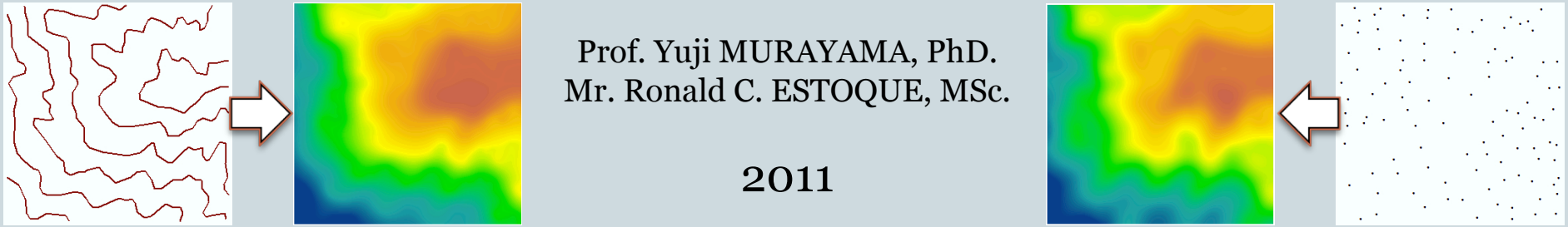
Creating a Digital Elevation Model (DEM):

A GIS lecture tutorial



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Contents, Data & Software Used

Contents

Data & Software

1. Paper-based topographic map
2. ArcGIS software

1. Introduction

Background

- A digital elevation model (DEM) is a digital file consisting of terrain elevations for ground positions at regularly spaced horizontal intervals (USGS, 2001).
- Its uses range from scientific, commercial, industrial, operational to military applications.
  - In the academe or a research institution, DEM is used primarily as an input or as a data source itself in studies along the fields of climate impact studies, water & wildlife management, geological & hydrological modeling, geographic information technology, geomorphology & landscape analysis, mapping purposes, & educational programs.

Source: Sulebak (2000)

- *However, sometimes DEM is not available.*

Objective

- Thus, the aim of this lecture tutorial is to outline & explain the method in creating a DEM from a paper-based topographic map in a GIS platform.

2. Basic concepts & definitions

Topographic map

- is a type of map characterized by large-scale detail and quantitative representation of relief, usually using contour lines in modern mapping.
- is a detailed & accurate graphic representation of cultural & natural features on the ground (Center for Topographic Information, 2007).

Contour line

- A contour line connects a series of points of equal elevation & is used to illustrate relief on a map. For example, numerous contour lines that are close to one another show hilly or mountainous terrain; when far apart, they indicate a gentler slope. *Source:* Center for Topographic Information (2007).

Scanning

- is a process of converting any paper-based material (in this case, paper-based topographic map) into a digital format, which is usually integrated into the GIS database (Lwin & Estoque, In press).

2. Basic concepts & definitions

Georeferencing

- refers to the process of assigning map coordinates to an image data (Leica Geosystems, 2005).
- Data that are already georeferenced can be used as reference in georeferencing.

