*i*CAMPUS: 3D MODELING OF YORK UNIVERSITY CAMPUS

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ABSTRACT

The initial results of reconstructing York University's 3D virtual model and future research directions are presented. The demand for 3D geospatial data and modeling for urban environments continuously increases as GIS models and applications are changing from traditional 2/2.5D to actual 3D spatial representations. The *i*Campus project is part of the celebration of the 50th anniversary of York University in 2009. It has been initiated in the Department of Geomatics Engineering aiming at the development of a three dimensional virtual photorealistic model of the Campuses of York University. Virtual models provide an enriching interactive visual exploration of 3Ddigital environments. This paper presents the background of the *i*Campus project and the initial preliminary outdoor and indoor modeling results obtained using available software such as Google SketchUp, Photomodeler and 3ds MAX. Initial reconstruction results of prismatic buildings and the terrain surface are given using the in-house developed software tool AUTHUR.

INTRODUCTION

GIS models and applications are changing from traditional 2/2.5D to actual 3D spatial representations. The higher level of space representation addresses more effectively important urban applications ranging from management, planning and development, to public safety, environment, and tourism to telecommunications, transportation, car navigation and 3D web mapping services. Therefore, there is an ever increasing demand for 3D geospatial data and modeling for urban environments. To date, lack of reliable, massive and continuous modeling of buildings has resulted in time-consuming, redundant, manual and expensive solutions, usually through stereo 3D digitization of city objects from aerial stereo-images and for airborne laser scanning point clouds. To address these important challenges new techniques and strategies are urgently needed to greatly increase the efficiency and accuracy of the generation, updating and visualization of 3D cityscape models. Two areas need to be addressed:

A) 3D modeling of large city areas, which addresses the building reconstruction of large areas and the photo-realistic texture-mapping rendering of building facades and interiors; and

B) Geographic Information Systems (GIS) -enabled modeling, which addresses the processing of spatial and semantic data for data exploration and knowledge discovery.

The 3D models are usually generated by integrating aerial, spaceborne and terrestrial imaging and ranging data for the reconstruction of the terrain surface and building geometry. Issues to be addressed are:

1) the seamless integration of multi-sensors (e.g., still and moving pictures, airborne/satellite with terrestrial images, airborne and terrestrial lidar data) for accuracy enhancement, resolving resolution from a single source and compensating for limitations related to occlusions, shadows, and disadvantageous viewing angles.
2) the enhancement of the multi-modalities of 3D modeling algorithms; for instance, by integrating various 3D modeling algorithms, each of which is developed for specific types of cityscape objects and selectively used for modeling them for handling high scene complexity.
3) the removal of 'street clutter' (e.g., trees, cars, people) for modeling street-side textures of 3D cityscape models.
4) the development of reliable visualization systems to effectively render massive 3D models in order to meet the new demands and realities of on-line mapping services.

3D modeling is been gaining significant attention in recent years. 3D city models as replicas of the real world are essential for urban applications such as mapping, planning, facilities management, telecommunications, transportation, marketing, infrastructure engineering, decision-support, emergency services, environmental studies, tourism and entertainment. There is also demand for on-line mapping services such as Microsoft Virtual Earth^{TM} and Google Earth^{TM}. Obviously, the most important elements in urban modeling are the buildings. Building reconstruction is either data-driven or model-driven. In the data-driven approach extracted lines, corners and planes from images and/or laser scanning data are grouped to reconstruct the boundaries of prismatic building models. In the model-driven approach solid geometric primitives are fitted to the observed or derived image and/or lidar data.

The main stages of 3D modeling are: data acquisition, generation of a 3D virtual model by 3D object reconstruction and photorealistic texture rendering, and interactive visualization of the virtual model on a computer or via web-mapping. Applications of 3D modeling can be found in architectural and cultural heritage applications using photogrammetric and laser scanning methods (e.g., Conforti Andreoni and Pinto, 2004, Gonzo et al., 2004, Baltsavias et al., 2006), in 3D geospatial information systems (Song and Shan, 2004) in urban environments (Baz et al., 2008) and in mapping and documentation of buildings for web information systems (Grussenmeyer et al., 2006).

*i*CAMPUS PROJECT

In celebration of the 50th anniversary of York University in 2009, the *i*Campus project has been initiated in the Department of Geomatics Engineering aiming at the development of a three dimensional (3D) virtual photorealistic model of the Keele and Glendon Campuses of York University. Keel campus for example covers an area of approximate 1.7 km X 1.2 km and has about 60 buildings. This will enable 3D visualization of both campuses and will offer telepresense navigation (virtual visits) in the form of interactive walks through the campuses, fly-through and access and retrieval of descriptive information about the represented objects, such as campus buildings. Virtual cityscapes provide an enriching, interactive, multi-media, visually appealing user experience that is ‘in tune’ with users’ natural visual-based, non-linear thinking for interactive visual exploration of digital environments.

