International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-1 Issue-5, October 2012

An Amalgamated 3D Spatial Data Model for City Modelling

E. E. Duncan, A. Abdul Rahman, C. B. Siew, S.U. Baig

Abstract*: *3D spatial data models for city modelling have seen great improvement and most cities around the globe are now attempting to create virtual 3D models of their cities. The current city Earth surface is actually an amalgamation of natural and man-made objects above, on and below the city terrain surface. 3D modelling of subsurface objects and their integration with the surface and above surface objects has not seen much progress and the attempt at viewing above surface and subsurface man-made objects for Earth realism not achieved. Level of Details (LoD) for spatial objects has not been extended to man-made features below the surface. LoD0 maps for surface and subsurface integration exist for most city centres but this does not exist for 3D city models. Hence the need for a 3D data model suitable for above and below surface man-made constructions. This paper discusses 3D spatial data models currently in existence for the integration of surface and subsurface models. A suitable geometric and topological 3D object oriented model (3DOOM) is proposed using the 3D TIN as the base model. A vector approach using implicit geometry is used within a Microsoft Visual C plus plus 2010 programming environment with OpenGL libraries to create 3D spatial objects for the above and below surface man-made constructions. The simulation of an integrated 3D spatial model is presented. A stand-alone above and below 3D spatial models for man-made constructions is assessed up to LoD4 for the subsurface and LoD3 for the above surface in an integrated model.

Index Terms*: *3D City Model, 3D TIN, 3DOOM, City Earth Surface, 3D Spatial Objects.

I. INTRODUCTION

Population growth in most major city centres of countries of the world is of great concern to the agencies or authorities of such modern cities. Visitors both within and outside the country visit these cities on a daily basis. Surface space is limited for a booming city, space above, on and below the city surface is being stretched to its limits and competition for space in these cities have increased thus introducing a high level of complexity for most modern cities. Man-made structures for underground space currently consist of tunnels, buildings, underground car parks, rail and road transport. Currently the urban space is a complex cadastre issue where land parcels or space can be described for the above, on and below surface parcel lots. For man-made objects the 3D data is obtainable from vector data or Computer Aided Design (CAD) drawings and can be represented in any 3D data model using the basic geometry element i.e. the node. Description of spatial information for any 3D city object is complex due to the spatial complexities of the various features that are found in any modern city. The construction of man-made structures in cities invariably involves an in-depth study of the subsurface to obtain information such as geology, geotechnical investigations and hydrogeological considerations amongst other considerations before a city object is constructed, hence information about the subsurface exists for most city objects but these are not integrated. 3D GIS can support such city models when all the geospace has been unified. Disasters in underground areas are also possible in city centres and if the underground space is not well modelled, rescue teams could find it very difficult to undertake rescue operations should disaster occur. Recent disasters in mining areas (Chile and New Zealand in 2010) should inform the geoinformation community of the need to incorporate the integration of surface objects with man-made subsurface objects and spaces or cavities. Section 2 is an introduction to city models, whilst Section 3 gives an overview of related works. The concept for a unified model is introduced inn Section 4 and the methodology, results and discussions based on simulated data is presented in Section 5. Section 6 is the concluding remarks and future directions for this research.

Revised Manuscript Received on 30 October 2012
***Correspondence Author(s)
E. E. Duncan*, Researcher, 3D GIS Group of the Faculty of Geoinformation and Real Estate of the University Technology Malaysia, Skudai, Malaysia.
Prof. Dr. A. Abdul Rahman, Researcher, 3D GIS Group of the Faculty of Geoinformation and Real Estate of the University Technology Malaysia, Skudai, Malaysia.
B. C. Siew, Researcher, 3D GIS Group of the Faculty of Geoinformation and Real Estate of the University Technology Malaysia, Skudai, Malaysia.
S. U. Baig, Researcher, 3D GIS Group of the Faculty of Geoinformation and Real Estate of the University Technology Malaysia, Skudai, Malaysia.

