The Development and Application of Navigable 3D Geodatabase

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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. These applications all calls for a 3D geodatabase that supports interactive and efficient queries and calculations of alternative shortest paths and realistic, real-time 3D visualisations. This paper will present: (1) a campus-wide query-able and navigable 3D GIS of the City Campus of RMIT University in Melbourne, Australia, developed within the ArcGIS environment using detailed floor plans in CAD format as key inputs; (2) an outline of the procedures deployed in the development of the 3D GIS; and (3) some information products, including alternative 3D network paths, derived from the 3D GIS for supporting on-campus pedestrian navigation, asset management, and emergency responses.

Keywords: 3D geodatabase, 3D network path, 3D campus GIS, RMIT University

1. INTRODUCTION

In 3D urban environments, pedestrians need support for efficient navigation within and among multi-storey buildings to carry out their daily activities. 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 (Rikkers *et al.* 1994, Pigot 1995, Pilouk 1996, Zlatanova 2000). 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 visualisations.

The importance of suitable 3D representations of navigable urban building space that support efficient and effective 3D visualisation and 3D network analysis, and the limitations of existing commercial softwares, are well recognised (Gwynne *et al.* 1999, Lee 2001, Zlatanova *et al*. 2002, Coors 2003, Lee 2004, Kwan and Lee 2005, Meijers *et al.* 2005, Pu and Zlatanova 2005, Lee and Kwan 2005, Slingsby 2006, Lee 2007, Lee and Zlatanova 2008).

Over the last few years, we have developed a 3D urban model for Melbourne central business district (CBD), using ArcGIS with 3D building blocks, to support the investigation of GNSS signal performance in urban canyons (Liu et al. 2009). This paper will present a query-able and navigable 3D building model for the City Campus of RMIT University, developed using ArcGIS with detailed 2D floor plans of multi-storey buildings. Methodology deployed in the development of the 3D model will be outlined in section 2. Some 3D spatial information products, including alternative 3D routes, derived from the 3D network model for supporting on-campus pedestrian navigation, asset management, and emergency responses, will be presented in section 3. Solutions to some software-related problems encountered will be outlined in section 4. Finally, some conclusions and future research issues will be given in section 5.

2. METHODOLOGY

The methodology involves an 8-step procedure, some of which have been automated with AutoLISP script and ArcObject functions.