To implement the *i*Campus project first the actual 3D data of the terrain structures (buildings, trees, terrain elevations) have to be acquired and determined for the 3D model reconstruction of the building and the trees. For the photorealistic visualization of the 3D structures, textures have to be draped/pasted of the surfaces (e.g., walls, roofs) of each 3D object. Accessibility and viewing of the 3D campus model will be performed via web mapping tools. 3D indoor modeling will provide navigation inside the campus buildings.

For the accurate and complete 3D reconstruction of building and tree geometries the following data sets have been acquired. FirstBase Solutions has provided aerial digital images at 0.15 m spatial resolution covering Keele and Glendon campuses, regular gridded DSM and DEM generated from the aerial images at 1.5 m ground spacing and the corresponding orthoimage at 0.15 m pixel spatial resolution. Optech has collected and provided airborne lidar data of Keele Campus from altitude of 2300 m with point distance density of about 1.9 m. Also Optech has provided terrestrial lidar street data (building facades, trees) from the LYNX Mobile Mapper system. 2D and where exist 3D vector data have been provided by the City of Toronto. For the mapping of texture on the surfaces of the 3D solid models terrestrial and aerial images were used. For the roofs, the textures were extracted from the aerial orthoimage. If certain walls or portions of wall appear on the aerial images due to perspective views, these textures are used as well. Terrestrial images provide the texture for the side wall of the prismatic models. Blue prints and floor plans provided information for dimensions and the layout of the interior of buildings. The viewing aspects, the interactive navigation and the data query are addressed for the spatial and semantic data exploration and discovery through web-mapping accessibility.

PRELIMINARY PROTOTYPING

The *i*Campus work started in the fall of 2008 and is still at its very early stages. Initially the feasibility of using the available software at the GeoICT Lab was set to be tested and assessed along with the obtained results. This will determine advantages, disadvantages and identify gaps so to define research and development areas and directions. The available software tools Google SketchUp, PhotoModeler, 3ds MAX and our in-house research software tool, called AUTHUR (AUtomatic THree-dimensional Urban Reconstruction) are used for the initial prototyping of the 3D building reconstruction.

Google SketchUp is an interactive 3D modeling software. The basic concept is to draw a shape and pull it into 3D. After the 3D model is ready the images of the object are interactively warped on the object surface for the texture mapping. The texture for the roof was extracted from the aerial orthoimage. Figure 1a shows the reconstructed building prototype as viewed in Google Earth.

PhotoModeler is a photogrammetric 3D modeling package. It was used to reconstruct the 3D surfaces of the building based on overlapping images and corresponding reference points. PhotoModeler performs camera calibration, determines the exterior orientation and defines the 3D coordinates of object points by space intersection. Texture mapping is performed by assigning a surface to specific image. For the building prototype a digital camera was used to capture overlapping images of the facades of the exterior walls. Again the roof texture was extracted from the orthoimage of campus. The prototype reconstructed building exported in KMZ format can be viewed in Google Earth (Figure 1b).

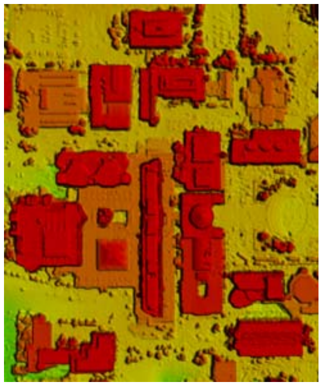
(a) 3D Model by SketchUp

(b) 3D Model by PhotoModeler

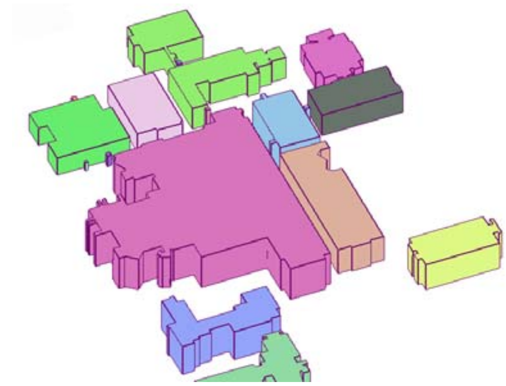
Figure 1. Screenshots of the prototype 3D reconstruction of Computer Science building.

