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Enhancing 3D LiDAR Data Handling

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ENHANCING 3D LiDAR DATA HANDLING

Low Cost and High Accuracy

Abstract

Remote sensing data's full richness have yet to be rigorously exploited. Nowhere is this more evident than in the limited capabilities of Spatial Information Systems (SIS) to manipulate data from aerial Light Detection and Ranging (LiDAR). Currently, multiple software packages are needed to conduct three-dimensional (3D) analysis of LiDAR data. This workflow heavily relies on importing and exporting different file formats, thus potentially losing accuracy and increasing costs. Ideally, all required functionality would be available within a single system. New functionalities in Oracle Spatial combined with our enhanced 3D-indexing for hosting and analysing offer a critical breakthrough in this area.

Increasing Popularity and Availability

Since the mid-1990s more than 250 aerial LiDAR systems have been sold in total (fig. 1). The trend clearly illustrates that the rate with which LiDAR systems are entering the market is doubling every 3-4 years with a significant upward trajectory. Organisations as diverse as Google Earth, the North Carolina State Department of Emergency Management, and Ireland's Department of Communications, Marine and Natural Resources are now regular clients for such data.

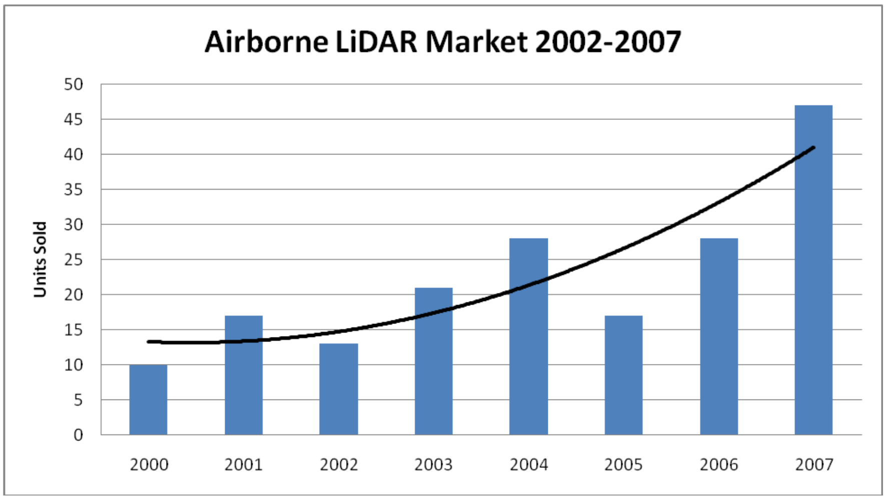

Figure 1. Units of LiDAR equipment sold from 2000 to 2007 (Airborne Lidar mapping, Leica, ASPRS annual conference, April 2008)

LiDAR technology has made some astonishing technological achievements by doubling the laser pulse rate approximately every 2 years and increasing data accuracy with the introduction of GPS+GLONASS, further improved by the use of "fitting" software, such as TerraMatch.

The rapid evolution of LiDAR for 3D data collection and processing and the increasing economical availability of such systems and data has meant that there is evermore pressure for the effective exploitation of the data, namely to develop profoundly improved mechanisms that would allow this new wave of data to be deployed and manipulated by a wide range of users, instead of only those having extensive technical training and specialty software.

Many of the benefits of this new, high-resolution LiDAR remain relatively unexploited as they are presently unmanageable in traditional Geographic Information systems (GIS) systems, because of a current inability of GIS to fully support 3D objects in a manner that is spatially accurate and meaningful. An alternative is needed to liberate the data's usefulness from this procedural bottleneck and thereby providing a critical step towards full engineering-enablement of GIS. A viable solution is to integrate all required functionality within a Spatial Database Management System (SDBMS).

