SPATIAL INTERPOLATION AND SURFACE ANALYSIS
Points to Cover

- Modeling surfaces in GIS
- Surface Interpolation
  - Key concepts and principles
  - Methods
- Surface Analysis
  - Slope
  - Aspect
  - Visibility analysis
Modeling Surfaces in GIS

- Surfaces represent continuous features or phenomena
  - Theoretically have an infinite number of data points
- A model of a surface approximates continuous surface using a finite number of observations
  - The issue of selecting a sufficient number of observations
- Vector approach
  - Regular or irregular networks connecting observation points
- Raster approach
  - Raster, the cells of which contain values representing a characteristic of the surface at each cell location
Surface Interpolation

- **Surface (spatial) interpolation** is the procedure of estimating the values of characteristics at unsampled sites within an area covered by exiting observations (Waters 1989)
  - Based on the phenomenon of **spatial autocorrelation**
    - Degree of dependency that exists between observations in geographic space where proximate observations appear to be more similar to each other than to more distant observations
    - **The First Law of Geography**: everything is related to everything else, but near things are more related than distant things (Tobler 1970)
Surface Interpolation

- Importance of the sample size

- Results of surface interpolation procedures depend on the quality of the sample point set
- The quality increases as the point set becomes sufficiently dense to capture subtle and dramatic changes in the surface

Source: Learning ArcGIS Spatial Analyst
Copyright © 2004–2008 ESRI
Surface Interpolation Methods

- **Local**
  - Apply a single mathematical function repeatedly to small subsets of the total set of observed data points
  - Link the regional surfaces to create a composite surface

- **Global**
  - Apply a single mathematical function to all observed data points
    - Produce smoother surfaces compared to the local methods
Surface Interpolation Methods

- **Exact**
  - Interpolated surface passes through all observed data points
    - Most appropriate when working with high data quality datasets

- **Approximate**
  - Alter the observed data points to fit a general trend
    - Most appropriate when working with low data quality datasets
Surface Interpolation Methods

- **Deterministic**
  - Based on the assumptions that there is an underlying pattern of variation in data values and it is known
    - Use a specific mathematical function to extrapolate values

- **Stochastic**
  - Make no a priori assumptions about the underlying pattern of variation on the data values
    - Incorporate random variation in the surface’s data values
Surface Interpolation Methods

- TIN Method
  - Adjacent data points are connected by arcs to form a network of irregular triangles using a particular method
  - The values inside the triangles are interpolated using linear algebra and trigonometry
  - An exact local method of interpolation
  - Most often used to generate digital terrain models
    - For high-precision modeling of smaller areas
  - Advantage
    - High accuracy
  - Limitation
    - Does not extrapolate outside the area covered by the data points
Surface Interpolation Methods

- **TIN Method**

Figure 6.19
Source: Heywood et al., 2011

- **Legend**
  - Sample point
  - Altitude (feet)

- **(a)** Original terrain surface with sample points
- **(c)** Triangulated Irregular Network
Surface Interpolation Methods

- **Trend Surface Method**
  - Global polynomial interpolation that fits a smooth surface defined by a mathematical function (a polynomial) to the input sample points (Arc GIS 10 Help files)
  - Uses, but does not honour, all the data points in the calculation
  - The surface is fitted using the least sum of squares regression fit

Surface Interpolation Methods

- Trend Surface Method

(a) Original terrain surface with sample points
(d) Trend surface 1st order polynomial

Figure 6.19
Source: Heywood et al., 2011
Surface Interpolation Methods

- Trend Surface Method

Figure 6.19
Source: Heywood et al., 2011

(a) Original terrain surface with sample points

(g) Trend surface 4th order polynomial
Surface Interpolation Methods

- Trend Surface Method
  - Trend interpolation results in a smooth surface that represents gradual change in the characteristic of an area of interest
  - This type of interpolation can be used for
    - Modeling gradually changing phenomena
      - Pollution over an industrial area
    - Examining or removing the effects of long-range or global trends
      - Trend surface analysis
Surface Analysis

- Analytical methods used in terrain analysis
  - Slope
  - Aspect
  - Visibility analysis
Surface Analysis

- **Slope Analysis**
  - Slope is the gradient (steepness) of a unit of terrain
    - Represented as an angle (degrees) or percentage
    - The concept is usually applied to topographic surfaces, but can be used for analysis of other surfaces as well
  - Calculation involves the rate of change between the $z$ values at two points (rise) and the distance ($x$, $y$ values) between the two points (run)

Source: ArcGIS 10 Help files
Surface Analysis

Slope Analysis

- In raster GIS, the slope is calculated as the maximum rate of change in value from that cell to its neighbors.
  - A plane is fitted to the z-values of a 3 x 3 cell neighborhood around the center cell.
  - Using the average maximum technique.