II. CITY MODELS

3D city models such as the City Geography Markup Language (CityGML) and the Keyhole Markup Language (KML) are being used and have been accepted as a standard for the exchange of 3D information [31]. According to [18], CityGML is to provide a city model, which can be applicable to many disciplines such as urban planning, disaster management, rescue operations, floods, noise mapping, cadastre, and facility management, the introduction of Application Domain Extensions (ADE) will help to achieve more of the application areas. Projects such as Cityserver3D, Geoserver, RedSpider, GeoOxygene, Deegree. Oracle spatial and many others implement the Open Geospatial Consortium (OGC) and the ISO standards.

Urban Planners, Architects, Geoinformation and Environmental professionals and city agencies usually come together and plan the city and create the uniqueness that is associated with each city centre. Man-made constructions found in most city centres include complex buildings, transport and utility networks, and horticulture above or below the city Earth surface. The city features are an aggregation of regular man-made objects with geographic locations expressed as explicit or implicit geometry in the form of points, lines, surfaces and bodies and their combinations.

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

City centres consist of complex 3D features which usually give the city a unique skyline, some of these unique skylines can be national monuments such as the Twin Towers of Kuala Lumpur, the Tower bridge of London and the Tower de Elysee of Paris just to mention a few. Apart from these, landmarks such as complex buildings, condominiums, flyovers and underground facilities such as shopping malls, parking lots, storage space and tunnels are also part of the city fabric. The spatial complexity of a city centre is an indication of the technological and economic growth of that country. The city Earth surface is now an amalgamation of features above, on and below, as most of these complex features have underground infrastructure and these can be captured in LoD 0 maps (Fig. 1), but their corresponding 3D representation is not being represented. For the city model to be complete, modelling of the underground constructions must also take place alongside modelling of the above surface constructions, hence, an integration of above surface and below surface man-made constructions needs to be modelled. The questions that might arise: where are the complex buildings with underground shopping malls or underground parking? Where is office A and office A's allocated parking space? Answering questions which involve the display of above surface and below surface geometry poses a difficulty to 3D GIS. Semantically this is possible, but a geometric and a semantic approach may be difficult. Topological relationships for most city models are still under research.

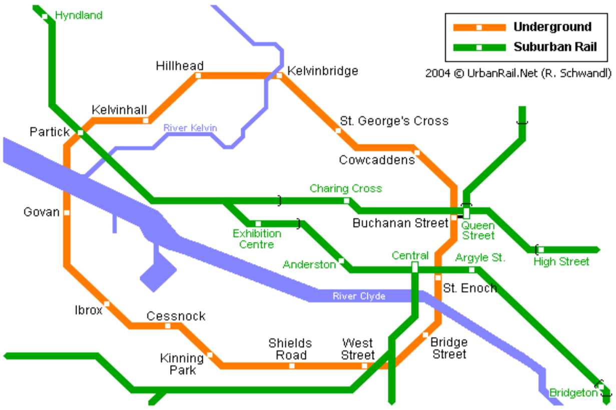


Figure 1. LoD0 for unified objects [32].

According to [18], to improve the quality of life in cities, issues such as energy, environment, security and disaster mitigation must be considered for such cities to attract the necessary tourists and investments. Current 3D virtual cities involves computer simulation and 3D spatial analysis using geographic data, which means the geometry and semantic information of every structure which is part of the urban fabric should be known in terms of its location, geometry and attributes. 3D city modelling involves the visualization of city objects as seen by the human eye instead of viewing maps in 2D. The geometry of such structures gives the dimensions of such structures to a very high degree of accuracy. Data for the city can be obtained from varied sources such as digital photogrammetry in the form of orthophotos and orthoimage in the case of Remote sensing data, updated multipurpose cadastre information will also be vital in the data collection process and help to solve the complexity of land ownership in the cities. Currently the earth surface can be viewed within a digital environment and earth realism can be achieved through such interfaces such as Google Earth, according to [33], 3D city model providers such as Aerodata, Bloom Aerofilm, Bluesky, Zmapping and Virtual City Systems also exist.