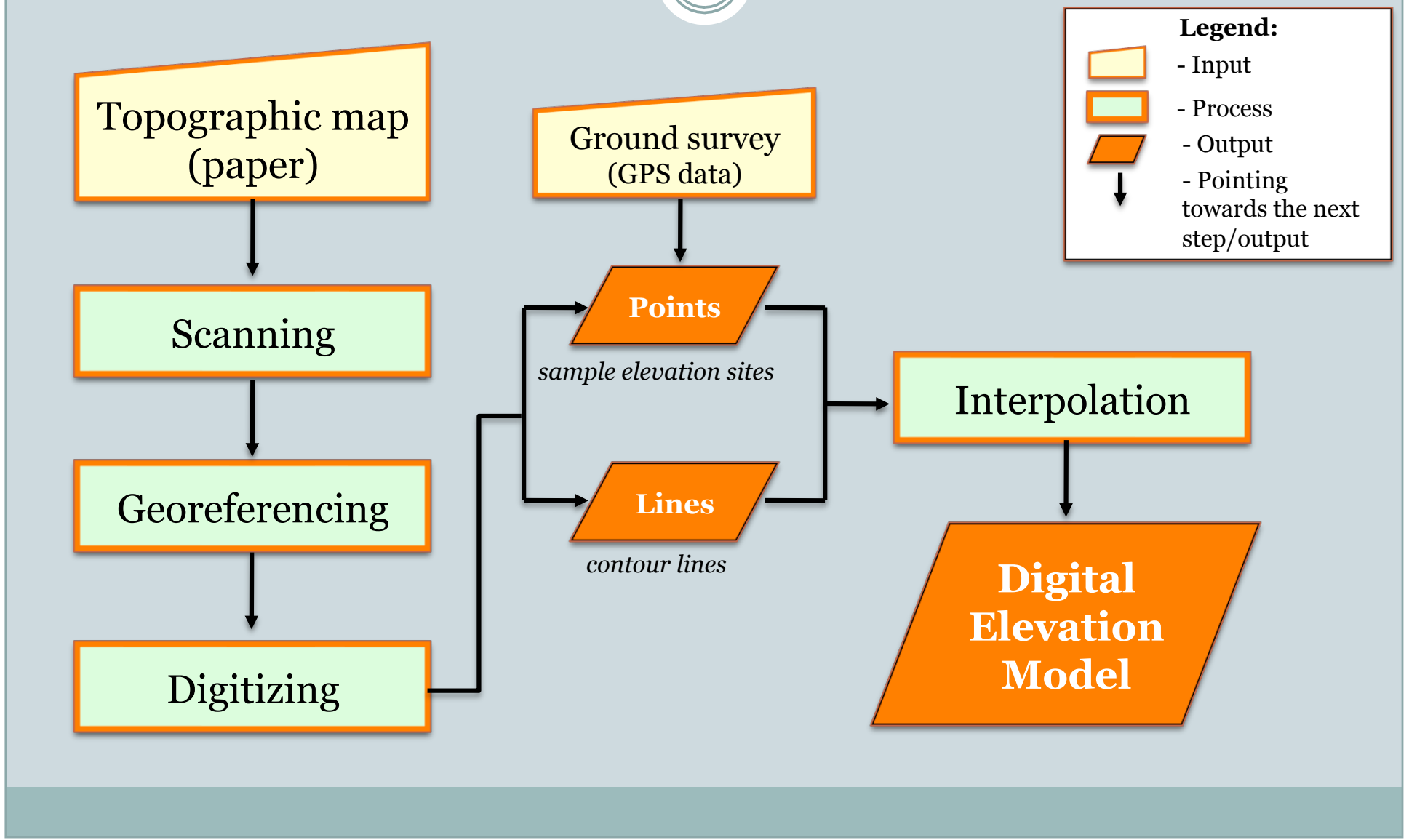
Digitizing

- is a process of converting spatial features (point, line & polygon) from a paper-based source into a digital form by tracing. This can be done using a digitizing tablet or by on-screen digitizing.

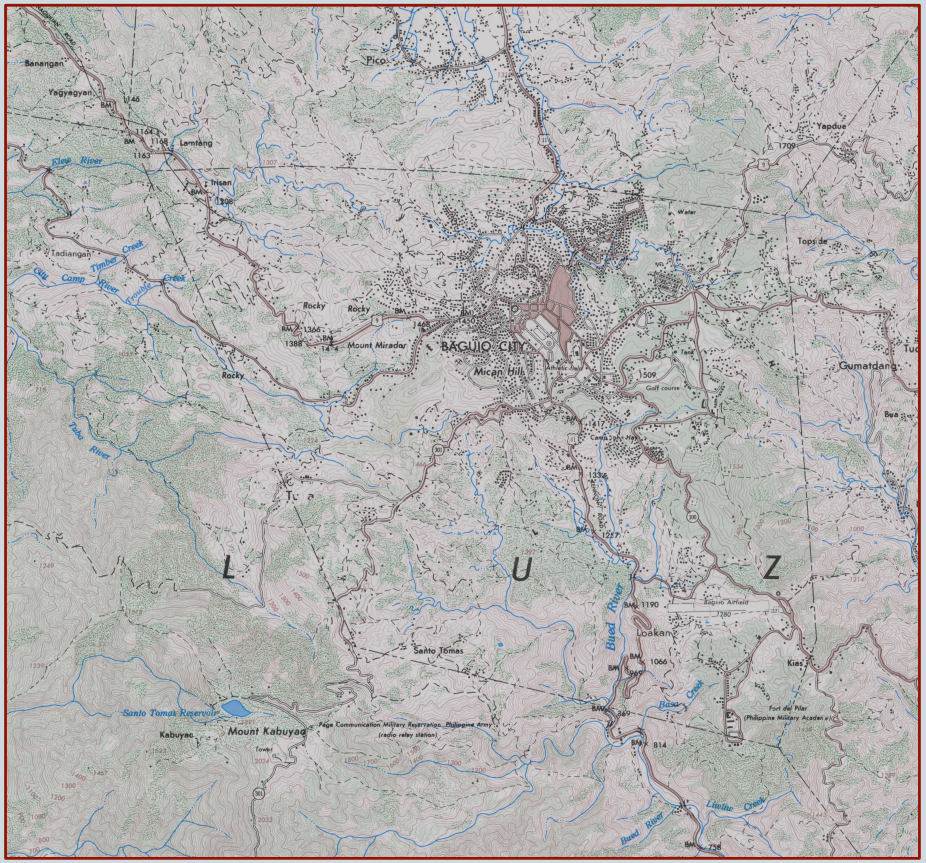
Interpolation

- is a process of assigning values to unknown points by using values from usually scattered set of known points.
- is a procedure used to predict cell values for locations that lack sampled points (Childs, 2004).

3. A flow diagram in creating a DEM



3.1. Scanning

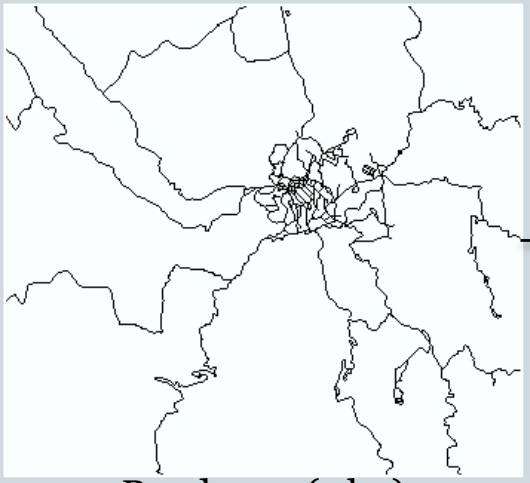


Scanned topographic map (.jpg)

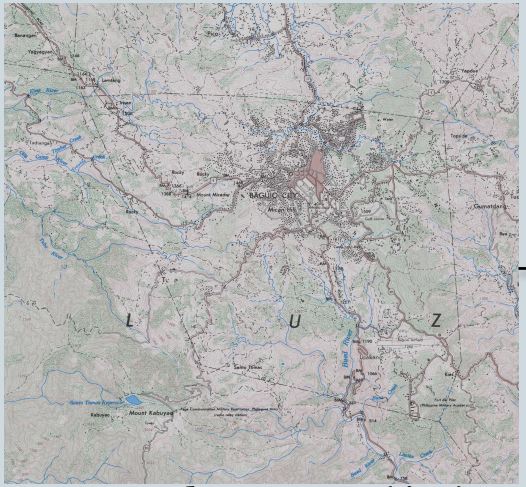
- Prior to on-screen digitizing, paper maps have to be integrated into the GIS database by converting them into digital format. The process of such conversion is known as scanning.
- Through scanning, map features including texts and symbols are automatically captured as individual cells or pixels and an automated image is produced.
- These features in raster format are then "vectorized" through tracing or on-screen digitizing.
- Generally, in order to have a good source image in the digitizing process, a scanner needs to have a good resolution and, depending on the underlying purpose, large enough to accommodate the whole map sheet being scanned.

