Northern Technical University
Technical Engineering College of Kirkuk
Surveying Engineering Department

Fourth stage

Cartography \ Theoretical part

Digital Cartography

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Topic1 / Introduction to digital cartography

Digital mapping or **Digital** cartography

The information collected and used to represent a map on computer screen is known as digital map data

There are two types of digital map data

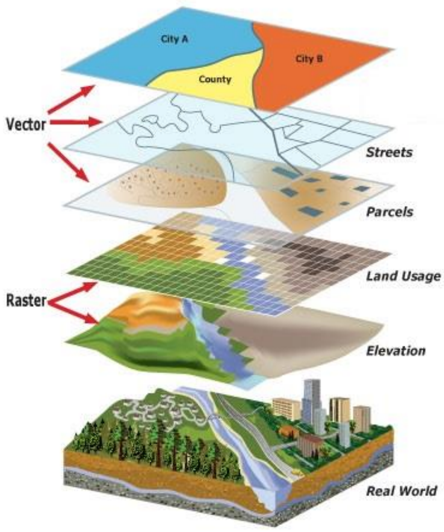
1-Raster Data

2-Vector Data

Raster Data: Is produced by converting paper map in to a series of **pixel** .data

Vector Data: Is map detail in the form of **point** & **line** and **polygon**

Digital mapping: Map information stored & displayed on computer screen



Digital cartography

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Five important advantages of digital map:

1-Real-time redesign: Digital maps can be redesigned by the user base and specific need.

2-Identity: The ability to identify an object on the map provides a robust interaction with graphic elements not available to paper maps.

3-Query: The ability to query information related to the map form is an exciting advantage. Map readers can reduce the complexity of the spatial information and focus only on selected elements.

4-Links to non-spatial databases: The link to data allows digital maps to access additional information not currently shown on the map.

5-Spatial analysis: The final advantage of the digital map is the ability for the user to perform both simple and complex spatial analysis tasks such as buffer. overlay and others.

The relationship between the cartography and cartographical features are:

1-Point feature

2-Linear feature

3-Area feature

-All individual feature associated with two types of data, which are:

1-Positional data → Point system
→ Cell system

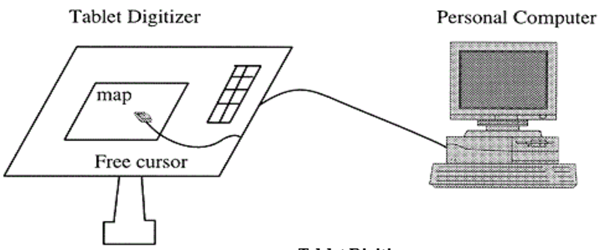
2 -Attribute data → Numerical attribute (size, area, inclination)
→ Semantic attribute (name, classes, quality)

Digitizing: The process of converting the geographic features on an analog map into digital format using a digitizing tablet, or digitizer, which is connected to a computer

Digitizer: it is the device that aids the user in converting geographical features to digital representation as the display device, there are raster and vector digitizer.

Generally there are three methods of digitizing, which are:

1-Pointing method 2-Linear method 3-Scanning method



Tablet Digitizer

The **selection** of any type from two digitizing methods which are **scanning** or **pointing** methods depends on types of

1-the available programs that we can use.

2-the ability of computer system in processing the information

The architecture of digital cartography

The architecture of digital cartography depends on the cartographic data which are consist of:

1-**Point data**: (Spatial data) it consists of files content the coordinates like (x, y , z)

2-**Attribute data:** it is a descriptive data

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There are many factors which can affect the accuracy of the digitizing process

1-Resolution 2- Consistency 3- Stability

-The process of converting a paper contour map into vector format includes the following step:

1-Scanning the map. 2- Removing the noise

3 -Detection, Linearization & Skeleorization of the contours

4-Vectorization of the contour

Scanning

The process of conversion of paper maps into digital format usable by computer is known as Scanning.

-It is used to convert an analog map into a scanned file, which is again converted to vector format through tracing

-Scanning automatically captures map features, text and symbols as individual cells, or pixels and produces an automated image

What are disadvantages of scanning method?

1-Converting large map with small-format scanner require tedious reassembly of individual parts.

2 -Large – formats, high – resolution scanner are expensive

3-Despite recent advancer in vectorization software considerable manual editing and attribute labeling May still is required.

