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Landslide Mapping and Characterization Using LiDAR

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Summary

Processed Light Detection and Ranging (LiDAR) data is becoming more readily available and is now a routine tool used by geotechnical engineers and geologists for the assessment of geohazards such as landslides. This presentation discusses some of the basic methods used to identify and characterize landslides using this data and touches on some of its advantages over more conventional mapping methods such as stereo airphotos.

Introduction

While Light Detection and Ranging (LiDAR) technology was developed in the 1960s, it is only in the last five to ten years that processed data covering large portions of Alberta and Western Canada have become readily available off-the-shelf. This increase in accessibility and affordability has resulted in LiDAR becoming a more accessible tool in the geotechnical/geohazard toolbox, previously only available to large projects.

LiDAR data is now used routinely in a GIS environment to identify and characterize landslides even for small geohazard projects. Techniques used include viewing the data as a hillshade, 3D oblique viewing, slope gradient and direction shading, roughness attributes, etc.

Theory

LiDAR is often defined as an acronym for Light Detection and Ranging. However, it is also a linguistic play on the words ‘Light” and “Radar” (i.e. Radio Detection and Ranging). It is a remote sensing technique which consists of measuring the time it takes light from a pulsed laser to hit the earth and reflect back to the source. The source of the light pulse can be airborne (airplane or helicopter) or terrestrial (stationary or mobile ground based). Because millions of light beams are sent per pulse, some reflect off the top of vegetation and buildings (first return), but some make it to the ground surface (last return). Coupled with accurate Global Positioning Satellite (GPS) tracking technology, the XYZ position of every returned reflected light point can be calculated. This raw collection of points is referred to as a LiDAR ‘point cloud’.

Using a combination of software algorithms and manual manipulation, Digital Elevation Models (DEM) can be generated using select points from the LiDAR point cloud. The DEM produced from the first return points is commonly referred to as ‘full feature’ and includes vegetation. The DEM produced from the last return points is referred to as ‘bare-earth’ as the vegetative canopy has been removed. It is this latter DEM (or DTM) that is of most interest to the geotechnical engineer and geologist for landslide identification.

As most geotechnical engineers and geologists would be considered end-users of this information, they typically would rather use a processed DEM as opposed to working directly with raw point cloud data. Pre-processing and interpretation of raw LiDAR point clouds is typically left to the persons collecting the data or firms specializing in this task.

For the bare-earth DEM to be useful, it must be loaded into some form of GIS software. Fortunately, most software packages allow for fairly sophisticated viewing and manipulation of DEM and/or LiDAR data. Various viewing methods can be used for different purposes. The simplest method of viewing the LiDAR data for landslide identification is referred to as 'hillshade' viewing. A hillshade is a relief map created from the XYZ points by simulating illumination from 0° to 90° from the horizon and Azimuths from 0° to 360°. This simulates shadows which creates the illusion of depth. Hillshade representations are typically grayscale, but can incorporate color to reflect other information, such as elevation.

Hillshade viewing allows the user to be able to visualize the terrain such that distinct landslide characteristics can be identified. The most readily identifiable landslide features include the headscarp and flanks of a slide which have characteristic arcuate (plan) shapes and steeper slope segments near the crest. Other characteristics of landslides identifiable by hillshade viewing include irregular stepped relief or flow-like features within the slide masses, convex or concave surfaces and/or distinct toe areas.

It should be appreciated the use of LiDAR does not replace the skill of the person doing the geohazard interpretation. The LiDAR merely provides a clear tool to look for the same types of indicators one would use in stereo airphoto interpretation. While several papers have been written on algorithms and processes to automate landslide identification by remote sensing, it should be appreciated the results from these methods are statistical and should be considered as screening tools. The methods discussed in this presentation are simple manual interpretation.

Another useful viewing method for bare-earth DEM for landslide identification is displaying it obliquely as a 3D view. Such an oblique view mimics what the terrain would look like from an airplane. Depending on the actual topographical relief of the area of interest, this oblique view can be viewed in true scale or with vertical exaggeration. Minor vertical exaggeration of 1.5X to 2X are often used in areas of moderate terrain relief. Larger exaggerations may be required for alluvial or beach environments. It can viewed with a simple hillshade or any other GIS raster or vector layer draped over it, such as a geological map or an airphoto. Oblique views can also be rotated and viewed from various different angles.

For more sophisticated analyses, bare-earth LiDAR can be displayed as a color shaded slope gradient map, which is also sometimes useful for picking out the extent of landslides or features such as toe, headscarp or scarps, grabens, etc.

In addition to the qualitative viewing methods used for identification and characterization of landslides described above, because the bare-earth DEM is also an accurate representation of the ground surface, measurements of the landslide features such as width, length, height of headscarp, etc. can be made. Representative cross sections can also be cut through any portion of the landslide for further interpretation. While the depth of the rupture surface is not possible to ascertain from LiDAR, volume estimates can be estimated based on reasonable assumptions.

Examples

Several different landslide examples are presented to illustrate the following concepts:

- Contrast between airphoto, full feature (i.e. top of vegetation) and bare-earth and how effective LiDAR is at highlighting normally obscured ground features.
- Importance of illumination on hillshade with west and east facing landslides.
- Different viewing techniques of several landslides presented with their various components identified.

Conclusions

LiDAR is proving itself to be a breakthrough technology for geohazard characterization and identification, particularly for landslides, as datasets are becoming increasingly more available and affordable. Analysis of bare-earth LiDAR is replacing more traditional forms of terrain geohazard analysis such as stereo airphoto interpretation which cannot 'see' through the tree canopy like LiDAR. Also, because the surface features of the landslide are accurately represented, mapping is more precise than estimates using conventional desktop stereo airphotos without expensive software.

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