Source: Lwin & Estoque (In press)

3.2. Georeferencing



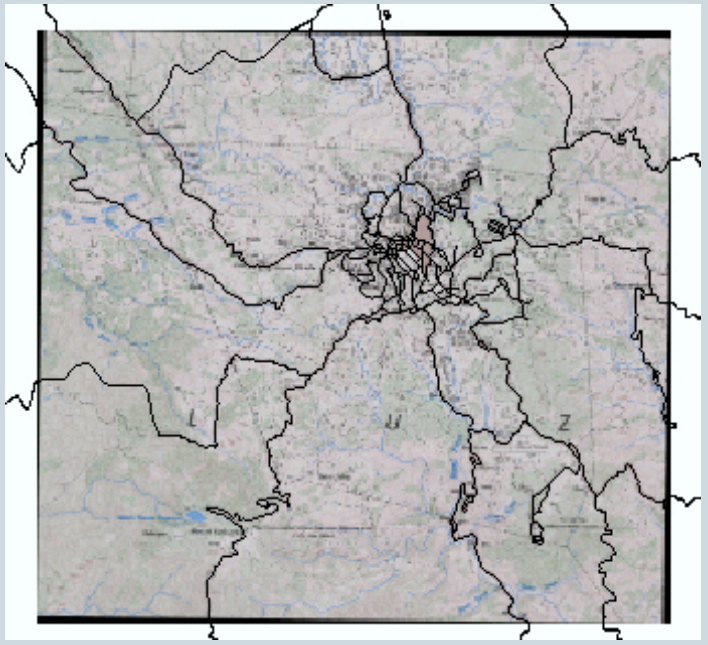
Road map (.shp)



Scanned topo map (.jpg)

GEOREFERENCING

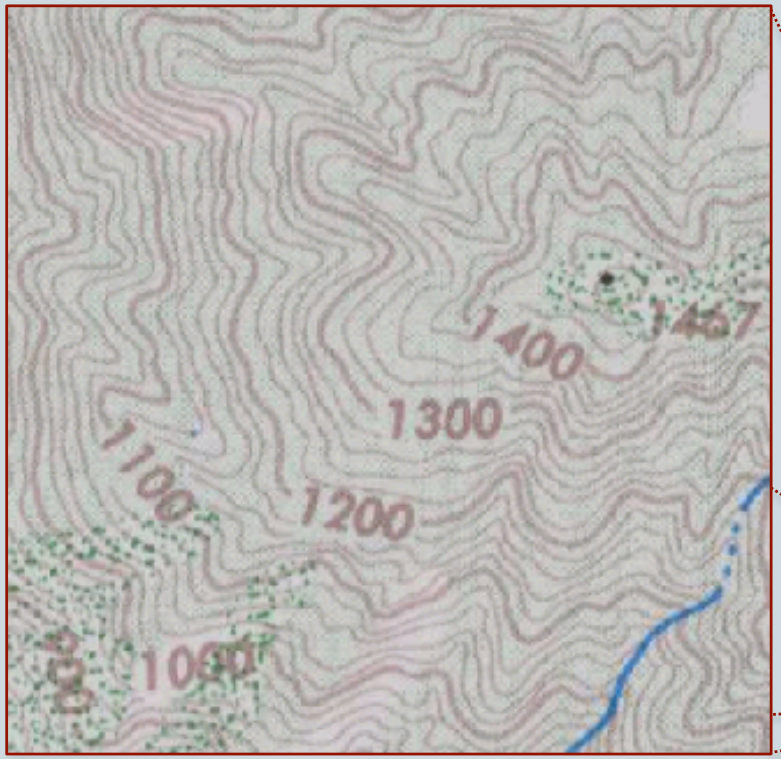
- In this presentation, georeferencing was done in ArcGIS software. (See Cassity, 2006; ESRI, 2008a)
- The road map, which is in shape file format & already georefenced was used as a reference feature. (*Other features can also be used).*
- Forty five (45) ground control points were collected. *(Collect as much points as possible to have a better accuracy).*



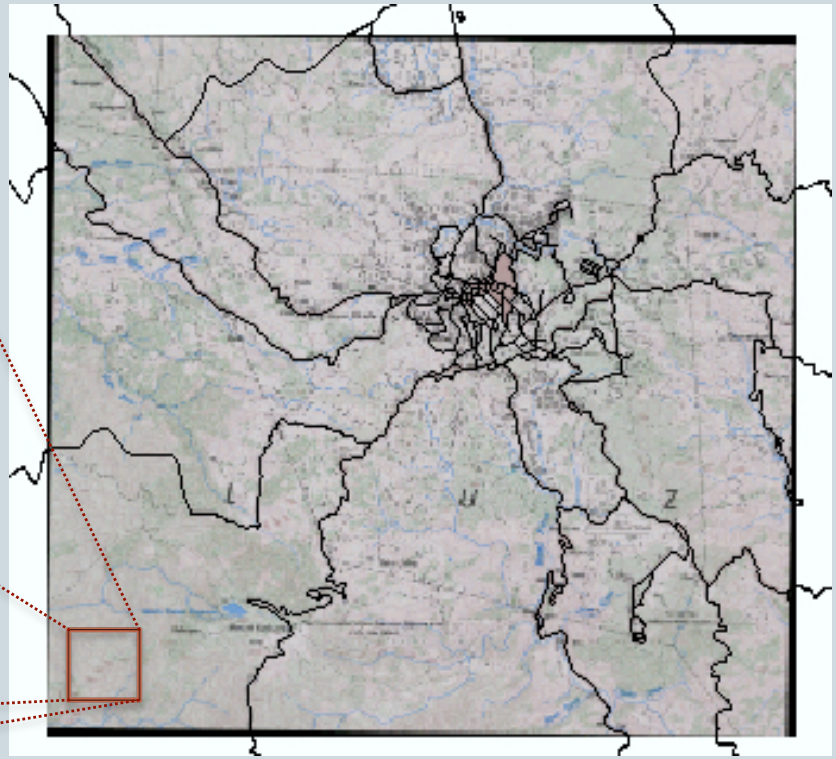
Road map overlaid on the georeferenced topo map