CityGML uses the ADE for modelling of underground buildings and tunnels but integration of the above on and below objects has not been achieved. Standards such as CityGML, GeoSciML and Industry Foundation Classes (IFC) has been developed for 3D spatial artificial and natural features above and below the Earth's terrain, these features have not been integrated due to challenges in geometric, topologic and semantic heterogeneities.

III. RELATED WORKS

Surface 3D objects in the case of 3D city models have been studied by various researchers using the vector approach [28], [20], [37], [4]. 3D data models such as the tetrahedral network (TEN) [41] the constrained tetrahedral network (TEN) [8], the Object Oriented Data Model (OODM) [34], [12], [27], Urban Data Model (UDM) [4] and the Simplicial Simplex Model (SSM) [37] approaches have been used for 3D city models. The 3D Formal Data Structure (3D FDS) has been the basis for most models for surface objects.

The 3D FDS model has been studied and enhanced: [21] enhanced it to 3D TIN using object-oriented techniques, [4] and [34] enhanced the 3D TIN using the UDM and Object Oriented 3D Integrated Spatial Data Model (OO3D-ISDM) respectively. [29] introduced the 3D TEN (TIN) by introducing the simplex and complex concepts and [37] introduced the SSM concept using the simplex concept. [12] introduced the OODM using concepts of 3D TIN and incorporating the simplex and complex concept from [29] and [37]. This model has also been modified into the cell concept by [35]. These models have been used for above surface city models, below surface models (geology) and on surface (terrain) but these have not been integrated for man-made features. Above surface 3D objects have made significant impacts in the areas of 3D structuring and topology [36], 3D visualization and virtual reality [37], [4], [26], [23], [30],[33], Research into subsurface data models have been reported extensively by [21], [22]. 3D subsurface objects have been studied for the past two decades, some recent models that have been represented: TIN [14], TEN [9], hybrid [10], [11], octree [2], 3D voronoi [6], tri-prism [13], [5], [3], [17] and 3D Voronoi Diagrams (VD) and Delaunay Triangulations (DT) [7]. Some of these models have been classified as facial models, volumetric models and hybrid models [12] in Table 1.

Facial Model	Volumetric model		Mixed model
	Regular Volume	**Irregular Volume**	
Triangular Irregular Network (TIN)	CSG	Tetrahedral Network (TEN)	TIN-CSG
Grid	Voxel	Pyramid	TIN-Octree mixed or Hybrid
Boundary Representations (B-Rep)	Octree	Tri-Prism (TP)	Octree-TEN mixed
TIN	cube	GTP	OO3D-ISDM

Table 1: Classification of 3D data models for subsurface objects (Modified after [12])

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-1 Issue-5, October 2012

Stand–alone subsurface 3D models have been investigated and implemented [19], [24], [1] , [15], in the areas of geology, this deals with natural objects such as the spatial distribution of three-dimensional (3D) continuous geological stratigraphy, borehole information and ore modelling of a mineral underground. These objects are referred to as fields whilst the object view approach considers the space as being empty and populated with discrete entities such as buildings, roads etc [7]. Most of the research carried out for subsurface 3D models have been to model the natural subsurface. [22] carried out extensive research on geological bodies (GeoToolKit) using the TEN model, and also for subsurface geotechnical consideration. [35] used the cell complex and implemented the model for geology. All the models above have been used for subsurface natural feature applications.

Surface and subsurface unified models have been studied by many researchers [14], [34], [15], [35]. Underlying their research is the principle of 3D FDS for 3D spatial data for 3D objects for both the surface and the subsurface. [28] proposed the 3D FDS for 2D GIS and this concept has been enhanced and made applicable for 3D GIS. This model has the point, line, surface and body as the entity object. These models were used for city and complex objects, visualization, terrain and geology using the 3D TIN concept. The 3D TIN (TEN) is adopted and further explored in the integration of the above and below surface 3D objects for the unified model. Concepts from [16] are also incorporated.

