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THE DEVELOPMENT OF INTELLIGENT 3D GIS APPLICATIONS IN URBAN SPACE

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ABSTRACT

Pedestrians need support for efficient navigation within and among high-rise buildings to carry out their daily activities in 3D urban environments. Organisations that expand and grow in 3D urban spaces rely on their capacity for accurately locating, mapping and reporting asset information in a complex 3D context to support their effective asset management. Emergency operations in 3D urban settings depend on support for efficient navigation between locations in one or more multi-storey buildings. Metropolitan high buildings are typically represented as two-dimensional (2D) floor plans to outline floor-level space configurations or, as three-dimensional (3D) building blocks to illustrate the topography of urban areas. These conventional representations of urban space cannot provide effective support to pedestrian navigation, asset management, and emergency operations in urban areas with tall buildings. These applications all calls for a 3D geospatial database that supports interactive and efficient queries and calculations of alternative shortest paths and realistic, real-time 3D visualisation This paper focuses on the representation of inter-space connectivity within and among multi-storey buildings in 3D urban space and on the development of intelligent GIS applications in urban environment, such as querying the spatial patterns and conditions of people and things and their changes with time, finding the shortest or alternative paths and generating corresponding directions, and displaying the results in 3D visualizations / animations. The paper presents a case study on the development of a navigable 3D geodatabase for RMIT City Campus and the development of 3D GIS applications in supporting on-campus and within-building pedestrian navigation, emergency response, and asset/space management. The development of a 3D geodatabase is achieved by translating digital floor plans of selected buildings on RMIT city campus, in CAD format, into 3D shapefiles; building a 3D network dataset in which rooms, floors and buildings are connected via corridors, elevators, stairs, passages, and paths; and building a 3D room-use dataset in which selected room-specific and asset-specific attributes are incorporated. The developed 3D GIS applications include shortest path or alternative path calculation, room-specific or asset-specific database query, and 3D visualization of calculated paths or queried results. Research efforts are currently directed towards more cohesive integration of query-able 3D building models, navigable 3D network models and 3D databases of time-critical events and indoor spatial objects. The paper intends to demonstrate that effective iintegration of 3D urban / building model, 3D geodatabase, 3D network, and 3D visualizations can greatly improve our understanding of, and effectively support human activities in the 3D urban spaces which are expanding rapidly and becoming more and more complicated.

INTRODUCTION

Pedestrians need support for efficient navigation within and among high-rise buildings to carry out their daily activities in 3D urban environments. Organisations that expand and grow in 3D urban spaces rely on their capacity for accurately locating, mapping and reporting asset information in a complex 3D context to support their effective asset management. Emergency operations in 3D urban settings depend on support for efficient navigation between locations in one or more multi-storey buildings.

Metropolitan high buildings are typically represented as two-dimensional (2D) floor plans to outline floor-level space configurations or, as three-dimensional (3D) building blocks to illustrate the topography of urban areas. These conventional representations of urban space cannot provide effective support to pedestrian navigation, asset management, and emergency operations in urban areas with tall buildings. These applications all calls for a 3D geospatial database that supports interactive and efficient queries and calculations of alternative shortest paths and realistic, real-time 3D visualisation.

This paper reports our research efforts aiming at the development of intelligent 3D GIS applications in urban space, by means of integrating 3D urban / building model, 3D geodatabase, 3D network, and 3D visualizations, to improve our understanding of the 3D urban spaces which are expanding rapidly and becoming more and more complicated, and support human activities in such 3D urban spaces.

In general, our focus is on the investigation of inter-space connectivity within and among multi-storey buildings in 3D urban space, through the development of related 3D GIS applications in 3D urban environment, such as querying the spatial patterns and conditions of people and things and their changes with time, finding the shortest or alternative paths and generating corresponding directions, and displaying the results in 3D visualizations / animations.

Specifically, this paper presents a case study on the development of a navigable 3D geodatabase for RMIT City Campus and on the development of 3D GIS applications in supporting on-campus and within-building pedestrian navigation, emergency response, and asset/space management.

KEY TASKS, PROCEDURES AND POSSIBLE APPLICATIONS

Key tasks involved in the development of a 3D geodatabase include

• translating digital floor plans of selected buildings on RMIT city campus, in CAD format, into 3D shapefiles;

• building a 3D network dataset in which rooms, floors and buildings are connected via corridors, elevators, stairs, passages, and paths; and

• building a 3D room-use dataset in which selected room-specific and asset-specific attributes are incorporated.

Key tasks involved in the development of 3D GIS applications include

• shortest path or alternative path calculation,

• room-specific or asset-specific database query, and

• 3D visualization of calculated paths or queried results.