3.3. Digitizing

- In this presentation, only a portion of the georeferenced topographic map was selected & digitized.
- The selected area is called "area of interest" or "aoi".

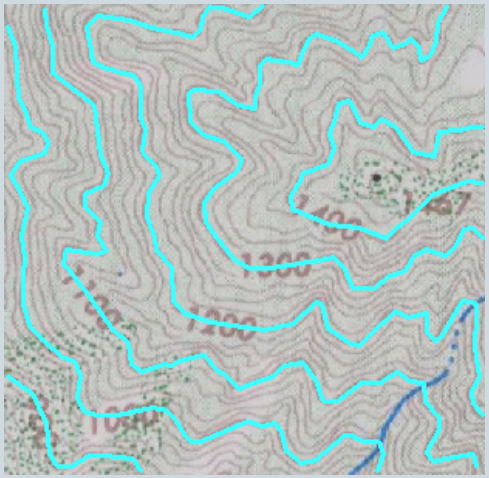


Area of interest

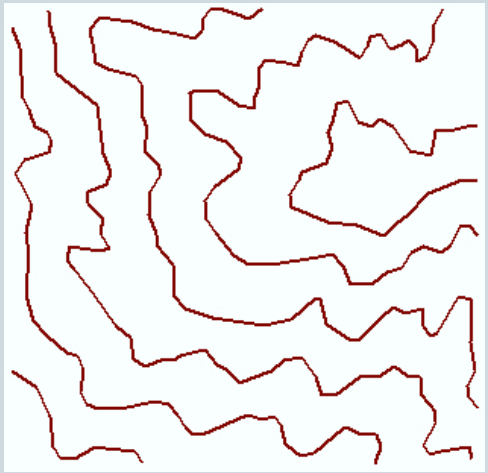


Road map overlaid on the georeferenced topo map

3.3.a. Digitizing (Lines)



On-screen digitizing



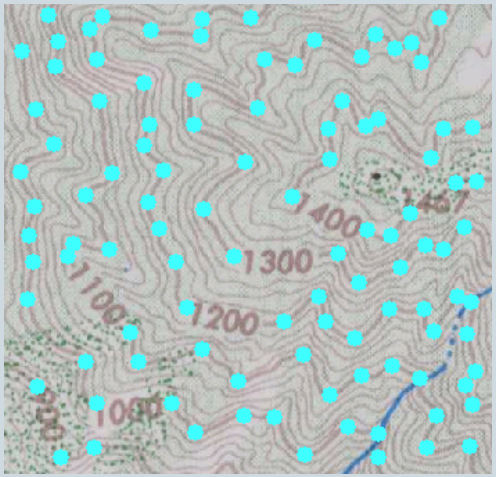
Digitized contour lines

- In order to have a more detailed DEM output, digitizing the contours at 20m interval is a good option. Lower contour interval denotes a more detailed topographic map or DEM.
- However, in this presentation, a contour interval of 100m was used. Thus, only the contour lines at 100m interval (i.e. 900, 1000, 1100, etc.) were digitized.
- Digitizing was done using ArcGIS software (on-screen digitizing).

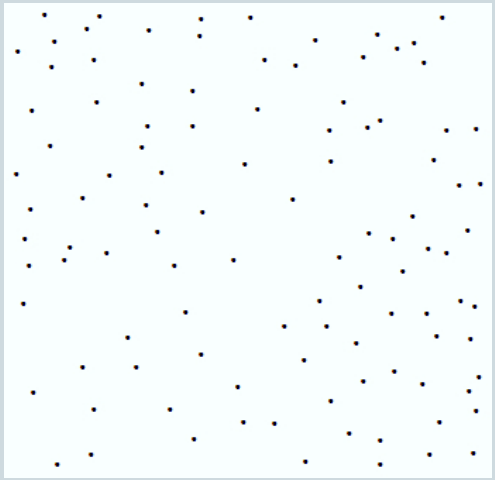
FID	Shape	ID	ELEVATION
0	Polyline ZM	1	900
1	Polyline ZM	2	1000
2	Polyline ZM	3	1100
3	Polyline ZM	4	1200
4	Polyline ZM	5	1300
5	Polyline ZM	6	1400

Attribute table (Elevation – m asl)

3.3.b. Digitizing (Points)



On-screen digitizing



Digitized sample points

- In this presentation, digitizing was done using ArcGIS software (on-screen digitizing).
- Alternatively, as shown in slide no.5, sample points can also be collected from ground survey using GPS.
- The more sample points collected & used, the more accurate the output will be in representing the earth's surface.