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

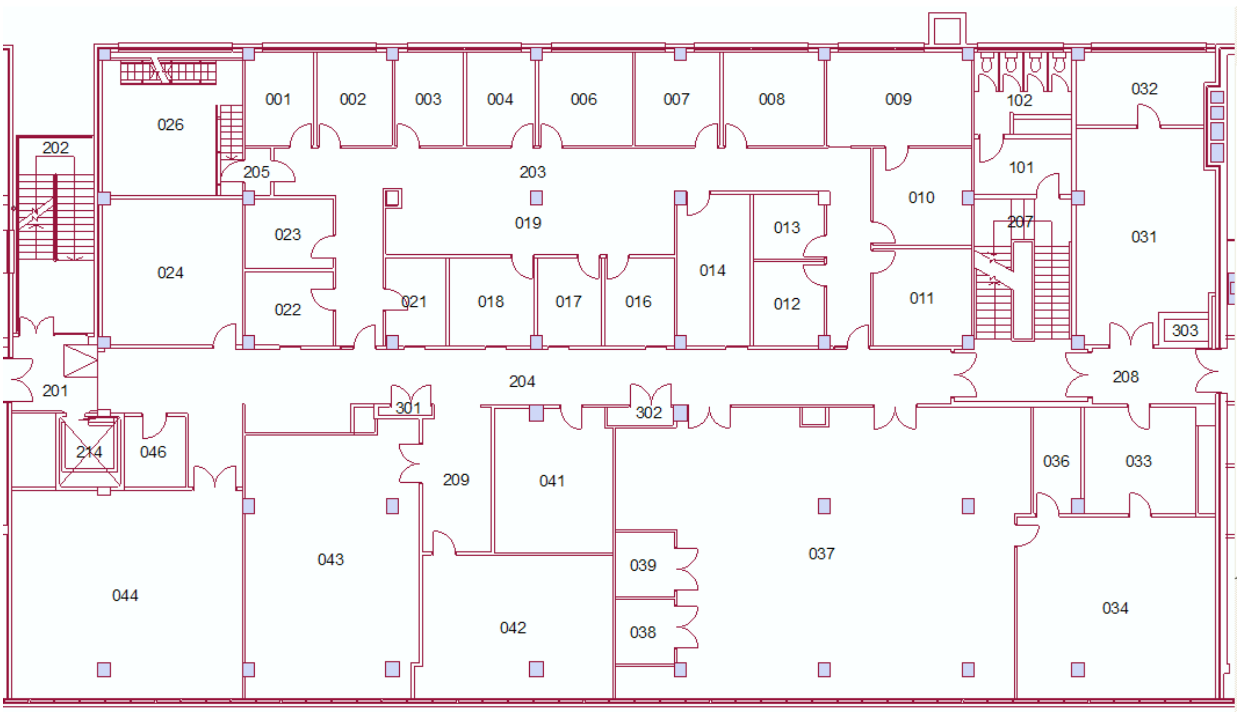


Figure 1

Step 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 (Figure 2).

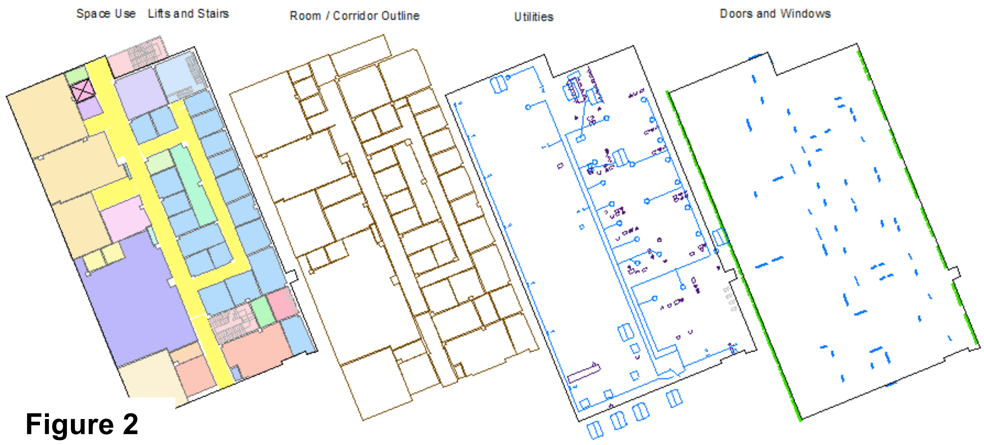


Figure 2

Step 3: A floor-level pedestrian path layer is derived for each floor plan, and georeferenced (Figure 3).

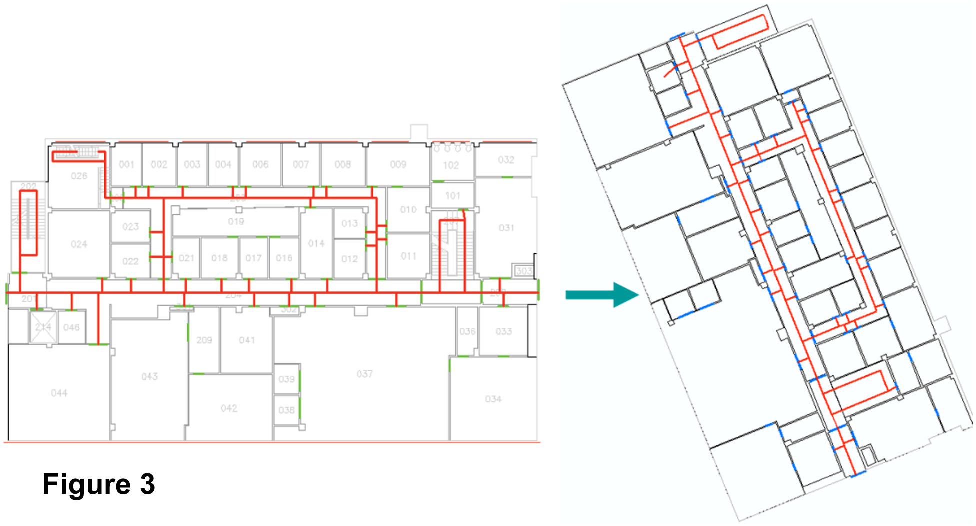


Figure 3

Step 4: These CAD layers are converted into 2D shapefiles. These 2D shapefiles are then converted into 3D shapefiles (Figure 4).

