

# Digital Elevation Model & Surface Analysis

## Topics:

1. Introduction
2. Create raster DEM
3. Examine Lidar DEM
4. Deriving secondary surface products
5. Mapping contours
6. Viewshed Analysis
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## 1. Introduction

A digital elevation model (DEM) is a digital representation of ground surface topography or terrain. It is also known as a digital terrain model (DTM). A DEM can be represented as a raster (a grid of squares) or as a triangular irregular network.

### Raster surfaces / Raster DEM (Digital Elevation Model)

Raster DEM represent a surface as a regular grid of locations with sampled or interpolated values. A grid consists of a rectangular array of uniformly spaced cells with z-values. The smaller the cells are, the greater the locational precision of the grid. The example below compares a higher precision grid (left) to a lower precision grid (right).



**DEMs** (Digital Elevation Model) provide one of the most visual and dynamic portions of GIS, since topography is both continuously varying and multi-faceted. Hence you can produce themes for GIS analysis that have multiple attributes and can be used to produce highly visual images.

## 2. Creating a Raster DEM

Two major types of vector data are used for building surface data. Mass points with an elevation value attached to each point or contour line in which each line represents an elevation isoline. All vertices along the line have the same elevation value.

In a raster DEM, each pixel value represents the elevation of the location. A Raster DEM can be generated from ASCII text file containing xyz values or vector data with elevation information in the attribute table (dem points, contours etc).

- Create a new folder **surface** under your **geog300** folder
- Start ArcMap with a new ArcMap file. Enable 3D and Spatial Analyst extensions by clicking Customize > Extensions and place a check mark beside 3D Analyst and Spatial Analyst. Close the window.

### Create a raster DEM from contour lines / DEM points

First we will set up working environment for running ArcTools

- Click Geoprocessing->Environments from top menu. Expand Workspace and set the Current Workspace to K:\geog300\surface.
- Disable background processing by clicking Geoprocessing->Geoprocessing Options, remove the check mark beside Enable under Background Processing.
- Add **dempoint\_trim**, **unbc\_cont5** from L:\labs\geog300\unbc\_dem to ArcMap
- Open the attribute table of **unbc\_cont5** and examine the field ELEVATION. The values in this field are the elevation of each contour line, which will be used in creating the raster surface.
- In ArcToolbox, click **3D Analyst Tools->Raster Interpolation->Topo to Raster**

|                        |   |
|------------------------|---|
| Input Feature:         | <b>unbc_cont5</b>                           |
| Field:                 | ELEVATION                                   |
| Type:                  | Contour                                     |
| Output surface raster: | <b>cont5_dem</b> (in your local DEM folder) |
| Output cell size:      | 25  |
- Click OK

The output raster **cont5\_dem** will be generated in your local folder and added to ArcMap.

Point elevation data can be also used for DEM creation

- Right-click **dempoint\_trim** and open the Properties window.
- Click on Fields tab. There are many data fields we do not need. We can hide these fields and just show the information we need. Uncheck all check-box except FID, Shape, and ELEVATION fields to show the three fields. Close the properties window.
- Now in the same way create a raster DEM using **dempoint\_trim** with Type set to PointElevation and Size to 25. Save the output as **point\_dem** in your local folder.

You can use both contour lines and elevation points to create a better and more accurate surface. In general, more information (elevation) are added, the better surface would be.

- Run **Topo to Raster** tool from ArcToolbox
- Add **dempoint\_trim** and **unbc\_cont5** form the dropdown list for Input Feature
- Set Elevation to Field for both datasets, set PointElevation Type for **dempoint\_trim** and Contour for **unbc\_cont5**
- Give the output raster to **cp\_dem** in your local folder.
- Set cell size to 25 and click OK.

## Create a raster DEM from ASCII file

Raster DEM can be created from an ASCII file

- In ArcToolbox, click **Conversions->To Raster->ASCII to Raster**

|                          |                                       |
|--------------------------|---------------------------------------|
| Input ASCII raster file: | L:\labs\geog300\unbc_dem\unbc_dem.asc |
| Output raster:           | K:\geog300\surface\asc_dem            |
| Output data type:        | INTEGER                               |

The output data type is set to INTEGER. That means the output cell values are integer type (whole number). A VAT table (Value Attribute Table) will be created for integer type of raster. You can also choose FLOAT to give the decimal value for each cell. The FLOAT type of raster (continuous data) does not have VAT table and take more disk space.