Source: ArcGIS 10 Help files
Surface Analysis

- The Slope Algorithm

  For each cell in the center of the 3x3 window, a slope value is calculated based on the rates of change of the surface in the horizontal and vertical directions around the center cell.

  \[
  \text{slope}_{\text{degrees}} = \frac{\sqrt{[\text{dz/dx}]^2 + [\text{dz/dy}]^2}}{57.29578}
  \]

  \[
  \frac{\text{dz/dx}}{\text{cell size}} = \frac{(c + 2f + i) - (a + 2d + g)}{8* \text{cell size}}
  \]

  \[
  \frac{\text{dz/dy}}{\text{cell size}} = \frac{(g + 2h + i) - (a + 2b + c)}{8* \text{cell size}}
  \]

Source: ArcGIS 10 Help files
Surface Analysis

- **Slope Analysis**
  - The procedure is mostly used to analyze elevation datasets
  - Can also be used with other types of continuous data, such as population, to identify sharp changes in value

Source: ArcGIS 10 Help files
Surface Analysis

- Aspect Analysis
  - Aspect is the orientation or compass direction of slope
  - Aspect values are measured clockwise in degrees from 0 to 360

Source: ArcGIS 10 Help files
Surface Analysis

 Aspect Analysis

- In raster GIS, aspect is conceptualized as the downslope direction of the maximum rate of change in value from each cell to its neighbors
  - A plane is fitted to the z-values of a 3 x 3 cell neighborhood around the center cell
  - The direction the plane faces is the aspect for the processing cell
  - Flat areas are given a value of -1

Source: ArcGIS 10 Help files
Surface Analysis

- Aspect Analysis
  - The Aspect Algorithm
    - For each cell in the center of the 3x3 window, an aspect value is calculated using an algorithm that incorporates the values of the cell's 8 neighbors.

The rate of change in the x direction
\[
\frac{dz}{dx} = \frac{(c + 2f + i) - (a + 2d + g)}{8}
\]

The rate of change in the y direction
\[
\frac{dz}{dy} = \frac{(g + 2h + i) - (a + 2b + c)}{8}
\]

\[
\text{aspect} = 57.29578 \times \text{atan2} \left( \frac{dz}{dy}, -\frac{dz}{dx} \right)
\]

Source: ArcGIS 10 Help files
Surface Analysis

Aspect Analysis

- The Aspect Algorithm

The aspect value is then converted to compass direction values (0-360 degrees), according to the following rule:

\[
\text{if } aspect < 0 \\
\quad \text{cell } = 90.0 - aspect
\]

\[
\text{else if } aspect > 90.0 \\
\quad \text{cell } = 360.0 - aspect + 90.0
\]

\[
\text{else} \\
\quad \text{cell } = 90.0 - aspect
\]

Source: ArcGIS 10 Help files
Surface Analysis

- Aspect Analysis
  - The procedure is used to analyze elevation datasets
    - Identifying north and south facing slopes, flat areas

Source: ArcGIS 10 Help files
Surface Analysis

Visibility Analysis

- Identification of areas of terrain that will be visible from particular points
  - Based on the ‘ray tracing’ method

Figure 6.32
Source: Heywood et al., 2011
Surface Analysis

Visibility Analysis

- In raster GIS, the cells in an input raster are classified based on whether they can be seen from one or more observation locations.
  - Requires an ‘observer’ point input data
  - Each cell in the output raster receives a value that indicates how many observer points can be seen from each location
  - The visibility of each cell is determined by comparing the altitude angle to the cell center with the altitude angle to the local horizon
Surface Analysis

Visibility Analysis

- The output is a viewshed raster
- Used in a variety of applications
  - Ensuring that radio transmitters and cellular towers cover the maximum area
  - Ensuring that visual impact of ‘visually noxious’ uses is minimized

Source: ArcGIS 10 Help files