GEOG 176A: Introduction to Geographic Information Systems

Lecture 14: Terrain Analysis II

(chapter 7)

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Representation of terrain

- **Vector**
  - Point samples (regular and irregular)
  - Contours
- **Raster**
  - DEM → DTM → DSM
- **TIN**
- **Others**
  - Voxel
  - 3D point cloud
Recall: Vector - Point samples

- Regular point samples
- Irregular point samples
Recall: IDW interpolation

- **Inverse Distance weighting**
- Closer points have more influences on the target value:

\[ Z = \frac{\sum w_i z_i}{\sum w_i} \text{ where } w_i = \frac{1}{(d_i)^p} \]

- P is the power parameter which determines the influence of the distance towards weights:
  - **p=0:** every point has the same weight regardless of their distance towards the target location
  - **p=large value:** points that are further away have less influence on the target location
Recall: IDW interpolation

- **Inverse Distance weighting**
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Practice: IDW interpolation

Practice question: you have three points whose elevation are 7, 9 and 11 meters, and their distances to the target locations are 1, 2 and 3 meters respectively. Using a power of 2, what would be your estimation for the elevation at the target locations?
Practice: IDW interpolation

Practice question: you have three points whose elevation are 7, 9 and 11 meters, and their distances to the target locations are 1, 2 and 3 meters respectively. Using a power of 2, what would be your estimation for the elevation at the target locations?

\[ Z = \frac{\sum w_i z_i}{\sum w_i} \text{ where } w_i = \frac{1}{(d_i)^2} \]

\[ Z = \frac{(1/1)^2 \times 7 + (1/2)^2 \times 9 + (1/3)^2 \times 11}{(1/1)^2 + (1/2)^2 + (1/3)^2} = 7.69 \]
IDW interpolation

How to determine which points goes into the estimation?

- **Fixed radius**: define a search distance (e.g., 100 meters) and all points that fall into this search distance will be used
- **Maximum points**: define a number (e.g., 5), and only use this number of points which are closest to the target location
Kriging

- A statistically robust approach

\[ z = \sum w_i z_i \]

- Weights \( w_i \) are determined in a statistical way with spatial redundancy considered
Kriging

- $w_i$ is calculated based on semivariogram
- **Semivariogram** is calculated based on the variance of attribute change with regard to distance

You will learn it in details in GEOG 176B!
Comparison between IDW and Kriging
Vector - Contours

- A line with **constant** elevation
- Contours **should not intersect** with each other
- The **interval** between contour lines should be set appropriately
Raster - DEM /DTM/ DSM

- Digital Elevation Model (DEM)
- Digital Terrain Model (DTM)
  - Height of the bare ground surface (e.g., ocean floor, lake depths)
- Digital Surface Model (DSM)
  - Highest thing on the earth surface (e.g., buildings, tree canopy)

All these models are represented as regular grid in GIS.
Digital Elevation Models

- Digital Surface Model (DSM)
- Digital Terrain Model (DTM)
DEM

- Two global scale DEM data sources:
  - SRTM
  - GDEM
DEM

- DEM is measured based on a datum (what if the datum changes?)
- Spatial resolutions
  - SRTM: inside the U.S. 30 meters; outside the U.S. 90 meters
  - GDEM: 30 meters for global coverage
- Vertical uncertainties
  - The elevation value within a cell may have a measurement uncertainty, e.g., 10 meters
A vector data structure that partitions geographic space into contiguous, nonoverlapping triangles. The vertices of each triangle are sample data points with x-, y-, and z-values. These sample points are connected by lines to form Delaunay triangles. TINs are used to store and display surface models.
Voxels

Do not contain geographic coordinate; often used in game engines for terrain visualization, such as caves.
3D point cloud

- **LiDAR**: Light Detection And Ranging
- Illuminate a target area with a laser and then analyze the reflected light
3D point cloud

- Can be either **airborne** or **terrestrial**
3D point cloud

- Elevation models constructed from LiDAR
Terrain analysis

- Slope and aspect
- Hillshade
- Elevation profile
- Intervisibility and viewshed
- Curvature
- Flow accumulation
Slopes and aspects

- Calculating slopes and aspects based on **8 neighbors** of DEM

→ **first derivatives** of DEM
Slopes and aspects

- **Slope**: maximum slope in the neighborhood
- **Aspect**: direction (in azimuth angle) of maximum slope

Slope as percent = \( \frac{\text{rise}}{\text{run}} \times 100 \)

\[ = \frac{A}{B} \times 100 \]