Attributes of sample_pts

FID	Shape *	Id	Elev_m_asl
0	Point	1	900
1	Point	2	900
2	Point	3	900
3	Point	4	1000
4	Point	5	1000
5	Point	6	1000

Attribute table (Elevation – m asl)

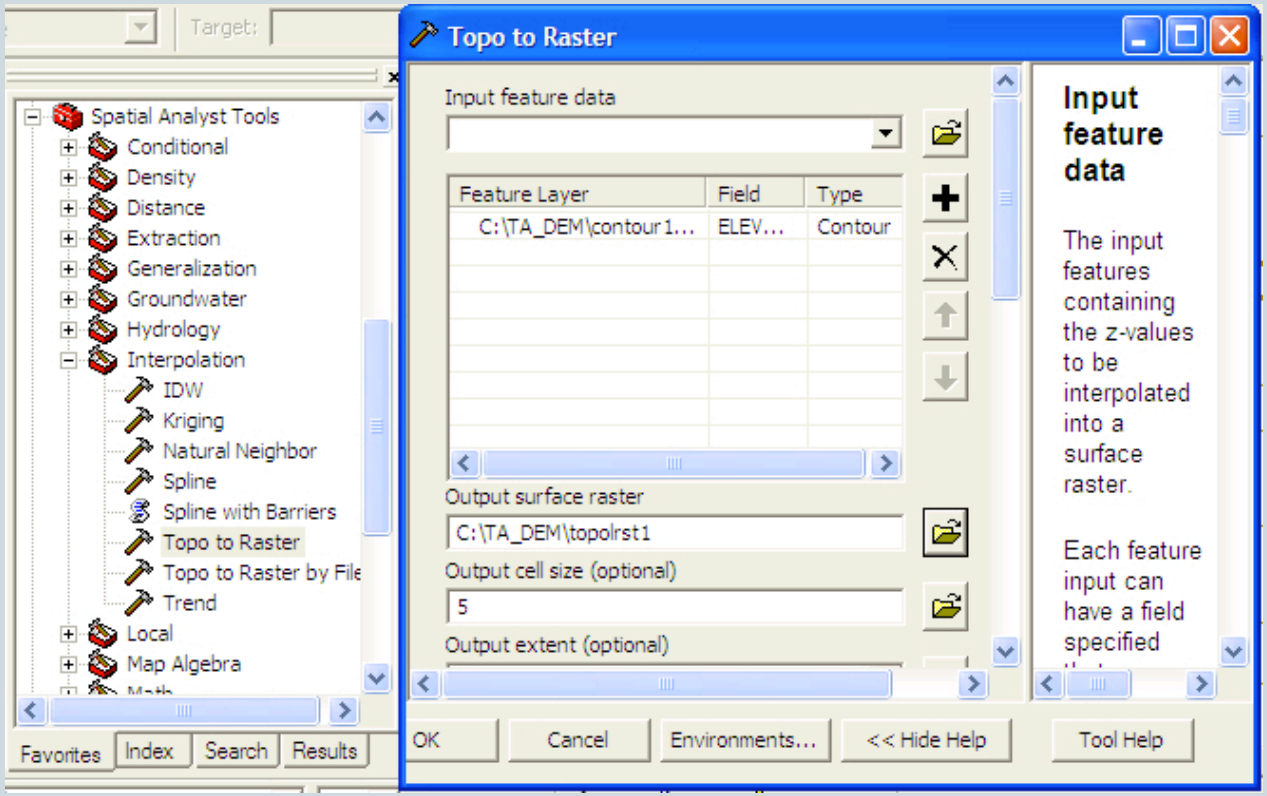
Note:

Sample points can also be extracted from contour lines (if digital contour map is already available).

3.4.a. Interpolation (using contour lines)

Method:

- The "Topo to Raster" interpolation method can be accessed from the "Spatial Analyst Tools" of ArcGIS under "Interpolation". *The digitized contour lines in section 3.3.a were used as input.*



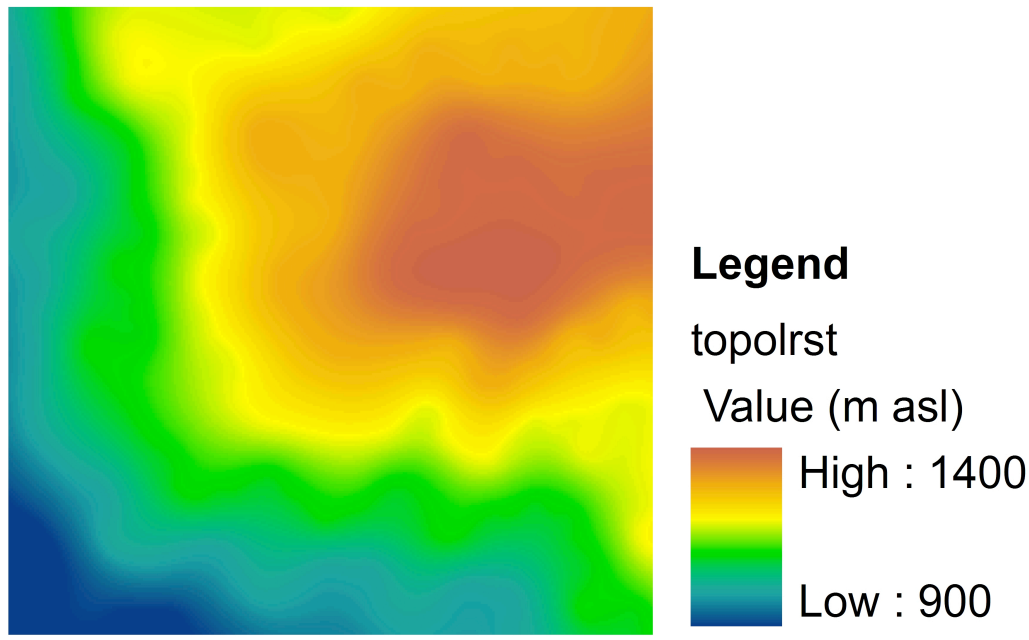
Screen shot of the "Topo to Raster" interpolation method

- This method allows the user or analyst to interpolate the digitized contour lines directly to generate a surface map or DEM.
- In the "Topo to Raster" window, one can specify the "field" containing the values to be used in the interpolation process.
- The output cell size can also be defined.