- Click OK. The new raster DEM **asc\_dem** will be created and added to ArcMap.
- Examine the cell values of **asc\_dem**. As the cell values are integer type, an attribute table VAT was automatically generated. Open the attribute table and you can find elevation values in VALUE field and the number of cell with the value in COUNT field

So far four surface datasets have been created: **cont5\_dem**, **point\_dem**, **cp\_dem**, **asc\_dem**. Examine the range values for each DEM dataset, you might find that the values are slightly different. Why?

- For comparison, change the symbology and choose the colour ramp to match the other three DEMs.

### 3. Examine Lidar DEM

In this section, we will examine a DEM created from Lidar data.

**LIDAR (Light Detection And Ranging)** is an optical remote sensing technology that uses laser pulses to find range and/or other information of a distant target. Like radar technology, which uses radio waves, the range to an object is determined by measuring the time delay between transmission of a pulse and detection of the reflected signal. LIDAR DEMs typically have very high resolution and are used for example in archaeology, geomorphology, hydrology and forestry etc.

- Turn off all layers except **cp\_dem** and add **lidar\_dem** and **lidar\_hsd** from L:\labs\geog300\unbc\lidar. The **lidar\_dem** is the DEM created from lidar data with one meter resolution. The **lidar\_hsd** is the hillshade created from the **lidar\_dem**
- Zoom in on the UNBC area, display the hillshade on top. With Identify tool, query the elevation layer to view values down the agora steps – you might be able to see individual steps. Compare these elevation values with those in the same location from the **cp\_dem** created in the last section.

Examine the LiDAR values also around the two detention ponds, and compare the extra details with the other (coarser) DEM.

In the east portion of the LiDAR DEM, you can see the parallel ridges that are beach lines from Glacial Lake Prince George created 10,000 years ago by a proglacial lake ponded up by retreating ice. The ridges run mostly N-S and are visible to the north of campus and southeast across the road from the Sports Centre.

Due the high density of LiDAR points, the DSM (Digital Surface Model) can be built from LiDAR points and then the canopy height can be calculated by subtracting the base earth DEM from DSM. Let's take a look how the canopy looks like.

- Add **lidar\_dsm** from L:\labs\geog300\unbc\lidar folder
- In ArcToolbox, Spatial Analyst Tool->Map Algebra->Raster Calculator
- Build the following express

**"lidar\_dsm" – "lidar\_dem"**

- Save the output raster as **lidar\_canopy** in your local folder.

You may notice that there are some negative values in **lidar\_canopy** due to data error. These area should be 0 (like lake area). To eliminate the negative value, use Raster Calculator to remove the negative value with the following expression

Con("lidar\_canopy" >= 0, "lidar\_canopy", 0)

- Save the result as **final\_canopy**. Examine **final\_canopy**

### 4. Deriving secondary surface products

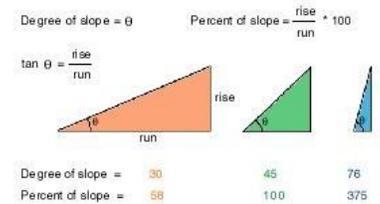
Just looking at 3D data is not enough. We often need to query data or derive secondary spatial information from the surface. For example slope, aspect etc.

3D Analyst provides you with tools that allow quantitative analysis of the shape of a surface such as creating contour lines, slopes which is often used in analysis to find the areas with low slopes for construction or areas

with high slopes, which may be prone to erosion or landslide and aspect information which used to determine how much sun a slope will receive - for instance, to model how vegetation will grow or snow will melt, or how much solar heating a building will receive.

In this part of lab, you will be exploring tools and functions to get secondary surface information.

**Slope** identifies the steepest downhill slope for a location on a surface. The Slope command takes an input surface data and calculates an output raster containing the slope of each cell. The lower the slope value is, the flatter the terrain is; the higher the slope value is, the steeper the terrain.



## Calculating average slope

Later in the lab, you will see how GIS can be used to create slope values across a surface, but here you will manually calculate slope using the difference in elevations between two points and the distance between them:

$$\text{Average Slope (percent)} = 100 * \text{vertical rise} / \text{horizontal run}$$

$$\text{Average Slope (degree)} = \text{Inv tan} (\text{vertical rise} / \text{horizontal run})$$

The measurement of vertical rise and horizontal run must be in the same units or you have to convert one. On a hardcopy map, we would calculate vertical rise from the difference in contour heights, and the horizontal run, given by measuring the distance with a ruler (and converting to actual ground distances).