The procedures for building the geodatabase involves 8-steps, some of which have been automated with AutoLISP script and ArcObject functions

1. Key source data sets used are 2D floor plans of multi-storey RMIT buildings, obtained from RMIT Property Services in DWG format

2. Each floor plan is used to derive suitable data layers, such as floor outline, room / corridor outlines, doors and windows, space uses, lifts and stairs, utilities (air ducts, power points, internet endpoints, etc), which are then georeferenced to the GDA94_MGA54 coordinate system

3. A floor-level pedestrian path layer is derived for each floor plan, and georeferenced

4. These CAD layers are converted into 2D shapefiles. These 2D shapefiles are then converted into 3D shapefiles

5. 3D shapefiles for the same floor are used to build a query-able 3D floor-level model

6. 3D floor-level models for the same building are used to build a query-able 3D building model

7. 3D building models for RMIT City Campus are used to build a query-able 3D campus model

8. Floor-level 3D pedestrian path shapefiles are used to build navigable 3D floor-level network models,, which are then used to construct navigable 3D building-wide, and campus-wide, network models

Possible applications of the geodatabase include

• The detailed 3D building models created can be used to visualize the internal structure of typical RMIT buildings, including rooms, stairs, elevators, windows, doors, utilities (air ducts and data service electrics) and toilets

• Recorded attributes, such as building, level, room number, room use, capacity, area, and room code, enable a range of table-based operations such as join, link, selection, update, summary, graph, and mapping, to support a wide range of asset management practices such as space planning and maintenance scheduling

• The navigable 3D network model created can be used to support efficient pedestrian navigation within and between buildings. ArcGIS Network Analyst tools can be used to find the shortest path between a starting point and a destination. Constraints on the route can be applied via user specified barriers (e.g. blocked elevators), thus an alternate routes or best route may be calculated

• By integrating querying and navigation capabilities, the 3D model becomes a powerful tool to manage assets. Lecture theatres, classrooms, computer labs, offices are spaces that all need to be allocated for efficient usage. The exact location of an asset can be determined visually. If an asset is reported broken any special requirements for repairing can be assessed. Objects can be queried efficiently, allowing important information to be extracted quickly.

Difficulties Encountered and Our Work-abouts

We have encountered several technical problems related to data translation, edit, display and analysis, and figured out some work-abouts, such as

• The information contained in the AutoCAD files are sorted into 5 feature classes: point, polyline, polygon, annotations and multipatch, which do not map directly into ArcMAP.

• Pre-processing floor plans in AutoCAD by organizing floor plan elements into relevant layers and exporting each layer as individual AutoCAD file offers greater control in sorting CAD floor plan entities and objects into proper ArcGIS shapefiles.

• The process of connecting neighbouring floor and building pedestrian path networks requires manual input of floor elevations to the connecting nodes, performed in the 2D ArcMap environment.

• In this study, centrelines of navigable building space have been determined for all the floors to ensure consistency and connectivity of pedestrian path networks between floors / buildings.

• Overlaying floor networks on top of each other makes it difficult to perform the right connection and easy to assign incorrect elevations to the connecting nodes.

• Viewing the network in ArcScene regularly can help identify and correct errors in network connection and node height assignment.

• In ArcGIS 9.3, no 3D edit tools are accessible in ArcScene, it is very time consuming in editing 3D networks in 2D ArcMAP environment and ensuring quality via 3D views in ArcScene. In addition, ArcScene does not have any network analysis tools and does not support true vertical lines.

• In this study, network analysis is performed in ArcMAP. Both the network and the calculated shortest path are in 2D. To avoid erroneous shortest path calculations, nodes connecting neighbouring floors via lifts are shifted slightly (e.g. 0.1 map unit) to ensure there is no overlap with its neighbouring nodes.

• It was found that when the room layer was displayed, it interferes with the cement layer and slows down navigation operations in ArcScene.

• An offset value of 0.1 assigned to the room layer can overcome this rendering problem.

CONCLUSIONS AND DISCUSSIONS

With enhanced 3D functionality available in ArcGIS 10, the prototype developed in this project can be easily deployed to any urban area with multi-storey buildings when relevant building floor-plans and related attributes are available in digital format.

We are continuing in the development of fine resolution, query-able and navigable 3D building and network models for the CBD of Melbourne. We are focusing on overcoming the problems encountered and towards more cohesive integration of query-able 3D building models, navigable 3D network models and 3D databases of time-critical events and indoor spatial objects, and on the development of more 3D GIS applications to support human activities in 3D urban spaces

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