We use automatic scanning when we have large data

Why digitize when I can scan?

Generally: Scanning map gives all information on the sheet. Even any dirty or defect, While digitizing gives only what the wear exactly need usually for deeply locking to technical procedures & gained accuracies of scanning & digitizing

What is the factors controls on the digital map accuracy?

1-Scale of the map effect the accuracy of digitized map

2-The map coordinate through digitizing are defined according to some tics

3-The distribution of taken tics is strongly effect the accuracy obtained from the digitizing maps

Topic2 /Methods of Data Collection

The methods of data collection

1 -Determine the coordinates of the position (x,y)

2-The classic method of data collection by field survey and by the analysis of orthophotograph

3-Analytical aerial survey such as **aeroplanes, helicopters, UAVs**

4-Statistical tables

5-Cosmic method or by cosmic techniques such as **Satellites**

6-Scanning or digitizing method. This method transfer the linear information to the digital information





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-The best one from these methods is the analytical aerial survey because this method is digital method , in fact therefore, it uses in data collection and easily can be collected by back-up the source files of information.

The **advantages** of the analytical aerial survey method:

a- It is using in the construction stage.

b- There is a big change, because it can give a high density of information.

c- It is characterizing by its accuracy and its process need short time

The **conditions** that must be available in the aerial photograph to use it in the analytical aerial survey are:

1-It must be orthophotograph.

2-The overlap between two photographs should be not less than 60%

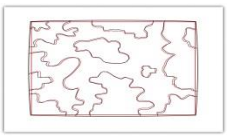
3-The corners of photograph can be registered.

The **false** types in the data collection:

1-The false coming from the equipment's.

2-The personal false.

3-The media or environmental condition.



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The false coming from the equipment, through conversion or transformation the system that used for digitizing map such as keyboard, ,curser of the input material.

For example, if the curser is not at suitable side or position on the base material from figures, areal or cosmic photograph, this may be lead to the false in the collected data, this type of false can be termed a map accuracy digiting process which it is equal to

$\gamma = F = S(x, y)$ S= Standard Division

The effected factors of the map accuracy digitizing process attribute.

1-The eccentric error

2- Personal false

3- The media or the environment

1-The eccentric error

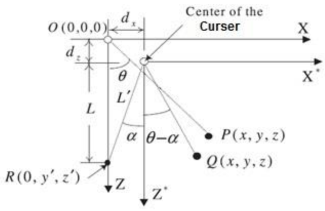
The center of the rotary table is not located exactly at the center of the actual space coordinates

If there is a grid, the center can be regard with coordinate that the curser has it This type of false can be improve by drawing more grid.

The eccentric error

The center of the curser is not located exactly at the center of the actual space coordinates O (0, 0, 0).

(X, Y, Z) is the coordinate system of the rotary-scanning measurement and also actual space coordinate system Q(x,y,z) be (X' , Y' , Z') is the coordinate system of the center of the curser be an actual space coordinate of the object P(x , y , z) is a computed space coordinate according to the measure point R (0 , y0 , z0) while (dx , dz) indicates the eccentricity of the center of the curser in the X and Z direction respectively.



2- Personal false

This type of false can be attribute to two factors which are:

a) Personal capability to determine the accurate map digitizing process that can use the following equation:

$$S = \sqrt{S^2 map\ or\ image + S^2{}_{\text{dig}}}$$

S: the rate of false

S^2 map= the rate of false on the map or image

S^2 dig= the rate of computer false

b) The Personal experience with the long time of working the experience will be increase and the rate of false will be decrease and vis versa

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Topic3 /Scanning

Scanning

The process of conversion of paper maps into digital format usable by computer is known as Scanning.

-It is used to convert an analog map into a scanned file, which is again converted to vector format through tracing.

-Scanning automatically captures map features, text and symbols as individual cells, or pixels and produces an automated image.