Approach

Until recently, SDBMS have not provided support for 3D data management. However, since its last release, Oracle Spatial includes new data types to store 3D point clouds and Triangular Irregular Networks (TINs). Nevertheless, there are some limitations to the functionality made available. In particular, when large datasets are to be handled, performance is a critical issue. Indexing in traditional databases is used to accelerate operations performed on the dataset at hand. In the spatial domain, indexes are used to organise the space and the objects within this space in order to eliminate the need to traverse a complete table when performing spatial queries. Given the sheer size of aerial LiDAR datasets efficient indexing mechanisms are essential. Our approach relies on the extensibility properties of Oracle Spatial to provide improved indexing capabilities to handle 3D LiDAR data.

Architecture

SDBMS vendors typically offer one of two types of spatial indexes: quadtree, which is a space-based spatial index or R-tree, which is an object-based spatial index. Several variations of these index structures have been developed in the past. Currently, the R-tree is the only truly 3D index available in Oracle Spatial.

The 3D extension of a 2D quadtree is the octree. In a quadtree data structure each node can have up to four child nodes and by doing so decomposes the space into 2D cells. Subsequentially, each node in an octree can have up to eight child nodes and, thus, divides the space into 3D cubes. This 3D space-based approach has not to date been implemented within any commercial system. Our efforts are devoted to providing an octree-based 3D index for LiDAR data within Oracle Spatial.

Such efforts are the focus of our recent work as part of the University College Dublin's YobiLiDAR project sponsored by Ireland's National Digital Research Center. Our objective is to develop an indexing alternative that is specifically designed for usage with LiDAR point cloud data with a view to making use of this data in a true engineering context (fig. 2).

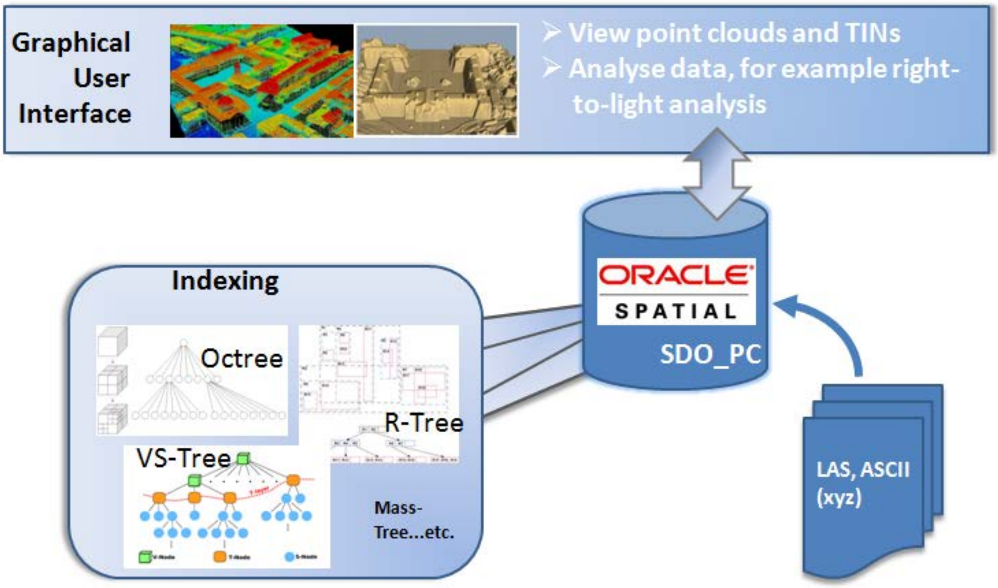

Figure 2. Architectural Overview

Visual Analysis

As part of our innovation we developed an appropriate 3D Viewer, which allows for a graphical manipulation of LiDAR data (fig. 3). The viewer is tailored to provide for 3D visual analysis and manipulations currently not available in the Oracle viewer. The YobiLiDAR viewer renders point clouds as well as Triangular Irregular Networks (TIN) and allows for the inclusion of new features and a subsequent analysis of their impact on the existing data, in addition to standard rotation/panning/zooming operations. The GUI hosts LiDAR point cloud data employing the new Oracle 3D data types SDO_PC and SDO_TIN (fig.3).