3.4.a. Interpolation (using contour lines)

Output:

- The DEM of the aoi generated using the "Topo to Raster" interpolation method is presented below.
  - A spatial resolution of 5m was assigned during the interpolation process.



Digital Elevation Model (output of the "Topo to Raster" method)

- The "Topo to Raster" method imposes constraints that ensure a hydrologically correct digital elevation model that:
  - contains a connected drainage structure; &
  - correctly represents ridges & streams from input contour data.

- It uses an iterative finite difference interpolation technique that optimizes the computational efficiency of local interpolation without losing the surface continuity of global interpolation.

- It was specifically designed to work intelligently with contour inputs.

Source: Childs (2004)

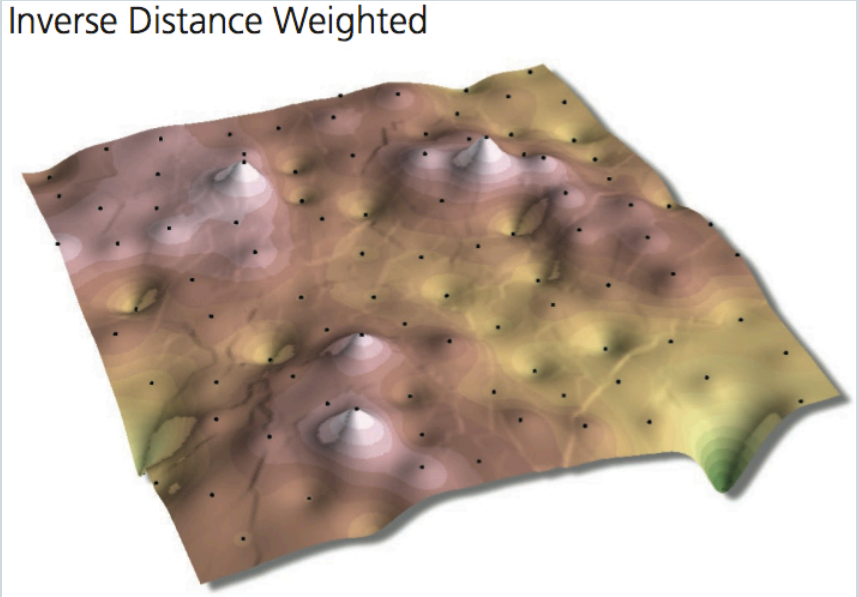
3.4.b. Interpolation (using sample points)

Methods:

- Some of the most common interpolation methods include Inverse Distance Weighted (IDW) interpolation, Spline, & Kriging. These are all available in ArcGIS software.

IDW (Sources: Childs (2004); ESRI (2008b))

- This method should be used when the set of points is dense enough to capture the extent of local surface variation needed for analysis.
- It estimates cell values by averaging the values of sample data points in the neighborhood of each processing cell.
- The closer a point is to the center of the cell being estimated, the more influence or weight it has in the averaging process.
  - The greater the distance, the less influence the cell has on the output value.



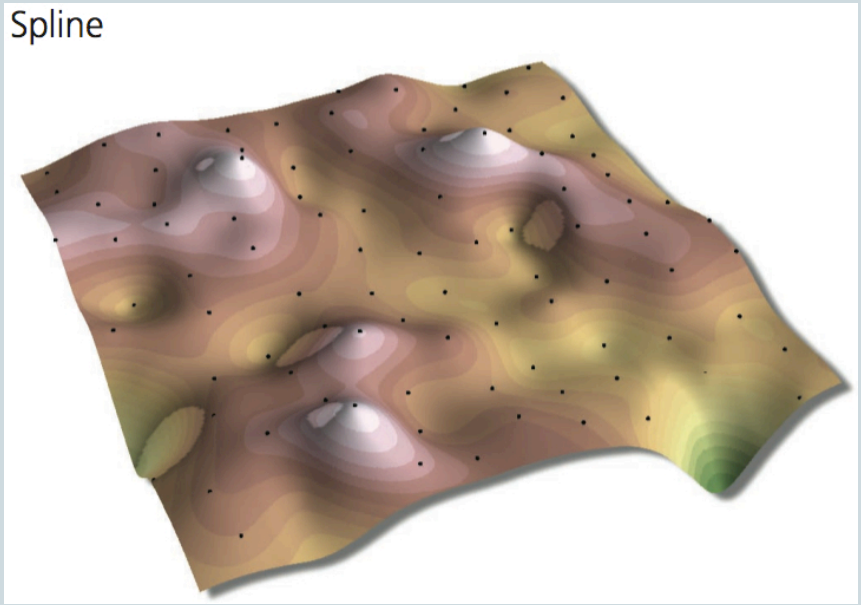
Source: Childs (2004)

3.4.b. Interpolation (using sample points)

Methods:

Spline (Sources: Childs (2004); ESRI (2008c))

- This is an interpolation method that estimates values using a mathematical function that minimizes overall surface curvature, resulting in a smooth surface that passes exactly through the input points.
- Conceptually, it is like bending a sheet of rubber so that it passes through the points while minimizing the total curvature of the surface.
- It can predict ridges & valleys in the data & is the best method for representing the smoothly varying surfaces of phenomena such as temperature.



