

LIDAR Mapping and Analysis Systems: A GIS-based Software Tool for LIDAR Data Processing

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The emergence of airborne LIDAR technologies has resulted in the ability to generate very high-resolution terrain elevation maps of the earth's surface. The advantages to this data are that for the first time we can create true-3D maps of the terrain and their associated surface features (bare-earth surface, trees, buildings, stream networks, etc.). The primary bottleneck in the use of this data has been the nature of the data itself. Airborne laser altimeters collect hundreds of millions of elevation points that need to be formatted, imported and processed in an efficient manner. LIDAR data has strained the limits of COTS Commercial Off-the-Shelf software, especially within a production environment. This has lead to the US Army Corps of Engineers to release an SBIR Small Business Innovation Research program, which EnerQuest Systems, has replied to and has been working on for the last 2 years. The cumulative product of this work is the LIDAR Mapping and Analysis System (LID-MAS). This paper will discuss the functionality and efficiencies of the LID-MAS software, which is built upon a suite of GIS, image processing and database management tools.

LIDAR Data Processing within a Production Mode

In the development of a LIDAR data processing system several technical factors have to be taken into account.

- The large number of data points present in the data (average of over 100,000 points per square mile) and the efficiencies of data processing in a production environment
- The archiving and management of the data
- The filtering of the Lidar data in order to generate a DEM of the bare-earth surface.
- Extraction of the elevation points associated with earth surface features (trees, building, etc.).
- The ability to view the data in both a 2D and 3D environment.
- The capability to generate output products that can be used within a COTS software environment.

For most users of LIDAR data it is the above issues that form the framework of a production bottleneck that is not met by COTS. These issues were met head-on in the development of the LID-

MAS software. These issues were resolved by taking an approach that included the use of GIS, image processing and database management techniques.

The size of the data and the data archiving and management issues were handled by the development of a LIDAR data archiving standard called the LAS file format. The LAS data format serves as the data storage, access, display and processing format. It is from this format that all LID-MAS LIDAR data access and processing takes place within a point and file attribution environment. The LAS format is in essence a binary file format that stores the raw x,y,z, and return values of a particular LIDAR data set and ancillary descriptive and numeric attributes, within the framework of a single flightline. The ancillary descriptive and numeric attributes that are used for data management, tracking, archiving, process flow, and metadata definitions. The LAS format is in essence a binary file format that stores the raw x,y,z, and return values of a particular LIDAR data set and ancillary descriptive and numeric attributes, within the framework of a single flightline. Advantages include a LIDAR data standard, binary data compression, reading and writing from a single file, and attribution of data so that the original data is always present, only class type of the point changes during processing.

The overhead of data processing is control in LID-MAS using the LAS file format and a GIS approach to data management. All code is written using C++, Visual Basic and the ESRI Map Object tool kit. This has led to the development of a suite of tools that perform data management, 2D and 3D viewing, filter processing and process reporting and metadata creation within a GIS environment.

- **2D and 3D Viewers:** Display windows and tools
- **LID-DBMS:** LIDAR Database Management System
- **LID-PROC:** LIDAR Filter Processing Tools
- **LID-DOC:** LIDAR Documentation Module

LID-VIEW is LID-MAS's display and visualization interface tool. LID-VIEW consists of two sub-modules: the 2D and 3D Viewers. The 2D and 3D Viewers allows the user to access, display and query LIDAR data within a 2D and 3D visualization environment. A user can view project and ancillary data in a standard GIS-based 2-Dimensional viewer. This includes LIDAR in a point, image and TIN file format and ancillary data in an ArcView Shape and CAD file formats. The 3D viewer will have the capability to display LIDAR points, image and elevation surface information in 3D space in a point and interpolated TIN file format. The 2D and 3D viewers come with a suite of menus, buttons and mouse driven tools that permit the user to zoom, pan, scroll, rotate and query the database.

The LID-DBMS module permits the user to set up sets of LIDAR flightlines in a LAS format as study areas that can be managed as individual projects. A user can identify and import a complete set of project flightlines, edgematch them and create a seamless LIDAR project data set. This project file can them be appropriately tiled based on project requirements or by using an optimization tiling scheme. This component of the system is established within the context of a GIS, thus allowing the user to access and display ancillary project datasets that are in a shape file, coverage, CAD or image file format. By using the LID-DBMS functionality of the system one can view and query the entire sub-sampled project dataset, groups of tiles, individual tiles, an individual flightline of data, a specific coverage / image, or individual features within a project coverage

LID-PROC is the processing and LIDAR filtering engine of the LID-MAS software. LID-PROC is composed of a suite of LIDAR processing filters used to generate bare-earth surface and to classify and extract the elevation of earth surface features (trees, building footprints, utilities, etc). This suite of filters allows the user to filter and process raw LIDAR data, generating classified and attributed LIDAR datasets. A user can create bare-earth surfaces and extract specific elevation features, such as building elevation footprints and vegetation canopy-elevation structure. LID-PROC is composed of an aggregation of filters used to primarily generated bare earth surfaces, identifying and extracting non-bare earth points from the raw LIDAR files that are in an .LAS file format. The core suite of filters found within the LID-PROC are listed below:

- Fast Fourier Transform [FFT] Filters
- Cross-Sectional Analysis Filter
- Polynomial Filter
- TIN Filter
- Multiple Return Analysis Filter
- Surface Difference Filter
- Spike Removal Filter

LID-DOC functionality is centered on the following functions:

- Project Report Generator
- Metadata Generator and Viewer
- On-Line Help
- Online User Manual

The above functionality is centered on the systems ability to generate a project report that tracks a LAS file or set of project related LAS files through its processing history. This function is operated using a report interface form that allows the user to interactively input project and tracking information. This interface will allow the user to view, edit and update and generate an actual project or LAS file report. This interface is intimately linked to the Metadata viewer and generator, that interactively generates metadata file for individual LAS, images, GIS and CAD coverages generated using the LID-MAS software. LID-MAS will also have a Windows based On-line Help and an On-line User Manual that details the LID-MAS modules, their functionality, LIDAR processing, data formats and user processing and analysis tips. Both the Online-Help and On-Line User Manual will have search capabilities that allow the user to search by word, phase, module functionality, etc. Both functions will be Windows based using Adobe Acrobat (.pdf) files as the source text and graphics files.

Summary

In summary the LID-MAS software represents a beginning to end LIDAR processing and production tool that permits users to generate bare-earth surface data within a GIS and image processing environment. This software tool greatly enhances the efficiency in which millions of LIDAR points are processed using the LAS file format and associated descriptive and numeric attribute information. This tool allows the generation of bare-earth surfaces and surface feature digital elevation data, for the efficient creation of digital elevation models.