IV. UNIFIED MODEL

The concept for a unified model based on man-made features for above, on and below the earth surface is presented in Fig. 2. This shows man-made features connected to the terrain model for above and below surface features and man-made features which are independent of the above and below features. Features for the latter have to be topologically connected in order to show above surface features, which have independent features below the surface.

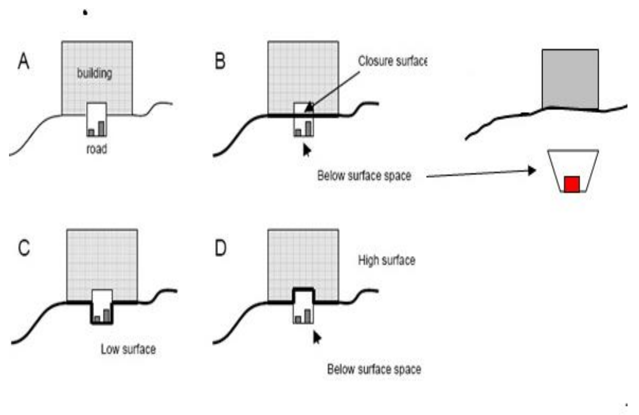


Figure 2. Concepts of surface and subsurface integration Adopted from [16]

[16] considered terrain (the earth surface) level chosen for some complex situations but situations also exist where the above object is totally independent of the object below, most models used the Digital Terrain Model (DTM) to serve as the connecting surface. Approach can be modified in various ways to attract more applications. 3D city objects have underground facilities such as storage, tunnels, cavities, underground rail systems and car parks, knowledge about these man-made objects are required.

An enhanced 3D TIN model is proposed, with the solid being formed by tetrahedrons or polyhedrons as described by [29]. This presents a solid composed of tetrahedrons, surface composed of triangles, a line is composed of arcs and point consists of nodes. The unified geometric semantic model is shown in Fig. 3.

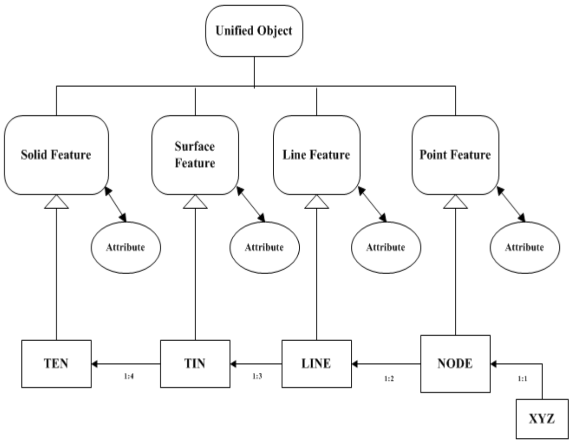


Figure 3. 3D Object Oriented Model

Nodes are formed by geographic coordinates XYZ which can form point features such as lamp posts, fire hydrant features. Two nodes is part of the line or segment and can be expresses as a beginning node and an ending node. Three of such lines or segments will become part of the edge of the TIN surface. Tin surfaces will have edges or lines which will be shared and create the shared sub feature level [16] for a multi-theme model. Implicit geometry is used to form the nodes with appropriate identifiers, the line identifier will have a beginning node and an ending node with the topological relationship of is on, is in, point and solid, line and solid, line and surface, point and surface being used to form the relationship for the unified model. The TEN is formed by four nodes, six lines and four triangles, to form solids for both the surface and subsurface. The TEN model is being adopted due to the fact that it can be used to model regular and irregular objects and can thus represent features above, on and below the earth surface. Using the cube as the basic feature for volume objects, the cube can be decomposed to five or six tetrahedrons.

The TEN model is an improvement over the 3D FDS model, this consists of the tetrahedron as a body, triangles representing the surface, lines as arc or edge objects and the node as point objects representing geometric (simplex), sub feature (simplex complex) and complexes. The topological relationship is given by the adjacency of spatial objects.

