CHAPTER 3 – POINT CLOUD PROCESSING SOFTWARE

Point clouds by themselves are not useful without software to process the data and make measurements and other calculations. Also, in order to be useful, the point cloud data needs to interface easily with Computer Aided Design/Drafting (CADD) and slope stability programs. This section discusses the point cloud file format, point cloud processing software, and interfacing between point cloud software and other CADD and slope stability software.

THE POINT CLOUD FILE

As discusses in Chapter 2, the point cloud is the basic output from a 3D laser scanner. The most generic point cloud file format is a 3D coordinate file (often referred to as an xyz file). The format for this file is ASCII and can therefore be read by all post-processing software. The comma or tab-separated format for a grayscale 3D coordinate file is as follows with one line for each laser point:

Grayscale point cloud: x1 y1 z1 intensity1
x2 y2 z2 intensity2
…

The x, y and z values refer to a specific coordinate system. If the point cloud is not registered, then by default the y direction is most often set to the instrument direction. After registration, the x, y and z directions are most often set to East, North and up, respectively. However these systems are not universal and the scanner or software manufacturer should be contacted for information on their specific 3D coordinate formats. The intensity for each point has a value that range from 0 (black) to 255 (white).

Similarly, the comma or tab-separated format for an rgb (red, green blue) 3D coordinate file is as follows:

Color point cloud: x1, y1, z1, r1, g1, b1
x2, y2, z2, r2, g2, b2
…

Here r, g and b each have values that range from 0 to 255. Because the xyz file is ASCII, these files are slow to read and write; they also only contain the basic point cloud information. In general, each scanner manufacturer, and also each point cloud processing software manufacturer, has their own specialized binary format. Some examples of file extensions associated with different binary formats are given below.

<u>Scanner manufacturer:</u>
Leica: .coe
Riegl: .3dd

Point cloud processing software manufacturer:
Polyworks: .pif file format
Split FX: .fx file format

At the present time the ASCII 3D coordinate file is the standard format for point clouds. However, because it is ASCII and only contains point cloud information, that is, no digital image or tin surface information, other formats have been discussed by both manufactures and users as better standard file formats for ground-based LiDAR output. These formats include the LiDAR Exchange Format (LAS) and the Virtual Reality Modeling Language (VRML). Additional details on these file formats are discussed in Chapter 6.

POINT CLOUD REGISTRATION

The first step in point cloud processing is to orient the point cloud into the real world coordinate system based on data taken in the field. Point cloud software usually includes several methods for point cloud registration. The most common method is to register the point cloud based on three or more targets of known position (3D similarity transformation). However, for some applications (such as slope stability), only the orientation registration is required. This means that the point cloud is oriented correctly, but the 3D coordinates are not registered to a known coordinate system (Universal Transverse Mercator coordinate system, for example). In these instances, simpler registration methods are possible, such as only measuring the orientation of the scanner (orient by scanner method) without any position surveying. In this case the scanner's position is defined by the bearing or direction of its line of sight, its inclination in the direction of the line of sight, and its inclination perpendicular to the line of sight. This provides enough information to correctly georeference the orientation of the scan (but not the position).

POINT CLOUD PROCESSING SOFTWARE

Most of the scanner manufacturers have developed their own point cloud processing software. In addition, several other companies have developed point cloud processing software. By exporting the point clouds in the xyz file format, point clouds from any scanner can be analyzed with any of the software packages. Point cloud processing software includes:

- Cyclone and Cyclone Cloudworx (Leica, www.leica-geosystems.com)
- Polyworks (Innovmetric, www.innovmetric.com)
- Riscan Pro (Riegl, www.riegl.com)
- Isite Studio (Isite, www.isite3d.com)
- LFM Software (Zoller+Fröhlich, www.zofre.de)
- Split FX (Split Engineering, www.spliteng.com)
- RealWorks Survey (Trimble, www.trimble.com)

Details on some of the software listed above are given in Appendix B (from POB, 2008).

The following editing/analysis features are found in most of the software packages:

- General point cloud visualization, including pan, tilt, and zoom;
- General point cloud editing, including adding and deleting points, noise removal, point decimation;
- Ability to make measurements such as distances, angles, areas and volumes;
- Ability to register scans, including the automatic detection of targets;
- Ability to stitch together multiple scans either using survey control or Iterative Closest Point (ICP) type algorithms;
- Ability to create a triangulated surface (Triangulated Irregular Network, or TIN);
- Ability to best-fit lines, planes, and other shapes to point cloud clusters;
- Ability to make profiles and cross sections through a point cloud; and
- Ability to handle various import and export formats (to CADD programs, for example).

The following advanced features are found in some, but not all of the software packages:

- Perform solid modeling (volume generation) based on user-defined lines, planes and other surfaces as bounds;
- Perform automatic extraction of standard shapes from cloud (e.g. pipe fittings, structural steel members, etc.);
- Have edge detection technology to determine boundaries of solids, planes and other shapes;
- Ability to drape a digital image over a triangulated surface;
- Automatically compute a full 3D polygonal mesh (not 2.5D) from a point cloud;
- Ability to integrate scans with floor plans, engineering drawings of objects and surveyed information; and
- Ability to make fly-throughs and other types of advanced visualizations.