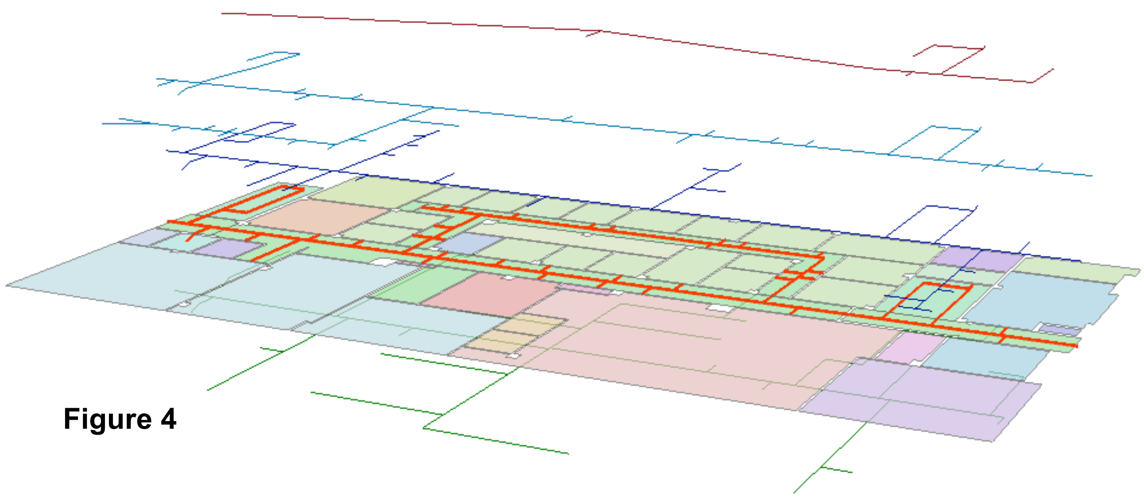


Figure 4

Step 5: 3D shapefiles for the same floor are used to build a query-able 3D floor-level model (Figure 5).