The AUTHUR software is an in-house 3D reconstruction tool for producing photo-realistic 3D cityscape using airborne lidar data. It has been developed in GeoICT Lab at York University in the last few years. This research tool provides several key functions for virtual 3D city reconstruction that includes automatic modeling of 3D rooftops, terrain surfaces, transmission lines, and individual trees in complicated urban scenes. Using the AUTHUR, these key urban scene objects can be reconstructed with precise 3D shapes from mainly using airborne lidar data. For the *i*Campus project, the research team at GeoICT Lab has modified AUTHUR to accommodate a wider range of primary data sources for 3D cityscape modeling instead of using only airborne lidar data. For instance, we are modifying the GMDL (Geometric Minimum Description Length) algorithm (Jwa et al, 2008) to automatically reconstruct prismatic building models from the digital surface model (DSM) generated from airborne multiple images because the AUTHUR algorithms were originally developed based on airborne lidar data as the primary information source. Figure 2(a) shows an example of DSM generated by the INPHO software using 6 highly overlapped Vexcel's UltraCam-D images. Figure 2(b) presents a 3D prismatic building reconstruction result produced as the GMDL is applied to Figure 2(a).

The GMDL is a new algorithm to iteratively generalize noisy building outlines or rooftop boundaries extracted from sensory data. The process assumes that individual buildings are isolated from their surroundings by a building detection algorithm (Sohn and Dowman, 2007). From each isolated building region, building outlines or boundaries of roof facets are roughly extracted with significant amount of noises produced by a simple line generalization method such as the Douglas-Peucker's algorithm. A global analysis of dominant line directions characterizing building shape is conducted based on a Hough Transformation-like line slope accumulator using noisy line primitives produced by Douglas-Peucker's algorithm. As each line primitive's slope is replaced with one of building's dominant line directions, a new building model hypothesis is generated and favourably scored if this new hypothesis can better represent a building with smaller numbers of line directions and vertices, while enhancing regular angle transition between connected vertices and directional repeatability than the null hypothesis. This process is iteratively conducted over all vertices until any newly generated hypothesis cannot produce higher scores than the one from a null hypothesized model.



(a) UltraCam DSM



(b) RTF terrain extraction result

Figure 2. GMDL building extraction result from Vexcel's UltraCam-derived DSM.

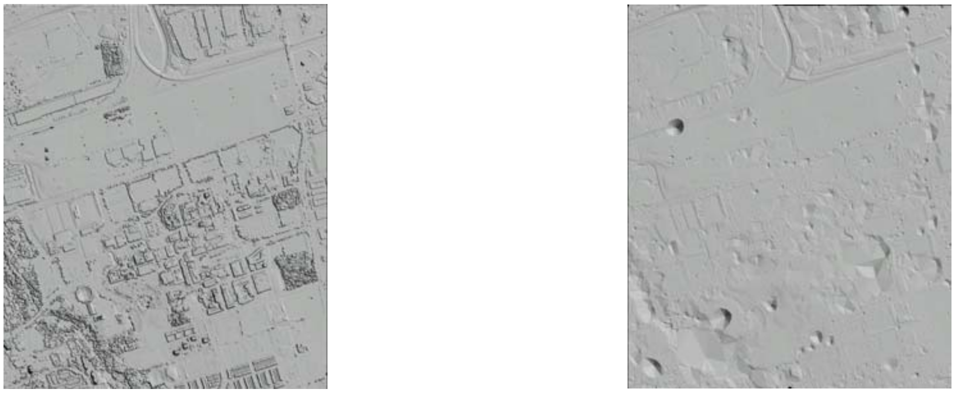
Another important research component for *i*Campus project is to investigate existing and new methods to classify campus scene objects from various sources. For achieving this goal, we start to investigate the performance of our terrain reconstruction filter, called RTF (Recursive Terrain Filter), which was originally developed using airborne lidar data (Sohn and Dowman, 2008). This technique was developed, in particular to allow a lidar filter to be self-adaptive to various landforms of different slopes. This terrain filter employs a tetrahedral model to generally represent a terrain surface with single slope (homogeneous terrain). A model-fitness between lidar points and the tetrahedral terrain model is measured in a framework of Minimum Description Length (MDL). In a coarse-to-fine scheme, this model-fitness scores triggered to recursively fragmented lidar DEM convolved with heterogeneous terrain slopes into piecewise homogeneous sub-regions where underling terrain can be well characterized by the terrain model.

