possible to offer a variety of advanced 3D graphics and games across all major mobile and embedded platforms.

2) 3D Data Model and System Design

One of major interests in this study is 3D structure of the urban environment. A variety of urban features, like large and tall commercial buildings, small buildings in residential areas, parks with trees and fences, roads and railroads, can be considered for this approach. For generalization, these features were grouped into several categories: terrain, building, transportation, vegetation, and user-defined ones.

In OPENGL-based 3D graphic application, it is necessary to 3D data structure, because this API does not provide its own data structure. Therefore, a simple 3D data structure was designed and applied for mobile devices. Basically, 3D vector model with database attributes is used in this system.

In terrain feature modeling, DEM and TIN data can be used in data modeling, and TIN model is used in the rendering stage due to its storage space efficiency. While, building feature can be modeled by the composite types of 3D primitives such as simple cube, triangle, square, pentagon, hexagon or other ones, similar to general 3D modeling tools in other 3D graphic applications. As one of important urban composing features, transportation feature such as road, traffic sign board, or other transportation utilities can also be modeled and edited. In the case of road, polygon primitives in the 3D coordinate system are used. However, unlike other features with actual 3D coordinates, vegetation features such as trees or flowers are not based on object model with actual coordinates, but an image-based 3D model.

Fig. 3(A) represents road, one of major transportation features, by polygon geometry with 3D coordinates and its texture, and Fig. 3(B) shows alpha blending effect in photo-realistic texture mapping using base image and target image. Fig. 3(C) is an example case of integrated rendering of road, transportation utilities and 3D apartment objects with

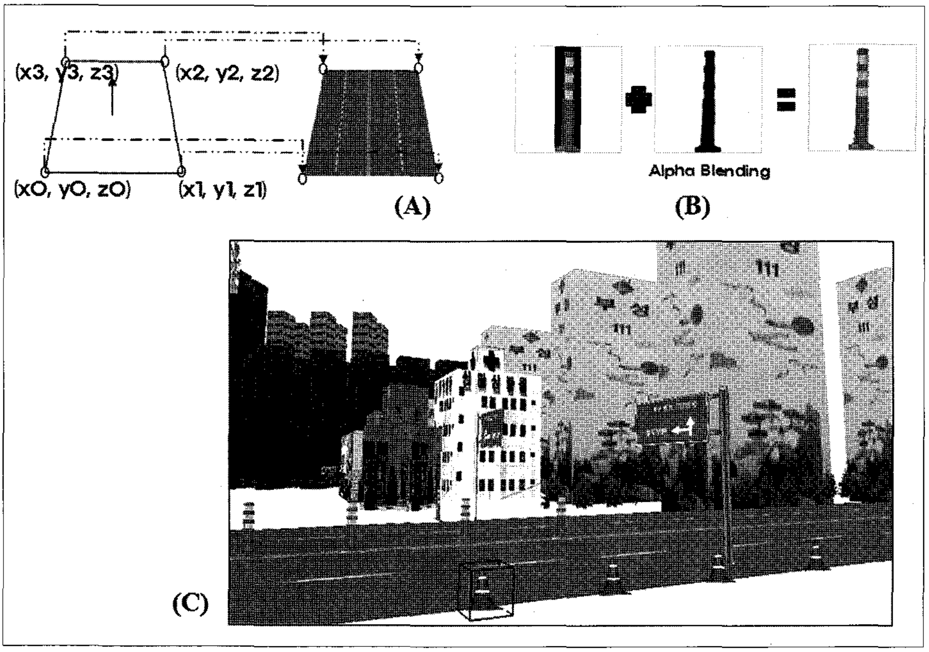


Fig. 3. (A) Road geometry with texture, (B) Alpha blending effect in photo-realistic texture mapping, (C) Integrated rendering of road, transportation utilities and 3D apartment objects with texture produced from this system. Texture is a sample image, and it can be substituted with actual image.