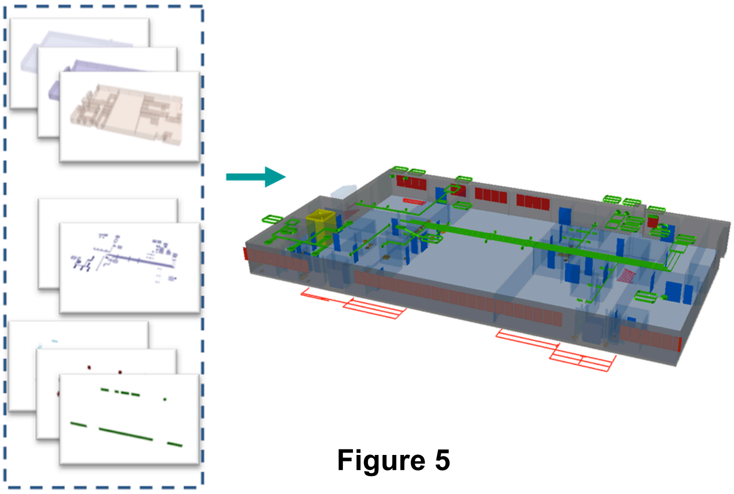


Figure 5

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

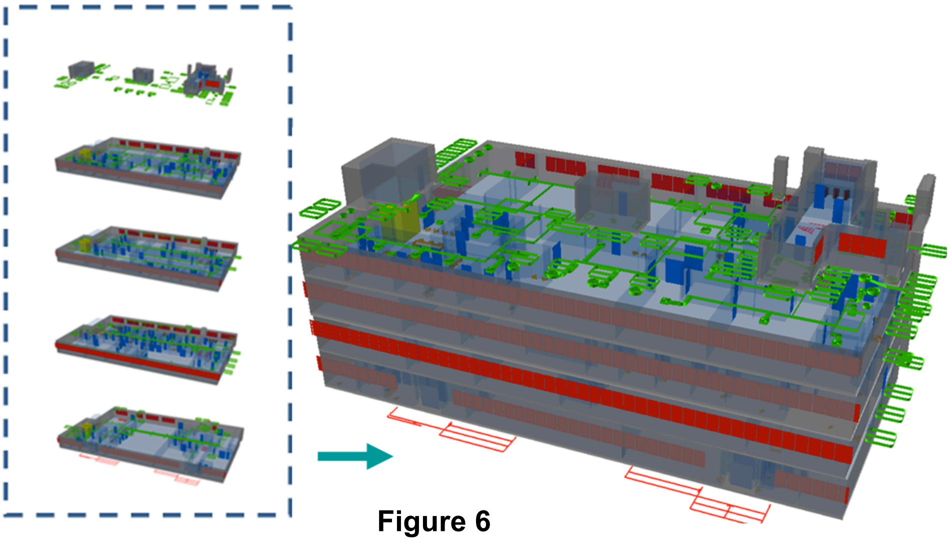


Figure 6

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

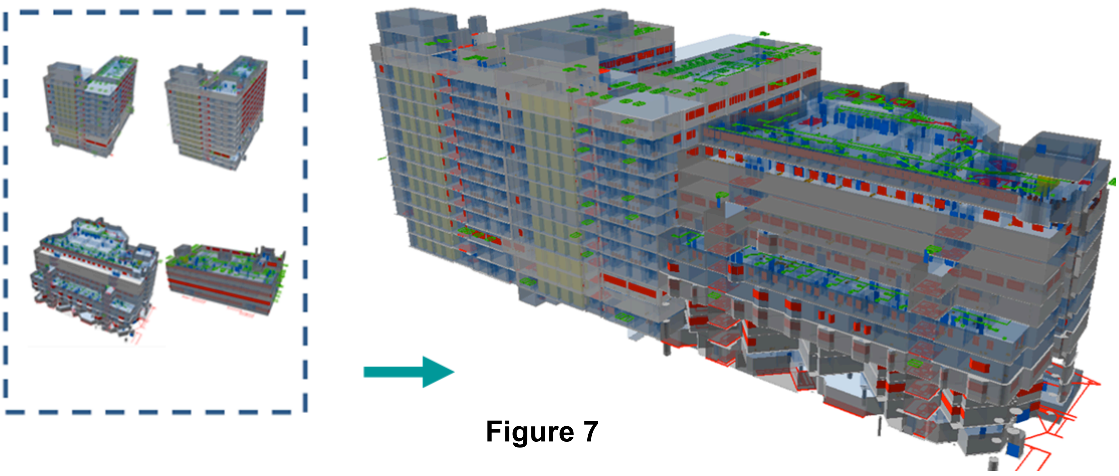


Figure 7

Step 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 (Figure 8).