A building consists of facades from all the sides, the roof and its footprint which intersects the terrain model and can be represented from LoD0 to LoD4 as described by [18]. Fig. 4 is the UML diagram for the top object classes in 3DOOM.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

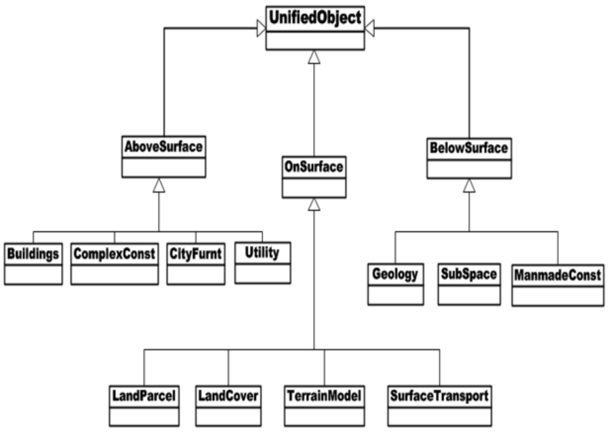


Figure 4. A UML diagram for the top classes in 3DOOM

V. METHODOLOGY, RESULTS AND DISCUSSIONS

The methodology adopted in achieving the framework discussed, was the development of codes using Microsoft Visual C++ version 2010 and using OpenGL libraries, the workflow is shown in Fig. 5.

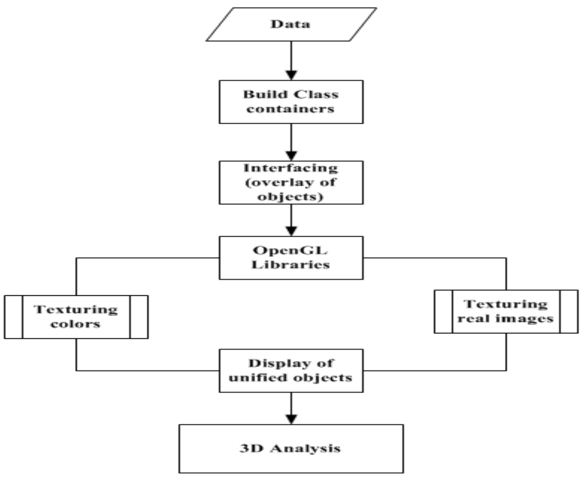


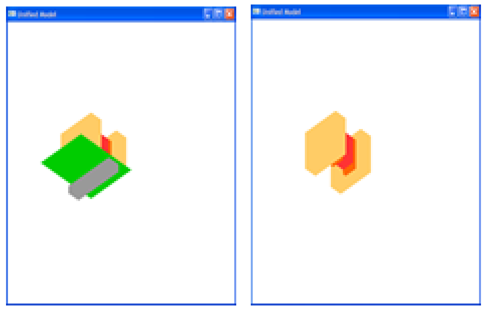
Figure 5. The methodology adopted for the unified model

The vertices of man-made constructions were obtained from Computer Aided Design (CAD) data, and classes were developed for man-made objects for the above, on and below the surface. This was overlaid and visualised using OpenGL libraries.

5.1 Results and Discussions

The unified model for two complex man-made constructions is shown in LoD1. Fig. 6 is a real complex object. Fig. 7 depicts a simulation of the complex object with a road under the building and a below subsurface man-made construction such an underground rail system or a tunnel.

Figure 6. A real complex object [25].



(a) (b)

Fig. 7 (a) A complex object with a rail system underneath
(b) The complex object with terrain and subsurface object removed

Levels of Details (LoD's) for the above surface were considered and windows and door positions on the buildings can be located geometrically. For the subsurface the challenge is an LOD 4 representation, this can be achieved with the right transparency and lighting selection. Table 2 gives an indication for surface and subsurface objects integration. Unified models for above surface objects and below surface geology have been studied. The concept for a new unified model seeks to enhance this further by incorporating the above surface objects and below surface geology and man-made objects which are naturally part of the complex city Earth surface.

Table 2. Surface and Subsurface objects integration.