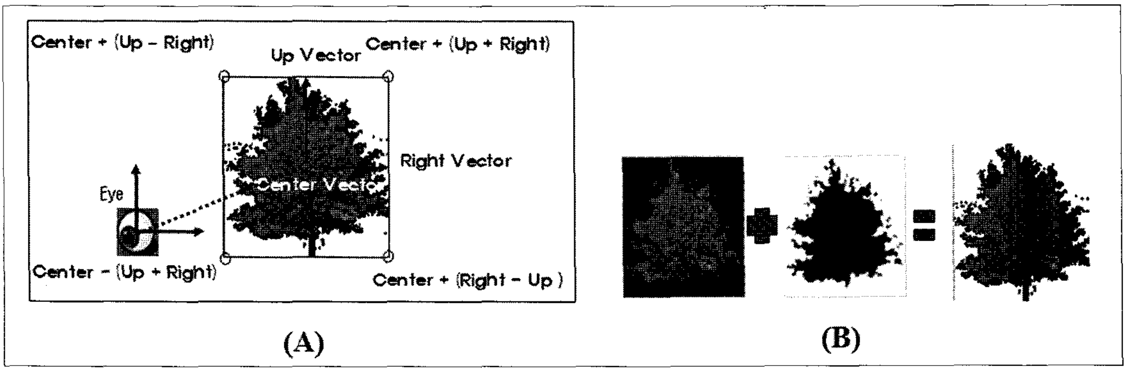


Fig. 4. (A) Tree geometry with texture for the billboarding technique, (B) Alpha blending effect in the photo-realistic texture mapping.

sample texture image produced from this system.

Fig. 4(A) and (B) represent tree image with respect to viewpoint for bill-boarding technique and alpha blending effect in photo-realistic texture mapping. This image can be included in integrated rendering with compound 3D models such as building, transportation, and other.

For this authoring and editing processes, we tried to feature-based approach by separate authoring and manipulating terrain segments, building segments, road segments, or other geo-based things from GUI for easy user interaction. While, data structure within this 3D geospatial rendering system includes geo-spatial data and attributes components. Geometry Information consists of index of objects and 3D coordinates of objects, and attributes of terrain, building and road are stored to attribute information. Also, attribute information is linked to geometry components.

3) Implementation Results

Fig. 5 represents OPENGL and OPENGL | ES-

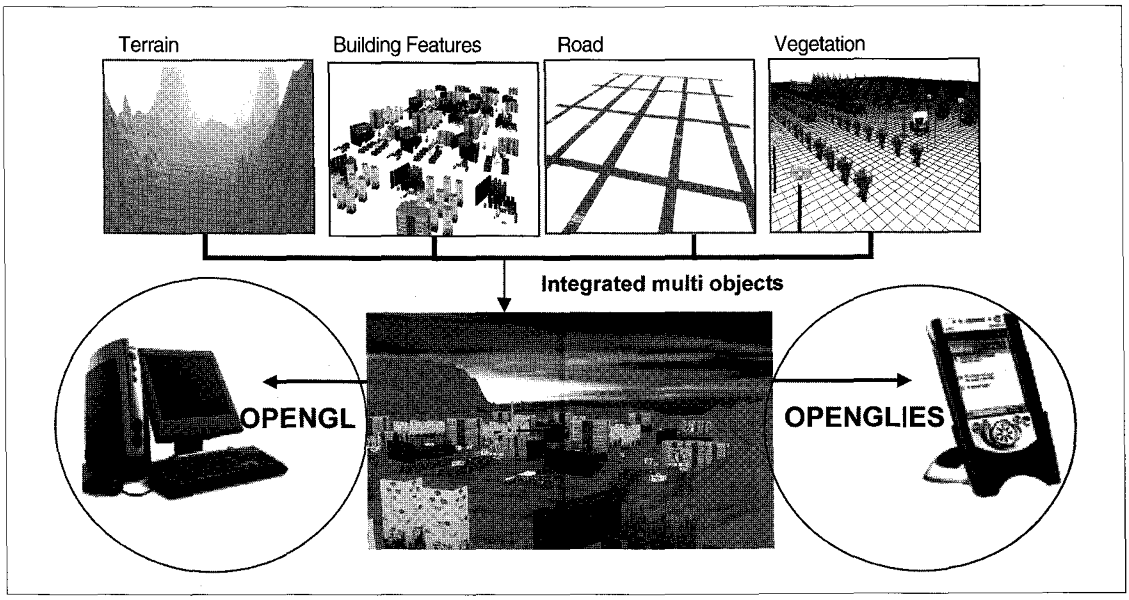


Fig. 5. Integrated scene composing by multiple urban landscape models, using OPENGL and OPENGL | ES API.

based processes for producing an integrated scene composed by multiple landscape modeling and rendering. As shown in it, stand-alone system and mobile system can be implemented using OPENGL and OPENGL | ES, respectively. Although this study is towards mobile 3D, stand-alone system also needs to implement, so that their functions used in a target system can be also utilized and migrated in the mobile environment. The preliminary study was done with desktop PCs in a laboratory to test the overall usability of mobile PDA for urban landscape processing.