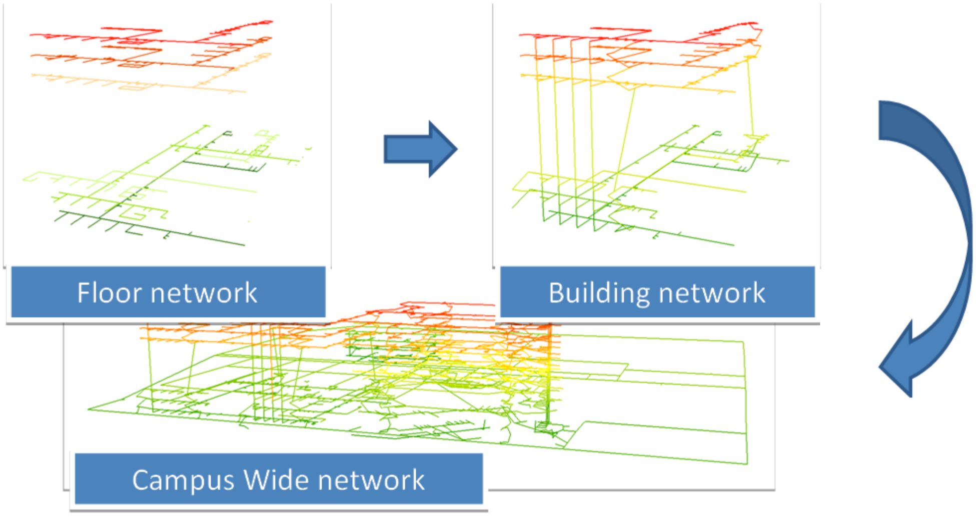


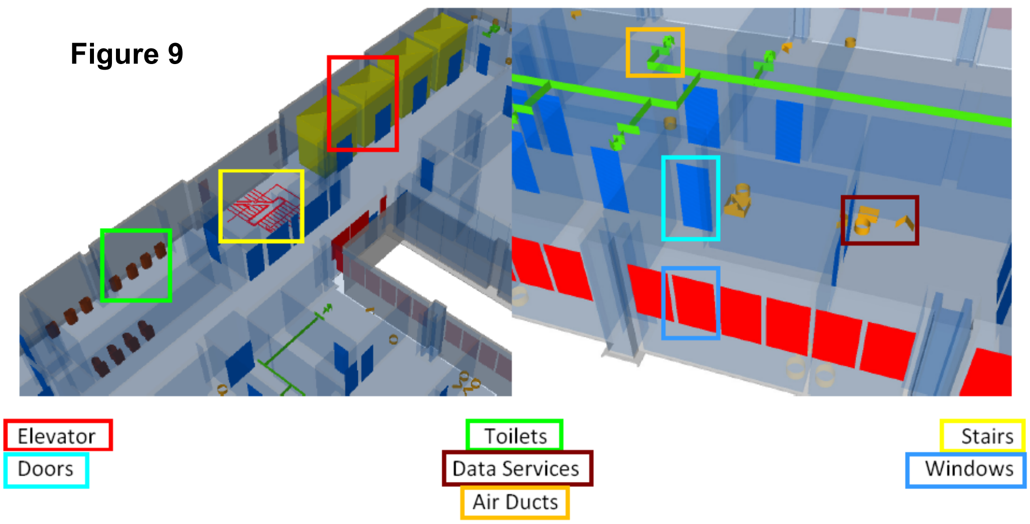
Figure 8

3. APPLICATIONS

The fine resolution campus-wide 3D building model is developed to support three key operations: interactive queries, network analysis, and 3D visualisation.

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 (Figure 9).

Figure 9



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 (Figure 10).

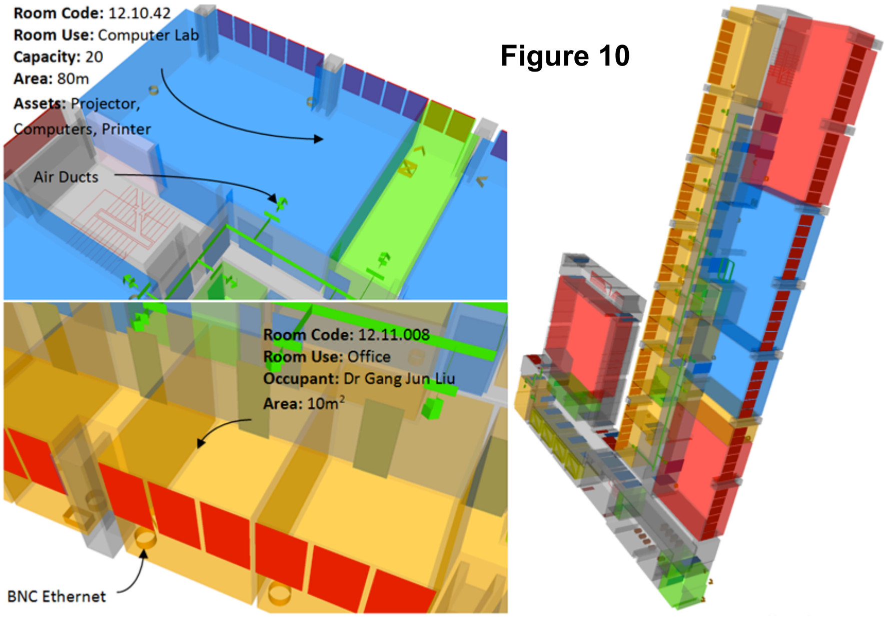


Figure 10

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 (Figure 11) or best route (Figure 12) may be calculated.