LoD	Surface	Subsurface	Integration	Map Type
LoD0	√	√	√	2D
LoD1	√	√	√	3D
LoD2	√	–	–	3D
LoD3	√	–	√	3D
LoD4	√	√		

VI. CONCLUDING REMARKS AND FUTURE DIRECTIONS

The city surface is currently very complex to define as it actually blends with the above, on and below the city Earth surface, hence the current city Earth surface is actually an amalgamation of natural, man-made objects above, on and below the city Earth surface and a detailed knowledge for such man-made objects are required by city planners, engineers and architects.

Unified models in the area of above surface objects and below surface geology has been studied. The concept for a new unified model seeks to enhance this further by incorporating the above surface objects and below surface geology and man-made objects which are naturally part of the complex city Earth surface.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

The UML diagrams developed shows the concept and methodology that can be adopted to integrate above and below man-made objects. The 3D TIN can be used for above and below objects integration. A 3D spatial model is proposed and implemented using simulated data, the analysis showed that surface and subsurface object integration can be achieved for various LoD combinations. The unified model will be enhanced in the areas of 3D topology and 3D analysis. An algorithm to fully integrate the above framework in a database will be part of the next phase of this research. Finally the applicability of the model generated will be applied in the areas of 3D analysis for 3D buildings, 3D cadastre in city modelling.

ACKNOWLEDGEMENT

The authors will like to acknowledge the Universiti Teknologi Malaysia (UTM), The Ministry of Higher Education (MOHE) and the Research Management Centre (RMC) of UTM for providing the necessary grants for this research [Q.130000. V.04J90; Q.130000.V.04J32]. The University of Mines and Technology (UMaT) is also acknowledged for granting study leave to an author.

