Laboratory Exercise 2

GEOG*3420 Remote Sensing of the Environment
University of Guelph, Department of Geography

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(Total of 39 marks)

Learning objectives
The intention of this lab exercise is to familiarize students with the processing of LiDAR data.

Before you begin
You will need to download the latest version of Whitebox (v. 1.1.1 beta) from the CourseLink page. Notice that this is different that the publically available version that is accessible from the Whitebox web site. In addition to the software, you will need to download the data associated with this lab exercise from the CourseLink page under the Lab 2 directory. Decompress (unzip) these data into a working directory. If you are using a mac or linux computer, you may need to give the Whitebox JAR file permission to execute before launching the program. Be sure to back-up your data frequently.

What you need to hand in
You will hand in a printed report summarizing the answer to each of the questions in the following exercise along with the necessary colour and grey-scale images. Notice that you will need to have paid your lab fee to have printing privileges in the Hutt building computer labs. If you have run out of print credits, talk to your TA about acquiring additional print credits.

Interpolating LAS Files
LAS files (*.las extension) are a binary file format specifically designed to store raw LiDAR data. Raw LiDAR data are simply collections of points, for which each point contains (x, y, z) coordinates, intensity of the return, time collected, and other information. If all of the data acquired from a typical LiDAR acquisition campaign were stored in a single LAS file it would be far too large to handle with most computers (it would likely be terabytes in size!). When LiDAR data are collected,
they are usually parsed into 1 km² tiles, with each tile containing 1-2 million points, depending on the point density.

The data for this lab consists of nine LAS tiles for a section of the beautiful town of Picton, Prince Edward County, Ontario. Point files are fine, but most of the time what you really want is a digital elevation model (DEM). DEMs are square grid images that resemble other types of remotely sensed images, except that each pixel contains an elevation value rather than a measure of surface reflectance. DEMs can be created from the ‘point clouds’ contained in LAS files through interpolation. Open the Nearest Neighbour Interpolation (LiDAR) tool from within the LiDAR tool folder. This tool will interpolate multiple LAS files in batch mode (i.e. one after the other) using the same specified interpolation parameters. Input all nine LAS files and specify an output suffix of ‘FR’ (to designate the first return). Interpolate the ‘Z (elevation)’, using the ‘First Return’ point return. Use a maximum search distance of 3 m and a grid resolution of 1 m. Press the OK button. Depending on your computer, this may take a few minutes to complete the interpolation of all nine LiDAR tiles.

It will be easier to process and display the data if they are contained in one large DEM, rather than nine smaller 1 km² DEMs. Use the Mosaic tool contained in the Image Processing Tools tool folder to mosaic (i.e. stitch together) each of the nine tiles. When the tool is complete, the mosaicked DEM should be displayed automatically. If it is not, display it by adding it as a layer to the active map.

Notice that there are several large holes in the data, designated by white, i.e. the map background colour. These data holes occur where there are no valid return points within the LiDAR data within the maximum search distance of 3 m specified in the interpolation step.

1. Why do you think that there were no LiDAR returns in this area of the study site? (1 mark)

Patches of missing data are not uncommon in LiDAR data sets. Usually these are dealt with by interpolating values for these areas. Use the Fill Missing Data Holes tool from within the LiDAR Tools tool folder to fill in these missing data patches and display the DEM.

The first-return DEM likely looks like a purple square at this point. That is because the display palette is being stretched by the presence of a few very large elevations (about 1800 m in height). These are likely the result of laser pulse returns that have bounced off of things in the air above the ground, e.g. dust or birds. The ground elevations actually range from about 70 m to about 150 m. Right-click on the DEM layer in the Layers Tab and select Layer Display Properties from the pop-up menu. Clip the display maximum to 0.1% and then press okay.

The surface topography depicted by a DEM is often significantly enhanced when analytical hillshading (sometimes known as a shaded relief map) is used. Create a hillshade image of the first-return DEM using the Hillshade tool. Place the hillshade
layer beneath the DEM and lower the DEM layer’s opacity (in **Layer Display Properties**) to 188, such that the hillshade layer will show through the DEM. Include a copy of this hillshaded and DEM map with your final hand-in (2 marks).

2. Describe the surface topography of the study site. What kind of landscape features can you observe in the DEM, i.e. things situated on the surface topography? (4 marks)

**Removing Off-Terrain Objects**

The term off-terrain object (OTO) is used to describe any entity in the landscape that is sitting on top of the surface topography (i.e. the ground level). This includes buildings, cars, trees and other vegetation, fences, hydropower towers, and many other common anthropogenic features. You have probably noticed many such features present in the DEM derived from interpolating the first-return points. Use all of the same procedures described in the previous section to create a map of the last-return points, this time specifying ‘**Last Return**’ as the point return in the **Nearest Neighbour Interpolation (LiDAR)** tool. Be sure to fill the missing data values and create the hillshade image. Be sure to rescale the palette such that the display maximum is the same elevation value used for displaying the first-return DEM. You may want to add a second map in the Layers Tab to display these data, such that you can quickly compare the first and last return DEMs by selecting either. If you do use two separate maps, then select the ‘**Link Open Maps’** option from the **View** menu so that both maps maintain the same extent when you zoom in and move around the either map. Include a copy of the last-return hillshade/DEM map with your final hand-in (2 marks).