Basic architecture in this system is data I/O, data manipulation, main graphic pipeline function, and user interface. First, data input/output part has file I/O function, attribute information and geometry information I/O to create. Second, data manipulation is linking process for geometry and attribute information, and all data that is used using file system or database system. Third, main graphic pipeline functions are to model, project, and render terrain, building, road, and other urban 3D features. These main functions are implemented by OPENGL functions for a stand-alone application and OPENGL | ES functions for mobile devices.

Table 2 shows the summary of OPENGL | ES function lists of Hybrid Rasteroid OPENGL | ES 1.1 API used in this study: geometric processing, rasterization, texture mapping, fragment processing, and other control functions. As well as these OPENGL | ES APIs, we devised some additional functions to store 3D data of primitive level to file system or database and to select appropriate image generating texture. By these functions, users can import and export their 3D feature data between stand-alone 3D system and mobile 3D system, and can produce photo-realistic 3D model.

Fig. 6 is a prototype version of OPENGL-based 3D landscape modeling and rendering system implemented in this study, and complex types of

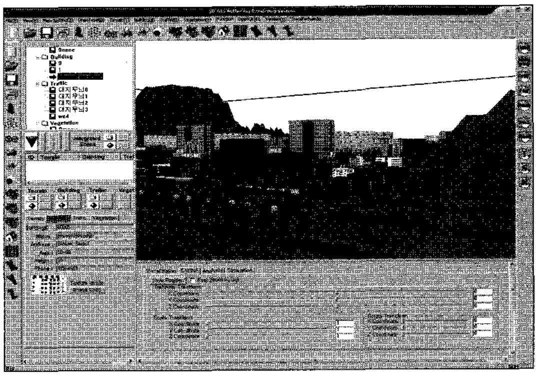
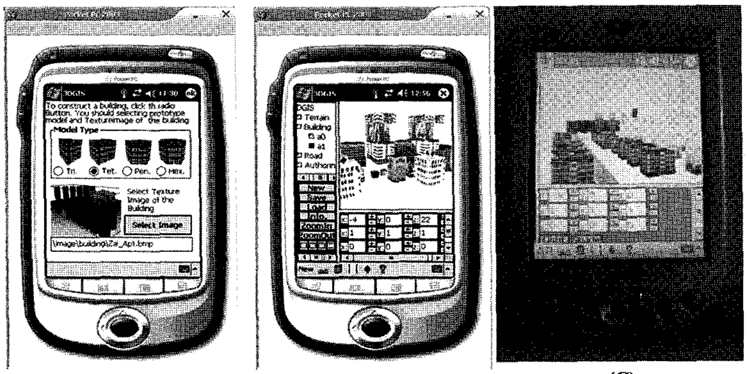


Fig. 6. Stand-alone 3D geo-based features' authoring and rendering system for multiple urban landscape objects using OPENGL API: Implemented result and user interface.

Table 2. List of some OPENGL | ES graphic functions used in this system.

Pipeline Step	Geometric Processing	Rasterization	Texture Mapping	Fragment Processing	Other
Used functions	• Vertex arrays for point, line, Polygon • Matrix stacks • Viewport and Depth range • Vertex lighting • Shade model • Other	• Anti-aliasing • Polygon culling • Polygon offset and Fill mode • Other	• 2D texture • Wrap repeat, Edge clamp • Compressed texture • TexSubImage and Copy TexSubImage • Multi-texture • RGBA pixel, packed pixel format • Bill-boarding • Other	• Blending • Logic Op • Dither • Alpha test • Depth test • Fog • Other	• Clear • Read pixels • Flush/Finish • Hint • Get static state • Other



(A) (B) (C)

Fig. 7. (A) Urban feature authoring in mobile device emulator, (B) User interface of mobile device, (C) Actual example of 3D modeling and rendering application on PDA.

urban landscape features can be manipulated in an integrated window, feature authoring view window, attribute window, and feature controlling combo boxes. Fig. 7 (A) represents a user interface for urban feature authoring in mobile device emulator, and Fig. 7 (B) and (C) are a user interface for integration and control of multiple feature and an example of 3D modeling and rendering application on actual PDA, respectively.