The focus of this report is on the use of ground-based LiDAR for highway rock slope stability. Therefore, rather than describe all of the items in the above lists, this report focuses on specific features in point cloud software that allow geotechnical information to be extracted from point clouds. It should be noted that most of the point cloud software is generic in nature and is able to perform analyses for a number of applications including mechanical design, architecture, construction, and mining. The Split FX software, on the other hand, was developed specifically for extracting geotechnical information from point clouds of exposed rock surfaces and has the following features:

- Ability to automatically delineate fracture surfaces in a point cloud and determine the orientation, area, and roughness of each fracture;
- Ability to plot fracture orientations on a stereonet (pole and contour plots);
- Ability to pick joint sets, and determine statistical properties of each set set;
- Ability to delineate joint traces (automatic and manual) and determine joint spacing, length and orientation (true spacing and orientation if digital image is draped);
- Ability to trace fractures on draped photos to determine fracture orientations;
- Ability to subtract two point clouds to determine rockfall volume and rate; and
- Ability to estimate a rockfall hazard rating from a point cloud.

Many of the above items can still be analyzed using the "generic" point cloud software. For instance, to determine the orientation of a fracture in a point cloud, the points making up the fracture can be selected by hand, and the software will determine the orientation of the best-fit plane through the points. This can be done many times throughout the point cloud, and the orientations can be plotted using a separate stereonet program. In a similar fashion, the generic software can be used to estimate fracture length and spacing, roughness, etc. This is discussed in more detail in Chapter 4.

INTEROPERABILITY WITH CADD SOFTWARE

CADD software principally includes Microstation (Bentley, www.bentley.com) and AutoCAD (Autodesk, www.usa.autodesk.com), though many other programs are available. It also includes highway-specific CADD software, such as Inroads and Geopak. The interoperability between point cloud and CADD software is very important, and in the past this has been an issue with using LiDAR in highway applications. It still is an issue as will be shown in Chapter 6; however, as the point cloud software has improved with the addition of many new features in the past few years, interoperability is now greatly improved. For instance, importing a point cloud with a high density of points into a CADD program is not recommended, since CADD programs are not set up to efficiently handle the large number of points and the large file size. Many options now exist for exporting 3D information to the CADD environment, and programs such as Cyclone Cloudworx have been designed specifically for manipulating point clouds within a CADD environment. First of all, point clouds can be cropped and the density of points can be decimated so the file size is optimized. Secondly, specific 3D shapes (pipe fittings, steel members) can be extracted from the point cloud, which are much easier to work with in CADD programs than the points themselves. Thirdly, two-dimensional plans and sections can be created in the point cloud software and exported to CADD programs.

INTEROPERABILITY WITH SLOPE STABILITY SOFTWARE

Slope stability software used for highway applications include Rockpack III (RockWare, Inc., www.rockware.com), the Rocscience suite (Dips, Swedge, Rocplane, Slide, Phase2; www.rocscience.com), the Itasca suite (FLAC, FLAC3D, UDEC, 3DEC; www.itascacg.com), Slope/W (Geo-Slope International, www.geo-slope.com) and many others. Two of the advantages of using LiDAR for highway geotechnical investigations are the ease and speed at which scans can be made and rock characterization information extracted from point clouds. Along these lines, it is important that LiDAR-generated data can be easily exported to the slope stability programs mentioned above. There are three basic kinds of information that the slope stability programs import, and the ability of point cloud processing software to export this information is discussed below.

Export Individual Fracture Information

Many slope stability programs (Rockpack III, Swedge) are able to directly input individual fracture information in a spreadsheet format. For each discontinuity, this information includes orientation, size or length, roughness, etc. The specific position of the discontinuity can also be input into some of the programs (3DEC). In general, exporting this kind of information is straightforward for the point cloud processing programs, assuming that the point cloud programs can calculate the information in the first place. Most point cloud programs can fit a plane through a selected set of points and calculate the orientation and size.

Export Fracture Set Information

Some of the slope stability programs (Swedge, 3DEC) use statistical information about the number of fracture sets and the statistical properties of each set (such as the mean orientation and the Fisher constant). Once the orientation of individual fractures has been determined from LiDAR, this information is relatively easy to calculate in a spreadsheet. It is also very easy to export to slope stability programs since it only involves a few numbers for each discontinuity set.

Export Rock Mass Strength and Modulus

Many of the slope stability programs (Slide, FLAC, FLAC3D, Slope/W, Phase2) use rock mass properties (Hoek and Brown rock mass parameters or Mohr-Coulomb rock mass parameters, for example) rather than individual fracture information. To date, none of the point cloud programs have the capability to make the necessary calculations. However, these rock mass properties can be calculated from the information extracted from the point clouds using the procedures described in Hoek (2007) and others.