Figure 3(b) presents a terrain reconstruction result extracted by the RTF filter as it is applied to Figure 3(a) of Vexcel's UltraCam-derived DSM. As shown in this figure, the RTF successfully removed most of campus buildings and trees while well preserved terrain morphology though the filter was applied to optical sensor-driven 3D point clouds rather than to lidar data. However, an intensive visual investigation also indicates that the filter did not work well to remove low vegetated objects and produce some commission errors over a region where many trees are located very closely to buildings so that height contrast between vegetated areas and a building is not well preserved in DSM. However, using airborne lidar data enables to avoid this problem due to its foliage penetration ability. Extracting a high quality of terrain surface is critical for *i*Campus project since the reconstructed terrain surface will be used for photo-realistic texture map of the background scenes including roads and grounds, and also it is important to classify non-terrain objects. Thus, one of our future research efforts for *i*Campus project will be directed toward resolving the aforementioned problems caused by the RTF filter when it is applied to optical sensor-driven DSM.

Autodesk's 3ds Max is being used so far for indoor modeling. It is a 3D modeling, texture rendering and animation software. Modelling is performed by starting with predefined standard primitives (rectangular prism, plane, pyramid, cylinder, sphere, etc.) with the user adding the details of the object. It offers a variety of functions for texture assignment and planar mapping. Figure 4 shows an indoor modeling scene generated using CAD floor plans which were extruded to the third dimension. Indoor modelling will allow for virtual indoor navigation and exploration.

Currently we are investigating the quality assessment of these results based on the available data to determine the levels of completeness and accuracy. While using these tools could be an easy 3D reconstruction process for several buildings, this could be a quite tedious task when the number of urban structures increases due to the laborious time-consuming interactive work involved. Thus, new strategies and techniques need to be developed to increase the efficiency and accuracy of the generation and visualization of 3D cityscape models. To derive object data from the aerial images and the DSM, feature extraction (i.e., detection of building edges and regions) operations can be used to support certain degree of automation in the process. Gunho et al., 2008 have used a data-driven approach to reconstruct buildings from airborne lidar data. The method consists of four steps: building detection, height and planar surfaces clustering of lidar points, reconstructing of rooftops and vertical walls.

Considering the available of data for this project a generalized approach is sought to develop an approach based on the advantages of each of the data types. Lidar point clouds provide significant shape information, image data are rich in semantic information and the existing vector building polyline data provide spatial localization constraints. For example, Chen et al., 2008 have integrated lidar point clouds and large scale vector data to perform building modelling.



(a) UltraCam DSM (b) RTF terrain extraction result

Figure 3. RTF terrain reconstruction result from Vexcel's UltraCam-driven DSM.

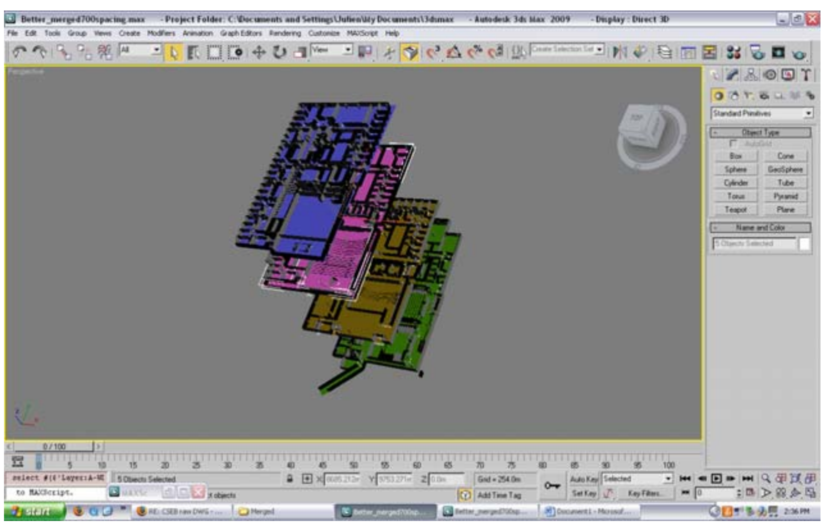


Figure 4. Screenshots of 3D indoor modeling prototype.

CONCLUDING REMARKS

GIS are shifting from 2/2.5D dimensions towards 3D representation models and operations. This change requires new techniques for 3D data generation, updating, handling and visualization. *i*Campus is part of the 50th year anniversary celebration of York University and aims to generate a virtual 3D model of York's Campuses. Airborne and terrestrial image and lidar data are used in this reconstruction of 3D shapes of prominent man-made and natural terrain objects. *i*Campus also investigates existing and new methods for buildings, trees and terrain reconstruction and for the photorealistic texture mapping on the reconstructed objects and surfaces. The preliminary results obtained from the available software packages Google SketchUp, PhotoModeler and 3ds MAX have been presented together with results obtained from the in-house generalised 3D modeling software AUTHUR. The research efforts are towards increased efficiency and accuracy of the reconstruction process by integrating optical, lidar and vector data, by covering both outdoor and indoor interactive 3D data visualization and exploration and by providing a web-based 3D mapping service for York University.

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