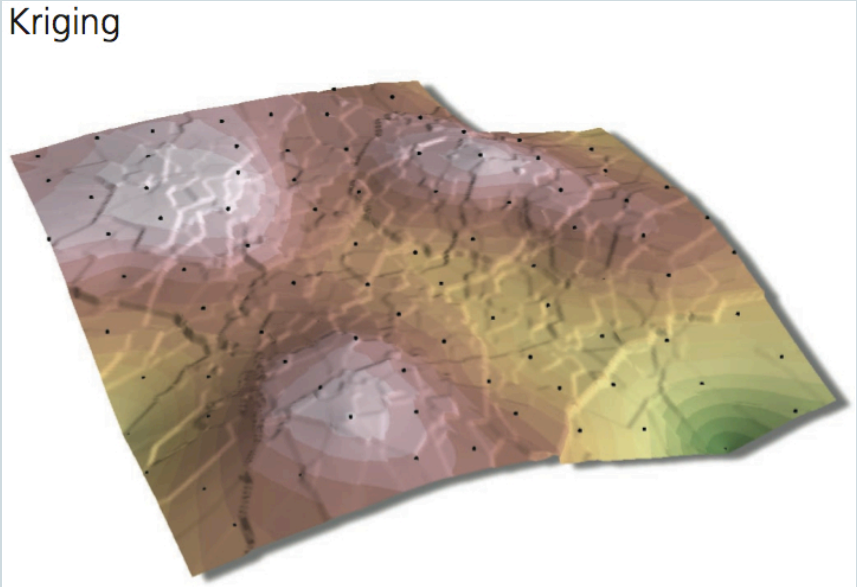
Source: Childs (2004)

3.4.b. Interpolation (using sample points)

Methods:

Kriging (Sources: Childs (2004); ESRI (2008d))

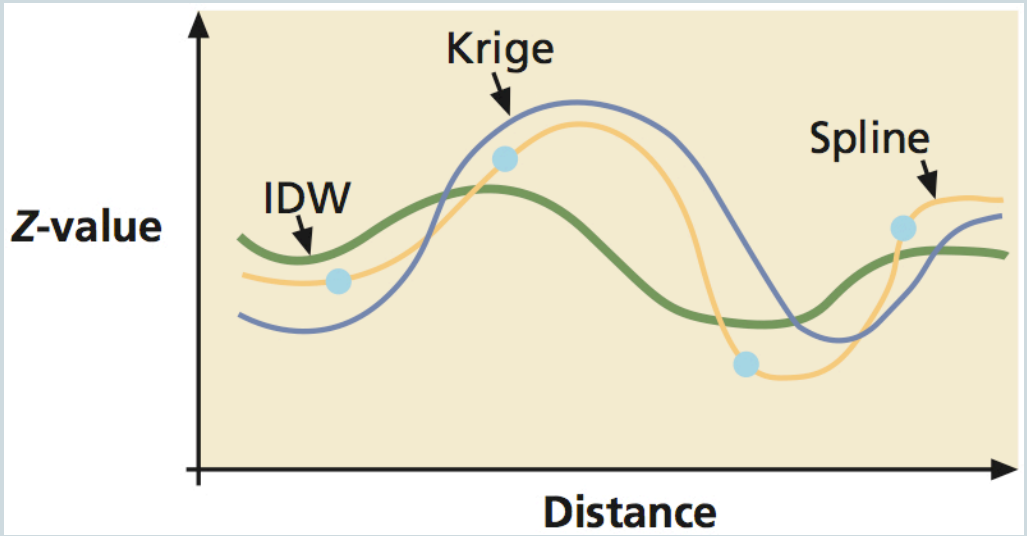
- This is an advanced geostatistical procedure that generates an estimated surface from a scattered set of points with z-values (or elevations).
- It involves an interactive investigation of the spatial behavior of the phenomenon represented by the z-values before you select the best estimation method for generating the output surface.
- It is most appropriate when a spatially correlated distance or directional bias in the data is known & is often used for applications in soil science & geology.



Source: Childs (2004)

3.4.b. Interpolation (using sample points)

Graphical comparison of IDW, Spline & Kriging.



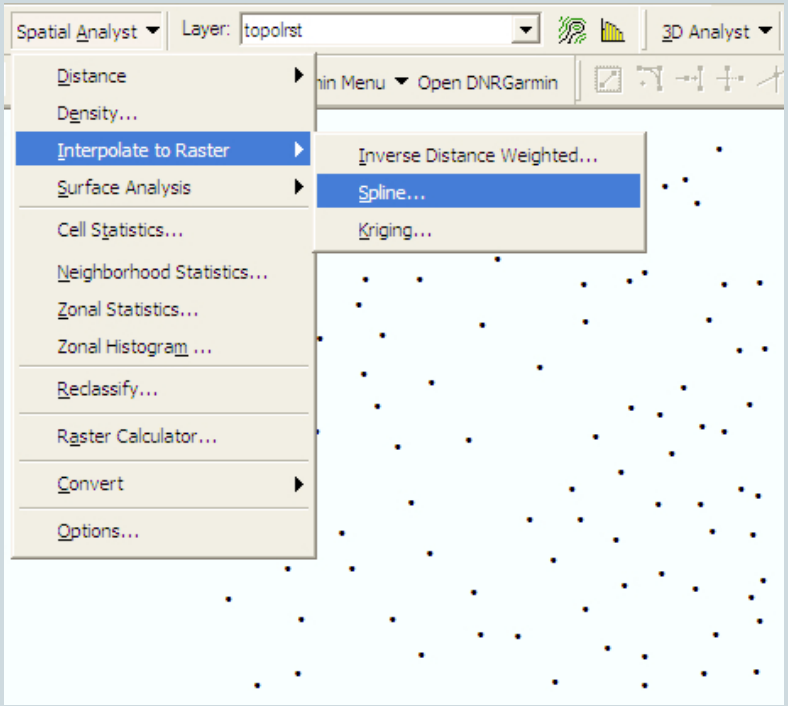
Source: Childs (2004)