REFERENCES

1. Apel, M.. From **3D** Geomodelling Systems Towards **3D** Geoscience Information Systems: Data Model, Query Functionality, And Data Management. Computers & Geosciences, v. 32, iss. 2, 2006 pp. 222-229.
2. Chen, H. H, and Huang, T. S., A Survey of Construction and Manipulation of Octree. *CVGIP* **43**, 1998, pp.409-431.
3. Cheng, P. G. and Gong, J. Y., Design of Three-Dimensional Spatial Data Model and Its Data Structure in Geological Exploration Engineering. *Acta Geodaetica et Cartographica Sinica* **30** 1, 2001, pp.74-81. (in Chinese)
4. Coors, V., 3D-GIS in Networking Environments, Computer, Environments and Urban Systems, Vol. 27/4, Special Issue 3D Cadastre, 2003, pp 345 – 357.
5. Dai, W. J. and Zou, Z. R., Study of the Volume-Based 3-Dimensional GIS Data Model. *Mine Surveying* (1), 2001, pp.20-22. (in Chinese)
6. Gabriel Courrioux, Stephane Nullans, Antonio Guillen, Jean Daniel Boissonnat, Philippe Repusseau, Xavier Renaud and Muriel Thibaut, 3D Volumetric Modelling Of Cadomian Terranes (Northern Brittany France): An Automatic Method Using Voronoi Diagrams. *Tectonophysics*. **331**, 2001, pp.181-196.
7. Ledoux, H. and Gold, C. M. Modelling Three-dimensional Geoscientific Fields with Voronoi Diagram and its Dual. Int. J. of Geographical Information Science. Vol. 22. Nos 4 – 5, April – May 2008, 547 – 574.
8. Penninga, F. and Oosterom, P. J. M., A Simplicial Complex-Based DBMS Approach to 3D Topographic Data Modelling, Int J. Geographic Information Science, Vol. 22. Nos 6-7, June-July 2008, 751-779.`
9. Pilouk, M., Tempili, K. and Molenaar, M., A Tetrahedron-Based 3D Vector Data Model For Geoinformation. Advanced Geographic Data Modelling, **40**, 1994,129-140.
10. Shi, W. Z., A Hybrid Model For 3D GIS. *Geoinformatics* **1**, 1996, pp.400-409.
11. Shi, W. Z., Development Of A Hybrid Model For Three-Dimensional GIS. *Geo-Spatial Information Science* **3** 2, 2000, pp.6-12.
12. Wu, L. X., Shi, W. Z. and Christopher, G. M., Spatial Modelling Technologies for 3D GIS and 3D GMS. *Geography and Geo-information Sciences* **19** 1, 2003, pp.5-11.
13. Zhang, Y. and Bai, S. W. An Approach of 3D Stratum Modeling Based on Tri-Prism Volume Elements. *Journal of Image and Graphics* 6 3, 2001, pp.285-290.
14. Abdul-Rahman, A. and Pilouk, M, *Spatial Data Modelling for 3D GIS*, published by Springer Berlin-Heidelberg, New York, 2008, 289pp.
15. Breunig, M. and Zlatanova, S. ***3D** Geo-DBMS.* In Zlatanova, S. And Prosperi, D. (eds.), Large-scale **3D** Data Integration-Challenges and Opportunities: 2006, 87-115. London: Taylor and Francis.
16. Emgard, L. and S. Zlatanova, Design Of An Integrated **3D** Information Model, in Coors, Rumor, Fendel and Zlatanova (eds.) Urban and Regional data Management, UDMS Annual 2008, Taylor and Francis Group, London, 2008, pp. 143-156.
17. Gong, J. Y., Cheng P. G., Liu R., Li D. J. and Liu S. H., Study on 3D Modeling and Visualization in Geological Exploration Engineering. In *Proc. ISPRS Commission II Sym. On Integrated System For Spatial Data Production, Custodian And Decision Support*, 2002, pp.133-138.
18. Kolbe, T. H., Representing and Exchanging 3D City Models with CityGML, Lee, J., Zlatanova, S. (Eds), 3D Geoinformation Sciences, Springer Verlag, Berlin Heidelberg, 2009.
19. Lattuada, R. Three-dimensional representations and data structures in GIS and AEC. In: Zlatanova, S. & Prosperi, D. (eds.), Large-scale **3D** data integration-Challenges and Opportunities: 2006, 57-86. London: Taylor and Francis.
20. Abdul-Rahman, A. The Design and Implementation of a two and Three dimensional Triangular Network based GIS, PhD Thesis, University of Glasgow, U. K., 2000, 204pp.
21. Breunig, M., Bode, T. and Cremers, A., Implementation of Elementary Geometric Database Operations for a 3D GIS. In: Proc. Of the 6th Int. Symp. On Spatial Data Handling. 1994.
22. Breunig, M., Cremers, A., Muller, W. and Siebeck, J., New Methods for Topological Clustering and Spatial Access in Object-oriented 3D databases. In: Proc. Of the 9th ACM Int. Symp. On Advances in Geographic Information Systems, 2001.
23. Charlton, J., Horne, M. and Giddings, B., A Holistic Approach to Urban Design Using 3D Computer Modelling, Design and Decision Support Systems, The Netherlands, 2008.
24. Hack, R., Orlic, B., Ozmutlu, S., Zhu, S. and Rengers, N. Three And More Dimensional Modelling In Geo-Engineering. Bulletin of Engineering Geology and the Environment 65(2): 2006. 143-153.
25. Hassan, M. I. and Abdul Rahman, A., An integrated Malaysia cadastral system. FIG Congress 2010, Sydney, Australia, 2010.
26. Horne, M., Thompson, E. M. and Podevyn, M., An Overview of Virtual City Modelling: Emerging Organisational Issues... CUPUM07 10th International Conference on Computers in Urban Planning and urban Management, Iguassau Falls, Brazil, 2007.
27. Koshak, N. and Flemming, U., Object Oriented Data Modelling and Warehousing to Support Urban Design. 6th International Conference and Decision Support Systems in Architecture and Planning, July 7 – 10, 2002. Ellecom, The Netherlands.
28. Molenaar, M., A Formal Data Structure for 3D Vector Maps, Proceedings of EGIS'90 Vol.2, Amsterdam, The Netherlands, 1990, pp 770 – 781.
29. Pilouk, M., Integrated Modelling for 3D GIS. PhD dissertation, ITC Publications No 40, The Netherlands, 1996, 200pp.
30. Podevyn, M., Horne, M., Fisher, P. and Thompson, E. M., Global Visualisation Engines – Issues for Urban Landscape Planning Participation Processes, Digital Design in landscape Architecture Proceedings, Anhalt University of Applied Sciences, 2008.
31. Ross, L., Bolling, J., Dollner, J. and Kleinschmit, B.., Enhancing 3D City Models with Heterogeneous Spatial Information: Towards 3D land Information Systems, Sester, M., Bernard, L and Paelke, V (Eds) Advances in GIScience, Proceedings of the 12th AGILE Hannover, 2009.
32. Schwandl, R. Glasgow, http://www.urbanrail.net/eu/uk/gla/ glasgow.htm 2004, Accessed on: 25th October 2010.
33. Thompson, E. M. And Horne, M., 3D-GIS Integration for Virtual NewcastleGateshead, 28th eCAADe Conference, Future Cities, September 15-18, 2010, Zurich-Switzerland, pp 2010, 767 -775.
34. Wang, Y. 3D GIS Spatial Modelling for City Surface and Subsurface Integration, published by IEEE, 2006, pp 1511 – 1518.
35. Zhou, I., Lu, G., Sheng, Y., Xu. H., and Wang, H., A 3d GIS's Spatial Data Model Based on Cell Complex. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol. XXXVII Part B2, Beijing, 2008. pp 905 – 908.
36. Zlatanova, S., Abdul Rahman, A and Pilouk, M "3D GIS: Current Status and Perspectives" ISPRS Commission IV, WGIV/1, 2002, pp1-6.
37. Zlatanova, S.. 3D GIS for Urban Development, PhD Thesis, ITC Dissertation Series No 69. The International Institute for Aerospace Survey and Earth Sciences, The Netherlands, 2000.

