Cyberinfrastructures for Mobile Lidar

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1. Introduction

In the last decade LiDAR has emerged as a popular technique for the rapid acquisition of survey data. The NCG acquired a Leica ScanStation in 2007. This has a maximum scanning rate of 4000 points per second, and over the next 30 months scanned every building on the campuses at Maynooth. Each building was separately scanned – the files are of the order of a few Mb in size – wireframes and eventually rendered models were created from the point clouds. Some buildings required multiple scans, which were then integrated into a coomon coordinate system using Leica's proprietary Cyclone software. The working folder is about 39Mb in size with 5000 individual files, which does not present an insuperable problem for data storage and access.

In 2010 we designed and built a mobile LiDAR platform, based a modified Volkswagen Transporter van, with a Riegl VQ250 as the primary sensor. The data output from the Riegl can be prodigious: the maximum scan rate is 300 KHz, The processing overhead before the point clouds can be visualised is extensive: georeferencing requires integrating post-processed GPS data from the on-board Trimble receiver with information from the on-board IXSEA LandINS Inertial Navigation Unit. The platform itself collects other forms of potentially spatially reference-able information including multiple video streams. The data are stored locally during acquisition using the on-board servers through the platform’s LAN, and then post-processed in the lab.

The sheer volume of data turns is a major data management challenge. A typical corridor survey along a road might last 30 minutes. At the maximum scan rate this represents the acquisition of some 5.4 million measurements from the Riegl scanner, each of which includes values in 3 dimensions (x,y,z) as well as a reflectance index and an RGB colour triple. If each point’s data record is 32 bytes, this amounts to some 16Gb of data in total. The INU itself adds a data stream with a scan rate of 200KHz which includes measurements of position, heading pitch and roll.

The sheer volume of these data,both before and after processing, presents a significant challenge for data management in LiDAR point cloud visualisation and subsequent CAD/GIS applications. One solution is to tile the data in 3D, but this lacks the potential elegance of seamless storage and retrieval. The solution we have chosen is to use a Spatial DBMS approach, based on PostgreSQL with PostGIS spatial extensions. Data is stored on a suitably configured LiDAR server and can be retrieved through a web interface for further analysis and processing.

The core component which permits this optimisation is based on the PostGIS spatial extensions to PostgreSQL, in particular the spatial index options. However, such indexing becomes a challenge given the volume of the LiDAR data that we are using to populate the database, and demands that there exists an efficient upload procedure. We have found it necessary to pre-process the LiDAR data prior to its upload; using the Longitude, Latitude, and Altitude fields we create a suitable version of the PostGIS base-geometry data type. The process has the following 5 steps:

1. Add the PostGIS geometry data type representation into the original file – for this we use accomplished using a bespoke Python program
2. Create an empty table using the header fields in the input file
3. Add a PostGIS POINT-geometry data type field
4. Create a spatial index on the field added in the previous step
5. Populate the table with the raw LiDAR

Experiments suggest that there is a non-linear relationship between the upload time, the number of rows of LiDAR data and the number of fields in each row.

A second issue is concerned with the integration of data from terrestrial, mobile, and aerial LiDAR in the database. Data from the mobile platform may be of the order of 4000 points per square metre, whereas that from an airborne platform may be around 10 points per square metre. There are several possible approaches. One solution is to subsample the mobile and terrestrial data to match the densities of the airborne data, and then create convex hulls around each set of subsampled data. The processing overhead required for this is initially high. However, undertaking this procedure significantly decreases the access overheads for subsequent visualisation and analysis. The original data are not discarded, so that if we develop another approach, we can start with the original data.

We have developed a web interface that allows the user to explore these data and extract spatial subsets for further detailed exploration and analysis (such as edge detection, geometry reconstruction). This system is known as GLIMPSE (Global LiDAR and Imagery Mobile Processing Spatial Environment). Based on the GLIMPSE architecture retrieving the LiDAR data for a user defined region (such as a section of road) from the database – currently some 29 billion points – is a relatively rapid exercise and is undertaken via the GLIMPSE interface. Whilst we have been using a workstation for the subsequent analysis, there is no reason why a browser linked to GLIMPSE could not be used on a mobile device, perhaps a smartphone in the field.

The GLIMPSE browser can provide 2D and 3D views of the data. The 2D view is used to explore and select spatial subsets of data for further processing – this might merely be visualisation of the point cloud in the 3D viewer However, the spatial subset of the data can be downloaded into a separate application for subsequent analysis, say, road feature detection. Typical retrieval times for a rectangular region query from the mobile data vary from around 10s (20m x 5m: 91000 points) to 50s (20m x 40m: 550000 points). For airborne data typical times vary from 5s (50m x 50m: 30000 points) to 60s (250m x 500m: 1.5 million points). However, these are server, network, and to a lesser extent, local processor dependent.

The key to the successful implementation of the underlying infrastructure has been a move away from a flat file structure to the use of a Spatial DBMS. With a suitably optimised structure and spatial indexing, extraction of subsets of the data via a spatial query has been shown to be both convenient and quick. The architecture of the system permits browser independence. Current enhancements include the development of an applications programming interface (API) in Python which will allow the data to be accessed either as a web service, via commercial software such as ArcGIS or open source applications such as Quantum GIS.

Whilst a collection of individual zipped *.las* files may take up less space than the system we have designed, rapid access to subsets of such unstructured data is both inconvenient and slow in comparison. It is also unlikely to be scalable. Data users are freed from having to host large quantities of data locally, and the concomitant large scale backup issues reside only at the server end. Another advantage is that being able to access only the data that is required for an application does not place the network under undue strain. Data limits are constrained by the availability of suitable server space or the costs of additional capacity. Should suitable resources be available, a cloud based solution is a possibility.

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Biographies

Martin Charlton is a graduate of the University of Newcastle upon Tyne. Following 13 years as lecturer in the Department of Geography he moved to NUI Maynooth as Senior Research Associate in the National Centre for Geocomputation. His research interests encompass all aspects of geocomputation and is one of the developers of geographically weighted regression.

After completing a honours degree in Computer Science and Software Engineering, Conor was awarded a Ph.D. in computer science and optics in NUI Maynooth. For the last three years he has been working on LiDAR data management and automatic feature extraction from LiDAR.

Paul Lewis *completed his PhD in Computer Science and Geocomputation in 2009. He works at the NCG as a Postdoctoral Fellow in the Mobile Mapping Systems group. His research interests are in large spatial-database integrated with web-applications for access to and visualisation of spatially encoded Video, Imagery and LiDAR data.*

Tim McCarthy is a Research Fellow at the National Centre for Geocomputation. He coordinates several research projects in the areas of GeoInformatics, Mobile Mapping and Spatial Analysis. He holds degrees from University College Cork (BSc, 1985) University College London (MSc, 1988) Birkbeck College, University of London in (PhD, 1999).