4. Conclusions

In this study, an integrated 3D modeling and rendering system dealing with 3D urban landscape features such as such as terrain, building, road and user-defined geometric ones was designed and implemented for mobile users of PDA using OPENGL|ES API, industry-based 3D standard graphic API. This mobile 3D geo-processing and visualization system enables to view actual 3D places in an intuitive and user-friendly way, and to provide more realistic location-based services. Main graphical user interface and core components in this mobile 3D system were implemented under EVC 4.0 MFC and tested at PDA running on windows mobile, Window CE or Pocket PC. Though this system is an early prototype of the future mobile augmented services with the user's 3D location and context-based information, it links with 3D geo-based spatial feature attribute.

Its authoring functions are composed of several core functions handling urban landscape features: modeling, editing and manipulating 3D landscape objects, generating geometrically complex type features, storage and management of database attributes of 3D objects, and texture mapping of complex types of 3D objects with users' image library composed of airborne or space-borne imageries. The rendering process functions are composed of optimizing of integrated multiple 3D landscape objects, rendering of texture-mapped 3D landscape objects, and real time perspective navigation of 3D integrated scene using user interaction.

It is expected that the mobile 3D geo-spatial information systems supporting registration, modeling, and rendering systems can be effectively utilized to real time 3D urban planning and 3D mobile mapping on the site.

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References

Arens, C., J. Stoter, and P. Oosterom, 2005. Modelling 3D spatial objects in a geo-DBMS using a 3D primitive, *Computers & Geosciences*, 31: 165-177.

Astle, D. and D. Durnil, 2004. *OPENGL|ES Game Development*, Premier Press, 293p.

Brachtl, M., J. Slajs, and P. Slavik, 2001. PDA based navigation system for a 3D environment, *Computers and Graphics*, 25: 627-634.

Coors, V., U. Jasnoch, and V. Jung, 1999. Using the Virtual Table as an interaction platform for collaborative urban planning, *Computers & Graphics*, 23: 487-496.

Ervin, S. M. and H. H. Hasbrouck, 2001. *Landscape Modeling: Digital Techniques for Landscape Visualiztion*, McGraw-Hill, 289p.

Honjo, T. and E.-M. Lim, 2001. Visualization of landscape by VRML system, *Landscape and Urban Planning*, 55: 175-183.

Huang, B. and C. Claramunt, 2004. Environmental simulation within a virtual environment, *ISPRS Journal of Photogrammetry & Remote Sensing*, 58: 73-84.

Knaus, C. (ed), 2003. *OpenGL ES 1.0 Reference Manual Version 1.0*, Silicon Graphics, Inc., 226p.

Kwan, M.-P. and J. Lee, 2005. Emergency response after 9/11: the potential of real-time 3D GIS for quick emergency response in micro-spatial environments, *Computers, Environment and Urban Systems*, 29: 93-113.

Losa, A. and B. Cervella, 1999. 3D Topological modeling and visualization for 3D GIS, *Computers & Graphics*, 23: 469-478.

Pullar, D. V. and M. Tidey, 2001. Coupling 3D visualization to qualitative assessment of built environment designs, *Landscape and Urban Planning*, 55: 29-40.

Rakkolainen, I. and T. Vainio, 2001. A 3D City Info for mobile users. *Computers and Graphics*, 25: 619-625.

Ranzinger, M. and G. Gleixner, 1997. GIS Datasets for 3D Urban Planning, *Computers, Environment and Urban Systems*, 21: 159-173.

Sirakov, N. M. and F. H. Muge, 2005. A system for reconstructing and visualizing three-dimensional objects, *Computers & Geosciences*, 27: 59-69.

Suveg, I. and G. Vosselman, 2004. Reconstruction of 3D building models from aerial images and maps, *ISPRS Journal of Photogrammetry & Remote Sensing*, 58: 202-224.

Takase, Y., N. Sho, A. Sone, and K. Shimiya, 2004. Automatic generation of 3D city models and related applications, *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, ISPRS*, XXXIV-5/W10.

Varshosaz, M., 2004. True realistic 3D models of buildings in urban areas, *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, ISPRS*, XXXIV-5/W10.

Zhou, G., C. Song, J. Simmers, and P. Cheng, 2004. Urban 3D GIS from LiDAR and digital aerial images, *Computers & Geosciences*, 30: 345-353.