AUTHOR PROFILE

E. E. Duncan holds an MSc degree in Topographic Science from the University of Glasgow in the UK and a BSc degree in Geodetic Engineering from the Kwame Nkrumah University of Science and Technology in Ghana, He has over 9 journal and 10 conference publications, his current interests are in the area of 3D GIS and a member of the Ghana Institution of Surveyors (GhIS) and an academic member of the Federation of ZInternationa Surveyors (FIG).

Prof. Dr. A. Abdul Rahman is a Professor at the Department of Geoinformatics and Dean of the Faculty of Geoinformation and Real Estate, Universiti Teknologi Malaysia (UTM), Skudai, Johor. He received a degree in Surveying and Mapping Sciences from North East London Polytechnic, England, UK in 1987, Postgraduate Diploma in GIS from ITC, Netherlands, and MSc in GIS also from ITC, Netherlands. In 2000, he received his PhD degree from the University of Glasgow, Scotland, U.K. Currently he serves as Chair for ISPRS Commission II/5 from 2008 – 2012 on Multidimensional GIS and Mobile Data Model.

Siew Chengxi Bernad, obtained a Bsc Degree in Geoinformatics in 2009 from Universiti Teknologi Malaysia (UTM), Skudai, Johor. He is a professional programmer in JAVA and C# programming language. He worked as an IT Manager in ABS Innovations Sdn Bhd and a Chief Technical Officer of Effisys Technology, Malaysia. He has been involved in developing various web applications and mobile applications.

Currently, he is a PhD researcher in 3D GIS Research Group in the Faculty of Geoinformation and Real Estate, UTM. His current research interests are in the area of distributed web environment for 3D GIS and compression techniques.

S. U. Baig holds a MSc degree in Photogrammtery and Geoinformatics) from Hochshule Fur Technik, Stuttgart in Germany and a MSc and BSc degrees in Computer Science from the University of Karachi, Pakistan. He is currently a PhD researcher with the 3D GIS group of the Faculty of Geoinformation and Real Estate at the Universiti Teknologi Malaysia (UTM) in Malaysia. His Research interests is in the area of Automatic generalization and visualization of 3D models.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)