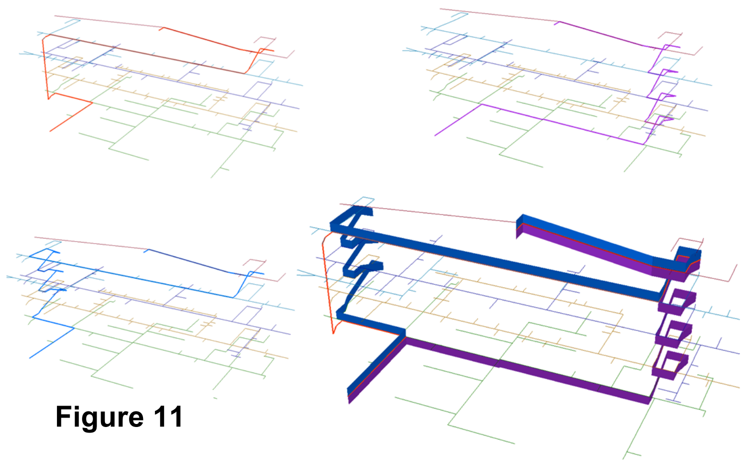


Figure 11

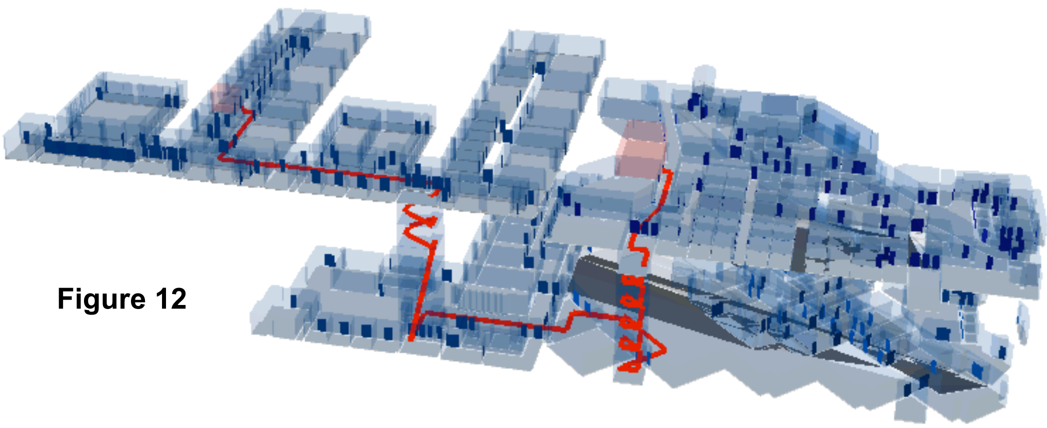


Figure 12

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.

4. DISCUSSIONS

We have encountered several technical problems related to data translation, edit, display and analysis.

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.

We found editing in the CAD environment is comparably more efficient, and derived all floor-level networks in AutoCAD. Drawing lines and editing them is time consuming in ArcMAP. This is because after each line is created, the program terminates the tool and reverts back to the arrow tool. This would incur a heavy time cost in digitizing many objects/entities. As the dataset grows, the time to create the corresponding line attributes associated with itself also increases.

A few issues with the creation of the line network are encountered, such as establishing network connectivity and maintaining network consistency, in terms of the way the line network can be created. 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.

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. All floor networks being overlaid on top of each other make 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. Because 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.

3D views often contain many layers, and rendering these layers can be quite demanding on the computer's resources. 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.

ArcScene does not have any network analysis tools. 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.

5. CONCLUSIONS

To support on-campus pedestrian navigation, asset management and emergency responses, a semi-automated procedure has been developed to build fine resolution, query-able and navigable 3D building and network models for the City Campus of RMIT University. AutoCAD tools and scripts are used for pre-processing detailed floor plans, including organising floor plan elements into pre-defined layers and deriving floor-level corridor centreline networks. Tools and ArcObject functions in ArcMAP and ArcScene are used for converting AutoCAD layers into shapefiles, georeferencing shapefiles, converting 2D shapefile into 3D shapefiles, editing 3D shapefiles, querying the 3D database, calculating the shortest and alternative pedestrian routes in the navigable 3D building or campus network models, and creating 3D visualisations and animations. Current research efforts are directed towards the overcome of the problems encountered and towards more cohesive integration of the query-able 3D building models and the navigable 3D network models via 3D databases of time-critical events and indoor spatial objects.

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