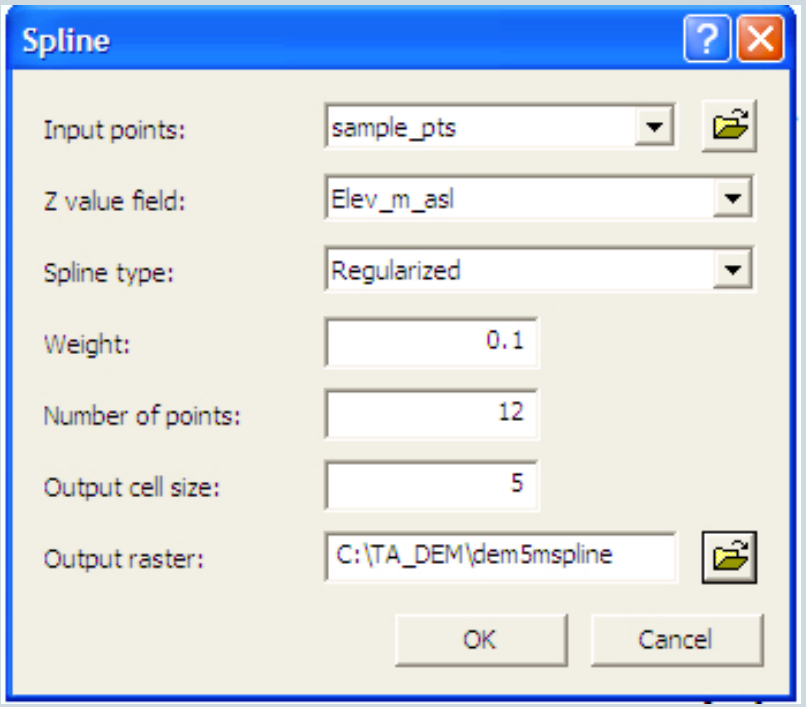
In this presentation, particularly on the next two (2) slides, the collected points from the topo map in section 3.3.b were interpolated using Spline method.

3.4.b. Interpolation (using sample points)

Method:

- The "Spline" interpolation method can be accessed from the "Spatial Analyst Tools" of ArcGIS under "Interpolation". *The digitized points in section 3.3.b were used as input. Alternatively, sample GPS points collected during field survey can also be used as input (See slide no. 5).*



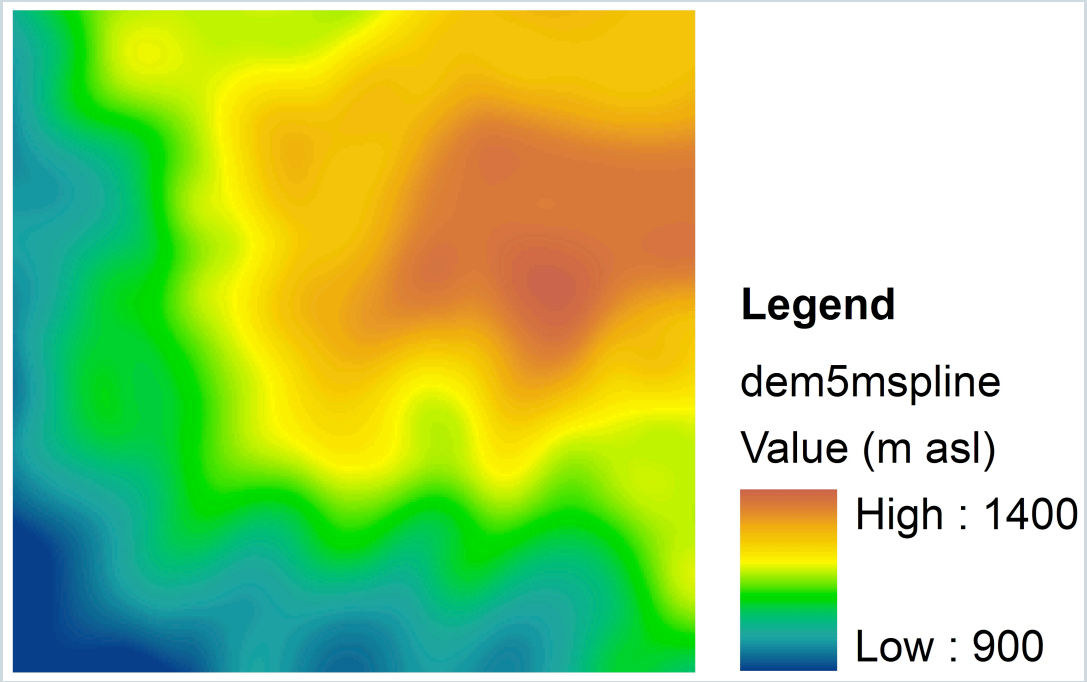


Screen shots of the "Spline" interpolation method

3.4.b. Interpolation (using sample points)

Output:

- The generated DEM of the aoi generated by using the Spline interpolation method is presented below.
  - A spatial resolution of 5m was assigned during the interpolation process.



Digital Elevation Model (output of the "Spline" method)

- Like the output of the "Topo to Raster" method, the DEM generated by using the "Spline" method can now be used for spatial analysis.
- Several topographic features like slope and aspect can also be derived from the DEM.
- DEM can be displayed using the "classified" or "stretched" options under "symbology" or by using different classification methods like natural break, equal interval, etc.
- In this presentation, the DEM is displayed using the "stretched" option under "symbology".

Remarks

- In this presentation, the methods in creating a DEM using contour lines and sample points digitized from a paper-based topographic map were illustrated and explained.

- There are a number of interpolation methods, thus, one should carefully select which method is more appropriate based on the distribution of sample data and the underlying purpose and phenomenon .

References & Suggested Readings

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