3. What are the main differences between the first- and last-return images? For what type of OTOS does the use of last-return points only in the interpolation work well for eliminating OTOS and for which type does it not work well? Why may this be? (4 marks)

Often, we are interested in creating a ‘bare-earth DEM’ from a LiDAR data set. Bare-earth DEMs have all OTOS removed. As demonstrated above, using last-return points only will not necessarily do a good job of creating a bare-earth DEM, and therefore, we usually have to perform additional processing to achieve this. Use the **Remove Off-Terrain Objects** tool found in the **LiDAR Tools** tool folder to remove the OTOS from the last-return DEM. Specify an output file suffix of ‘bare earth’, a maximum OTO size of 150 pixels, and a minimum OTO edge slope of 10 degrees. The **Remove Off-Terrain Objects** tool can take a while to run depending on your computer system so be patient. Create a bare-earth DEM map like the other two maps and also include this image with your final hand-in (2 marks).
4. How well does the **Remove Off-Terrain Objects** tool work for removing OTOs? Are there types of OTOs or places in the landscape where it appears to work better than others? (4 marks)

Bare-earth DEMs allow us to better depict surface topography, which can be very useful for modelling surface drainage and other applications in hydrology and geomorphology. Another benefit in creating a bare-earth DEM is that it allows us to map the off-terrain objects. Use the **Subtract** tool in the **Mathematical Analysis** tool folder to difference the bare-earth DEM from the first-return DEM (*be careful to get the order correct here; you should end up with an image where OTOs have positive values*).

Now use the **Reclass** tool to make all values in this new layer that are zero or less (you probably have noticed that there are some small negative values) equal to NoData. Specify an input image of your difference raster, call the output image OTOs, and reclassify using a **new value** of NoData (you can actually type that in to the box), a **from** value of -5, and a **to less than** value of 0.01. Now you can create a new map, display your hillshaded image derived from the first-return DEM and overlay the OTOs layer. Lower the opacity value of the OTO layer such that in areas where there are OTOs, the hillshaded image shows transparently through. Also, you may need to clip the display maximum to account for those rather high values near 1800 m. Include an image of this map with your final hand-in (2 marks).

5. Approximately how tall are the five large rectangular buildings on top of the plateau area in the central bottom region of the study site? (1 mark)

6. A story (in the building sense) is usually about 10 ft. or approximately 3 m high. Are there any buildings in this section of Picton that are 10 stories tall or higher? (1 mark)

7. Describe a possible application of this type of OTO data. (2 marks)

**LiDAR Intensity Data**

So far we have used the elevation data associated with each point only. Along with the \((x, y, z)\) location of each return point, most LiDAR system are also capable of measuring and recording the intensity of the return, a measure of the reflectivity of the surface material off which the laser pulse bounced. This is the reflectivity of this surface material within the specific wavelength of the laser system used by the LiDAR unit.

It can be a bit difficult to interpret and use these data since they are usually uncalibrated and because intensity images don’t represent a snapshot at a single moment in time (as other remotely sensed images do) but are rather built up during multiple passes of the aircraft over the surface. Use the **IDW Interpolation (LiDAR)**
tool to interpolate each of the LAS tiles. This time specify ‘Intensity’ as the interpolation parameter, use ‘All Points’ as the point return, and use a maximum search distance of 3 m. When Whitebox has completed the interpolation, mosaic the tiles into a single intensity image, display the image, and clip the display maximum value to improve the palette scaling. Include this hillshade/OTO image with your final hand-in (2 marks).

8. What sort of features appear to be dark and what features are light-coloured in the intensity image? (2 marks)

9. How noisy do you find the image to be? Would you be able to use the intensity image as a replacement for an air photo or fine-resolution satellite image of the area in mapping applications? (3 marks)

10. Why do you think that there are no shadows in the image, e.g. near taller buildings? (Hint: because this is collected with an active remote sensing system, the time of day that the data were collected would not have affected the image.) (2 marks)

**Point Density**

When a LiDAR survey company is contracted to acquire a new data set, they are given mission parameters including, among other things, the required average point density. This value is important because it determines the possible resolution of the interpolated DEM product derived from the LiDAR points. That is, it wouldn’t make much sense to have interpolated a 1 m DEM from our LAS files if the average point density was much less than 1 point m⁻². Use the **Point Density (LiDAR)** tool from the **LiDAR Tools** tool folder to create point density grids for each of the nine LAS tiles. You can specify a grid resolution of 1 m and be sure to use the ‘All Points’ option. When the analysis is complete, mosaic each of the point density tiles and display them. Clip the display maximum to 0.1%.

Clearly point density is not uniform throughout the study area. For example, you have probably noticed the distinct diagonal bands of high and low point density values that crisscross the study area.

11. What do you think caused the bands within the point density image? (1 mark)

12. In addition to the banding described above, there is also a spatial variation within the point density image that is associated with land cover of specific types. What type of land cover is associated with high point densities (Hint: overlay your OTOs layer and look for a relation between the layers.) (1 mark)
13. Use the **Image Average** tool in the **Statistical Analysis** tool folder to calculate the average point density. What is the average point density, in point m⁻² for the study area? Based on this finding, do you think that we were justified in interpolating our DEMs to a 1 m grid resolution and why? (3 marks)