- Open a new empty map file and add **creeks** and **lakes** from L:\labs\geog300\unbc and **unbc\_cont5** from L:\labs\geog300\unbc\_dem
- Examine **creeks, lakes, unbc\_cont5**. There is only small stream running into Shane Lake (south-west area of the lake near 510674, 5971143), query the highest and lowest contour lines it crosses, this should be = 825m / 815m - and assume the lake surface is 1 meter lower at 814m. The distance using the measuring tool  comes to about: 125m. The heights and the distance are both in meters.

$$\text{Vertical Rise} = 825 - 814 = 11\text{m}, \quad \text{Horizontal Run} = 125\text{m}$$

$$\text{Slope (percent\%)} = 11 / 125 * 100 = \sim 8.8\%$$

To convert slope to degrees: Calculate using the inverse tangent of height change / distance. Use the computer calculator: Start->All Programs -> Accessories -> calculator, Click View -> Scientific.

In this example:  $\text{slope (degree)} = \text{Inv Tan} (10 / 125) = \sim 5^\circ$

## Deriving slope raster from surface

Sometimes the elevation of a point on a surface is less interesting than the slope of the surface at that point. To get this information, you can derive a new raster that shows the slope of the surface. Slope is rapidly calculated for each triangle face in a TIN or a raster DEM pixel.

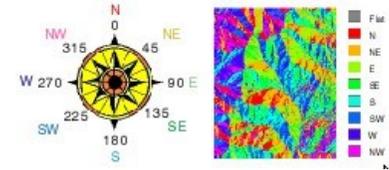
The raster **dem** will be used as the surface data.

- Add **dem** from L:\labs\geog300\unbc
- In ArcToolbox, click **3D Analyst Tools->Raster Surface->Slope**
  - Input Raster: **dem**
  - Output Raster: K:\geog300\surface\slope
  - Output Measurement: Degree
- Leave the z-factor as it is
- Click OK. The output **slope** raster will have the same resolution as **dem** (5 meters). Query cell value with **Identify** button to find the slope value.

## Deriving Aspect from surface

Aspect is the direction that a slope faces. It identifies the steepest down slope direction at a location on a surface. It can be thought of as slope direction or the compass direction a hill faces. Aspect is calculated for each triangle in TINs and for each cell in raster.

Aspect is measured clockwise in degrees from 0 (due north) to 360 (again due north, coming full circle). The value of each cell in an aspect grid indicates the direction in which the cell's slope faces. Flat slopes have no direction and are given a value of -1.



- Turn off the *slope*
- In ArcToolbox, click **3D Analyst Tools->Raster Surface->Aspect**  
 Input Raster: *dem*  
 Output Raster: K:\geog300\surface\aspect
- Click OK. The output *aspect* raster will have the same resolution as *dem* (5 meters).



Add **lookouts** from unbc folder if necessary. What is the slope and aspect respectively at the western lookout?

## Deriving a hillshade of a surface

Hillshade shows the hypothetical illumination of a surface, given a specified light source. Hillshade can be used to analyze the intensity and duration of sunlight received at a location on a surface. They are also used in conjunction with elevation layers to give depth to terrain maps.

The hillshade function obtains the hypothetical illumination of a surface by determining illumination values for each cell in an elevation grid. It does this by evaluating the relationship between the position of the light source and the direction and steepness of the terrain. By default, shadow and light are shades of gray associated with integers from 0 to 255 (increasing from black to white).

### Creating a hillshade raster

- Turn on *slope* and *aspect*
- In ArcToolbox, click **3D Analyst Tools->Raster Surface->Hillshade**  
 Input Raster: *dem*  
 Output Raster: K:\geog300\surface\hillshade, Take the default for Azimuth and altitude
- Click OK

## 5. Mapping contours

Contour lines are a familiar way of representing surfaces on maps. A contour is a line through all contiguous points with equal height (or other) values. The distribution of the lines shows how the values change across a surface. Where there is little change in a value, the lines are spaced far apart. Where the values rise or fall rapidly, the lines are close together. By following the line of a particular contour, you can identify which locations have the same value. By looking at the spacing of adjacent contours, you can have a general impression of the gradation of values.