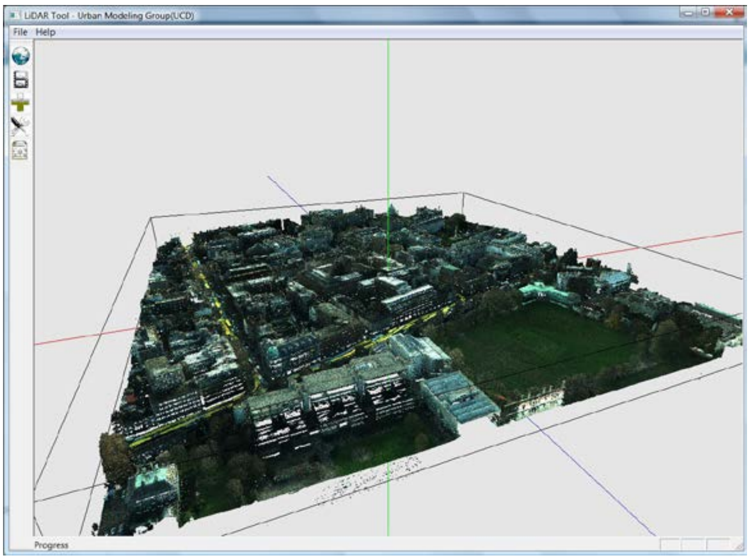

Figure 3. Point Cloud rendering in YobiLiDAR

Emerging Impact

The YobiLiDAR project is implementing 3D indexing methods for LiDAR data, which is stored in an Oracle Spatial 11g database. This facilitates search and manipulation of very large 3D point clouds in an effective and timely manner.

The innovation enables a large 3D LiDAR point cloud consisting of several million points to be treated as single dataset, with no need to be split into multiple tiles.

A simple example of where the data and proposed capabilities are of use is in the context of the ever increasing controversy surrounding "right-to-light". With ever more frequency this claim is being used as the basis to thwart planning permission for large projects. In such a case, an existing LiDAR set could be used to evaluate with a high degree of accuracy a visual acuity how a proposed structure might impact surrounding structures.

The project's toolkit removes the need for multiple software applications to store and use a large LiDAR data set, thus significantly reducing costs and training time, as there is no need to translate into formats of different software packages.

Concluding Remarks

From ongoing evaluations of current commercial systems and discussions within the LiDAR community, it has emerged that before the advantages of LiDAR data can be fully exploited, support for the hosting and querying of such data must be significantly improved by SIS vendors, through the improvement of 3D functionalities. Crucial for the evaluation of data are 3D indexing capabilities. To date, commercially available indexing techniques consist of quadtree indexing in 2D and R-tree indexing (2D and 3D). R-tree indexes are based on MBR, which make them difficult to apply on point data, as the definition of an MBR on a set of data points is rather arbitrary. Additionally, R-tree approaches are implemented differently by individual vendors. Furthermore, different implementation strategies have implications on the performance of the indexing technique itself and consequently impair accurate comparisons among systems.

Before any widely-accepted progress for employing LiDAR data sets in an engineering context can be made, it is necessary that fully 3D spatial indexing is implemented in vendor systems. The YobiLiDAR project offers insights on how to tackle these differences by providing an integrated toolkit on the basis of Oracle Spatial 11g, which empowers storage and analysis of LiDAR data in a Database Management System.

Acknowledgements

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Further Reading

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Personnel

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Dr. Bianca Schön is a postdoctoral researcher with the college of Engineering, Mathematical and Physical Sciences in University College Dublin, Ireland. She gained her PhD from University College Dublin, Ireland and has worked as a technology consultant before joining the YobiLiDAR research team. Her main interest lies in spatial database management systems, intelligent systems, computer graphics and human computer interaction.

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