Data collection and 3D reconstruction

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3D Geographical Information Systems need 3D representations of objects and, hence, 3D data acquisition and reconstruction methods. Developments in these two areas, however, are not compatible. While numerous operational sensors for 3D data acquisition are readily available on the market (optical, laser scanning, radar, thermal, acoustic, etc.), 3D reconstruction software offers predominantly manual and semi-automatic tools (e.g. Cyclone, Leica Photogrammetry Suite, PhotoModeler or Sketch-up). The ultimate 3D reconstruction algorithm is still a challenge and a subject of intensive research. Many 3D reconstruction approaches have been investigated, and they can be classified into two large groups, optical image-based and point cloud-based, with respect to the sensor used, which can be mounted on different platforms.

Optical Image-based sensors produce sets of single or multiple images, which combined appropriately, can be used to create 3D polyhedronal models. This approach can deliver accurate, detailed, realistic 3D models, but many components of the process remain manual or semi-manual. It is a technique which has been well-studied and documented (see Manuals of Photogrammetry, 2004; Henricsson and Baltsavias, 1997; Tao and Hu, 2001).

Active scanning techniques, such as laser and acoustic methods, have been an enormous success in recent years because they can produce very dense and accurate 3D point clouds. Applications that need terrain or sea-bed surfaces regularly make use of the 2.5D grids obtained from airborne or acoustic points clouds. The integration of direct geo-referencing (using GPS and inertial systems) into laser scanning technologies has given a further boost to 3D modelling. Although extraction of height (depth) information is largely automated, complete 3D object reconstruction and textures (for visualisation) are often weak, and the amount of data to be processed is huge (Maas and Vosselman, 1999; Wang and Schenk, 2000; Rottensteiner et al 2005).

Hybrid approaches overcome the disadvantages mentioned above by using combinations of optical images, point cloud data and other data sources (e.g. existing maps or GIS/CAD databases) (Tao, 2006). The combination of images, laser scanning point clouds and existing GIS maps is considered to be the most successful approach to automatically creating low resolution, photo-textured models. There are various promising studies and publications focused on hybrid methods (Schwalbe et al, 2005; Pu and Vosselman, 2006) and even on operational solutions. These approaches are generally more flexible, robust and successful but require additional data sources, which may influence the quality of the model.

In summary, 3D data acquisition has become ubiquitous, fast and relatively cheap over the last decade. However, the automation of 3D reconstruction remains a big challenge. There are various approaches for 3D reconstruction from a diverse array of data sources, and each of them has some limitations in producing fully automated, detailed models. However, as the cost of sensors, platforms and processing hardware decreases, simultaneous and integrated 3D data collection using multiple sensing technologies should allow for more effective and efficient 3D object reconstruction.

Designing integrated sensor platforms, processing and integrating sensors measurements and developing algorithms for 3D reconstruction are among topics which should be addressed in the near future. Besides these, I expect several more general issues to emerge:

1. Levels of Detail (LOD). Presently, a 3D reconstruction algorithm is often created for a given application (e.g. cadastre, navigation, visualisation, analysis, etc.), responding to specific requirements for detail and realism. Indeed, 3D reconstruction is closely related to the application that uses the model, but such a chaotic creation of 3D models may become a major bottleneck for mainstream use of 3D data in the very near future. Early attempts to specify LOD are already being done by the CityGML team, but this work must be further tested and refined (Döllner et al, 2006).

2. Standard outputs. Formalising and standardizing the outputs of the reconstruction processes with respect to formal models and schemas as defined by OGC is becoming increasingly important. Currently, most of the algorithms for 3D reconstruction result in proprietary formats and models, both with specific feature definitions, which frequently disturb import/export and often lead to loss of data (e.g. geometry detail or texture).

3. Integrated 3D data acquisition and 3D modelling, including subsurface objects such as geologic bodies, seabed, utilities and underground construction. Traditionally, the objects of interest for modelling in GIS have been visible, natural and man-made, usually above the surface. As the

convergence of applications increases, various domains (e.g. civil engineering, emergency response, urban planning, cadastre, etc.) will look towards integrated 3D models. With advances in underground detection technologies (e.g. sonic/acoustic, ground penetration radar), already developed algorithms can be reapplied to obtain models of underground objects.

4. Change detection. Detection of changes is going to play a crucial role in the maintenance and update of 3D models. Assuming that automated 3D acquisition mechanisms will be available, the initial high costs of acquiring multiple data sources can be balanced and justified. Changes can then be detected against existing data from previous periods or initial design models (e.g. CAD). In both cases, robust and efficient 3D computational geometry algorithms must be studied.

5. Monitoring dynamic processes. The focus of 3D reconstruction is still on static objects. Although most sensors produce 3D data, hardly any dynamic 3D reconstruction is presently being done. Most dynamic software relies on geovisualisation tools (e.g. flood monitoring; Jern, 2005) for analysis and decision making.

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