### Deriving contours from a surface

You can create contour lines for a whole surface, or you can click a point and create a single contour that passes through it.

- In ArcToolbox, click **3D Analyst Tools->Raster Surface->Contour**  
     Input Raster: **dem**  
     Output Line Feature: K:\geog300\surface\cont5  
     Contour Interval: 5
- Click OK

The output contour line feature **cont5** will have elevation value stored in CONTOUR field. Examine the contours lines and the interval with Identify tool or in the attribute table.

## 6. Viewshed

**Viewshed** identifies the cells in an input raster that can be seen from one or more observation points or lines. Each cell in the output raster receives a value that indicates how many observer points can be seen from each location. If you have only one observer point, each cell that can see that observer point is given a value of one. All cells that cannot see the observer point are given a value of zero. The observer points feature class can contain points or lines. The nodes and vertices of lines will be used as observation points.

**Viewshed** is useful when you want to know how visible objects might be—for example, from which locations on the landscape will the water towers be visible if they are placed in this location? Or what will the view be from this road?

Assume these sample locations are treated as lookout locations; we want to know which area can be seen from these lookout locations

- Add **samples** from L:\labs\geog300\unbc
- First we will set raster working environment for this operation
- Go to Geoprocessing->Environments and set the environments as the following:
 

|                              |                    |
|------------------------------|--------------------|
| Current Workspace:           | your local folder  |
| Scratch Workspace:           | your local folder  |
| Processing extent:           | same as <b>dem</b> |
| Raster Analysis – Cell size: | same as <b>dem</b> |
- First we will change the Primary Display field and the Label field for **samples**. Double click **samples** to open the properties window.
- Click Field tab and choose ID from the dropdown list for the Primary Display Field. Click Label tab and choose ID for the Label field. Click OK.
- In ArcToolbox, click the Spatial Analyst->Surface ->**Viewshed**
- Set the parameter as the following:
 

|                |  |
|----------------|--|
| Input Raster:  | <b>dem</b>                             |
| Input point:   | <b>samples</b>                         |
| Output Raster: | K:\geog300\surface\ <b>samples_vsd</b> |
- Leave everything else as they are and click OK to generate the new raster.
- Open the attribute table of **samples\_vsd**. The VALUE field indicates the number times a cell can be seen and the COUNT field tells you that the total number of cells that can be seen
- Examine the last record; the total number of cells that can be seen 3 times is 1719.

Examine the first record; the value in VALUE field is 0. That means 1023968 (COUNT)cells can't be seen by any of these point locations.

## 7. Extracting elevation values for points location

Sometime you may want to know the elevation at certain location(point features). This can be easily done by running a tool Extract Values to Points. We will do an elevation extraction to *samples*

- In ArcToolbox, click **Spatial Analyst Tool->Extraction->Extract Values to Points**
- Set the parameter as the followings:
 

|                              |                                |
|------------------------------|--------------------------------|
| Input point features:        | <b><i>samples</i></b>          |
| Input raster (surface data): | <b><i>dem</i></b>              |
| Output point features:       | <b><i>samples_elev.shp</i></b> |
- Open the attribute table of ***smamples\_elev.shp*** and examine the field RASTERVALU. This is the field added by running the tool and the field values are the elevation from the Input raster(***dem***)

## 8. 3D visualization

Viewing data in three dimensions gives you new perspectives. 3D viewing can provide insights that would not be readily apparent from a planimetric map of the same data. For example, instead of inferring the presence of a valley from the configuration of contour lines, you can actually see the valley and perceive the difference in height between the valley floor and a ridge. **ArcScene** application is the core of the 3D Analyst extension.

### Start ArcScene

- Start ArcScene by clicking Start->All Programs->ArcGIS->ArcScene
- If the table of contents does not show up, Click Window->Table of Contents
- Add the ***dem*** from L:\labs\geog300\unbc
- Right-click ***dem*** and open the properties window. Click the Base Height tab and click the radio button beside 'Floating custom surface' and choose ***dem*** from the dropdown list. This will use the elevation in ***dem*** as the ground height. Click OK
- Use the 3D navigation button and view buttons to see the surface from different points of view.



The area looks pretty flat. Let's do a bit of changes to make more contrast on elevation.

### Setting Scene Properties

- Right-click Scene Layers in the table of contents and choose Scene Properties
- Type in 3 or 5 for Vertical Exaggeration. This will result in more contrast on elevation.
- Using 3D navigation button and view buttons to see the surface from different view again. You can now clearly tell which location is lower or higher.