Slope as degrees = \( \phi \)

\[ = \tan^{-1}(A/B) \]

Aspect of elevation
- Flat (-1)
- North (0-22.5)
- Northeast (22.5-67.5)
- East (67.5-112.5)
- Southeast (112.5-157.5)
- South (157.5-202.5)
- Southwest (202.5-247.5)
- West (247.5-292.5)
- Northwest (292.5-337.5)
- North (337.5-360)
Slope and aspect

- Calculating slopes

\[
\begin{align*}
[dz/dx] &= (((c + 2f + i) - (a + 2d + g)) / (8 \times x_{\text{cellsize}}) \\
&= (((50 + 60 + 10) - (50 + 60 + 8)) / (8 \times 5) \\
&= (120 - 118) / 40 \\
&= 0.05 \\

[dz/dy] &= (((g + 2h + i) - (a + 2b + c)) / (8 \times y_{\text{cellsize}}) \\
&= (((8 + 20 + 10) - (50 + 90 + 50)) / (8 \times 5) \\
&= (38 - 190) / 40 \\
&= -3.8
\end{align*}
\]

\[
\begin{align*}
\text{rise run} &= \sqrt{([dz/dx]^2 + [dz/dy]^2)} \\
&= \sqrt{(0.05)^2 + (-3.8)^2} \\
&= \sqrt{0.0025 + 14.44} \\
&= 3.80032 \\

\text{slope degrees} &= \text{ATAN} (\text{rise run}) \times 57.29578 \\
&= \text{ATAN} (3.80032) \times 57.29578 \\
&= 1.31349 \times 57.29578 \\
&= 75.25762
\end{align*}
\]

The calculation details, but you don’t need to remember these.
Slope and aspect

- Slope example
Slope and aspect

- Calculating aspects

\[
\begin{align*}
[dz/dx] &= \frac{(c + 2f + i) - (a + 2d + g)}{8} \\
&= \frac{(85 + 170 + 84) - (101 + 202 + 101)}{8} \\
&= -8.125 \\

[dz/dy] &= \frac{(g + 2h + i) - (a + 2b + c)}{8} \\
&= \frac{(101 + 182 + 84) - (101 + 184 + 85)}{8} \\
&= -0.375 \\

aspect &= 57.29578 \times \arctan\left(\frac{dz/dy}{-dz/dx}\right) \\
&= 57.29578 \times \arctan(0.375, 8.125) \\
&= -2.64 \\

cell &= 90.0 - aspect \\
&= 90 - (-2.64) \\
&= 92.64
\end{align*}
\]

The calculation details, but you don’t need to remember these.
Slope and aspect

- Aspects example
Hillshade

- **Shaded relief maps** depict the brightness of terrain reflections
- **Hillshade tool** creates a shaded relief raster from a surface by considering the illumination source azimuth and altitude
- **Azimuth**: the angular direction of the sun, measured from north in clockwise degrees from 0 to 360
- **Altitude**: is the angle of the sun above the horizon

\[
(1) \quad \text{Hillshade} = 255.0 * \left( (\cos(\text{Zenith}_\text{rad}) \times \cos(\text{Slope}_\text{rad})) + (\sin(\text{Zenith}_\text{rad}) \times \sin(\text{Slope}_\text{rad}) \times \cos(\text{Azimuth}_\text{rad} - \text{Aspect}_\text{rad})) \right)
\]

Again, no need to remember!
Hillshade

- Hillshade example

Sun coming from 315 degree (azimuth) and at 45 degree in height (altitude)
Elevation profile

- Create an elevation profile along a line
Intervisibility and Viewshed

- **Intervisibility**: visibility between two points
- **Viewshed**: given one or several observing points, find out which areas can be seen and which areas cannot
Intervisibility and viewshed

- How to determine visibility?
Curvature

- The curvatures of terrain → **second derivatives** of DEM

Profile curvature affects the acceleration or deceleration of flow across the surface
Curvature

- Examples

Plan curvature:
The rate of change in terms of aspects

Profile curvature:
The rate of change in terms of downhill slope
Flow accumulation

- Sum of upstream elements draining into the target cell
Flow accumulation

- Extract **ridges** from terrain
  - Flow accumulation → find the raster cells where **flow accumulation = 0**
  - Result is generally good in mountain areas
Your tasks

● Finish Chapter 7
● Lab 4 due Sunday, September 2nd, 23:55 pm
● Start reading Chapter 8

Next lecture: Making Maps with GIS (Chapter 8)