### Draping contours and 2D data on surface

Contours are a familiar surface representation for many people, and they have many uses in a scene. You can display contour features in a 3D scene by setting the base height of the contours from their value in the feature table. Contours in a scene can enhance terrain visualization. The example below shows contours superimposed on terrain surface model.

- Change the symbology of ***dem*** to a color schema (elevation color)
- Add ***unbc\_cont5*** from L:\labs\geog300\unbc\_dem
- Right-click ***unbc\_cont5*** and choose Properties. Click the Base Heights tab
- Click the Base Height tab. Click the radio button beside 'Floating custom surface' and choose ***dem*** from the dropdown list. This will use the ***dem*** as the ground height. Click OK

You can drape 2D data on the surface to make a 3D effect.

- Turn off **unbc\_cont5** layer. Add data **creeks** from L:\labs\geog300\unbc to ArcScene.
- In the same way drape **creeks** on the surface

### Draping an image on the top of surface

- Turn off all layers in the table of contents
- Add image **campus50cm\_2010** from L:\labs\geog300\unbc
- Add data **unbc\_campus\_features**, and **unbc\_campus\_roads** from L:\labs\geog300\unbc\campus\_digitizing
- Move the **unbc\_campus\_features**, and **unbc\_campus\_roads** above **campus50cm\_2010**

Rearrange these layers to make them all visible.

- Set based height to **dem** for image layer **campus50cm\_2010** and choose Properties.
- Set Base Height to **dem** for **unbc\_campus\_features**, and **unbc\_campus\_roads** respectively and change the layers to appropriate symbols.

### Extruding the features in a layer

A 2D feature can be extruded in 3D view, such as building height.

- Open the properties of **unbc\_campus\_features** and click the Extrusion tab. Place a check box to extrude the features
- Click the button right to 'Extrusion Values or Expression' and double click **Height\_ft** in the field list to set the Extrusion Values. This will result the building footprint to stand up to the height specified in the field Height\_ft.



- Click OK. The features are extruded and stand up from the ground.
- You can save the ArcScene file to your local folder.

## Assignment 6: Surface analysis (5%) due next week Oct.23, 24, 25

In this assignment, you will perform a surface analysis for Forest for the World area

Data: L:\labs\geog300\unbc: **dem, lookouts, lakes, trails, ffw\_bndy**

- Extract elevation, slope, and aspect value for each lookout location.
  - Calculate the average slope from east to west lookout
  - Generate a viewshed with lookout as the observer locations
1. Copy **lookouts** from L drive to your local folder. Use your local copy for this assignment.
  2. With **Extract Multi Values for Points** tool in ArcToolbox (Spatial Analyst->Extraction->Extract Multi Values to Points), extract **dem, slope, aspect** (generated in this lab) values for each lookout location. Add all three rasters for the Input Raster. You will have three raster values from inputs for each lookout location. Note: this tool does not generate a new point layer as you did in the lab with **Extract Values for Points tool** instead the raster values will be added into the input point features (**lookouts**, your local copy).

- Check the attribute table of lookouts. What elevation, slope and aspect are for each lookout respectively?
3. With elevation value extracted for each lookout location, calculate average slope in percent from west to east lookout (show your work)
  4. Set processing extent to **ffw\_bndy** and cell size same as **dem**. Generate a viewshed for the Forest For the world area with **lookouts** as the observer locations.
  5. Clip **lakes, trails** with **ffw\_bndy** and save them as **lakes\_ffw, trails\_ffw** respectively
  6. Make a simple map showing the viewshed symbolized based on the number of times visible from the lookouts together with **lookouts, lakes\_ffw, and trails\_ffw**. The map should be well layout and with proper title, legend, scale and your name. Export the map to a JPG or PNG image

**Deliverable:**

- Make a title page with the course name, assignment number, your lab session, your name and studentID.
- Answers for 2, 3, and a map from step 6. Insert the map from step 6
- Save the file as **lastname\_firstname\_geog3002018\_A6**. Email the file to your TA with subject Geog300 A5

**NOTE: Please name the file correctly (*lastname\_firstname\_geog3002018\_A6*)**

**Assignment is due next week (Oct.23, 24, 25). NO late assignment is accepted**

~~~~~ The End ~~~~~