-It is important to refer to the fact that the point one is belong to the pointing method, while the point two is belong to the pointing and scanning method. Therefore, there are other point can be affect on the personal false by using the scanning method, like

1-The capability of scanner

2-The sensitivity of the scanner to part of millimeter

Instance, if we have a square (0.1 mm) the scanner can be record it, while, when the square is equal to (0.08 mm or 0.09 mm), the scanner can record it as (0.1 mm) coordinate, especially we can find the type of false when we use the drum type scanner

Type of scanner

There are four types of scanner

1-Drum Scanner

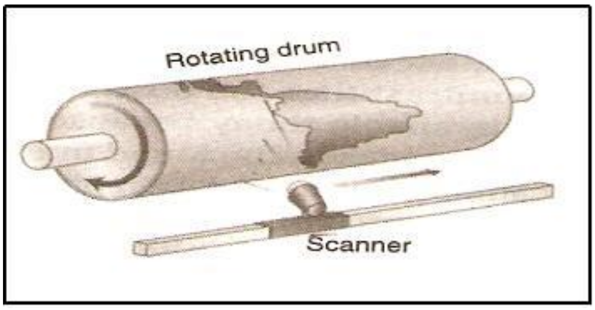
2-Page Scanner

3-Hand Scanner

4-MSS Scanner

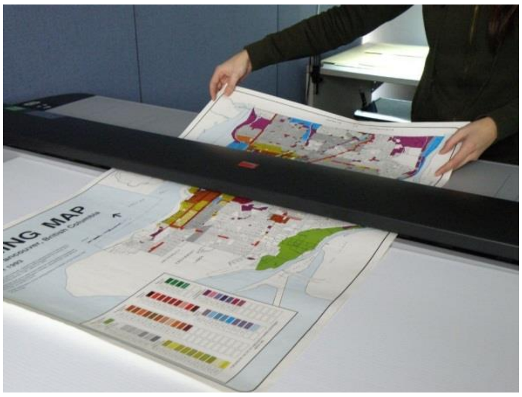
1-Drum Scanner

This type of scanner used to convert a hard-copy image or map to the digital form.



2-Page Scanner

This type of scanner has the ability to draw a pictures and figures.

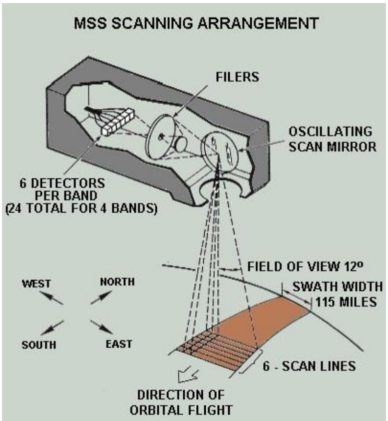


3-Hand Scanner

This type of scanner can be uses in the special case and it is limited to the paper copy.

4-Multi-Spectral Sensor (MSS) Scanner

It is a type of space electro sensing, which record the special image that belong to the reflectance of electromagnetic waves from the earth



The characteristic of MSS

1-It has a high radiometric resolution with the narrow wave length

2-The spectral wave band cover relatively a great part from the electromagnetic spectrum that ranged between the Ultraviolate (UV) wave (0.3 nm) and the thermal infrared wave (IR) (14 NM)

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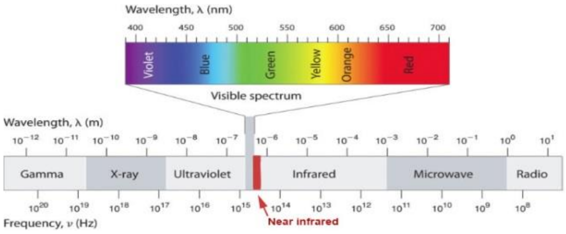

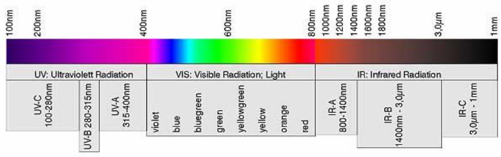

The characteristic of MSS

3-The optical system that can be uses in the data collection within spectral wave bands at once, this properties can be solve the problem of data balance (separately in spectrum) among them especially and radially.

Note:

The correction of radiance ability is easy to data collection by using the MSS, because it depends on photo chemical operation like photography.

4-The result of MSS are multi uses.

Disadvantage of MSS

1-The dimension of image (the result) is smaller than the dimension of aerial photograph (230 *230 mm)

2-The user must choice the best image depending on its experience while in the other Method the user uses the photograph which all phenomena are clear.

3-Analysis problem, when the researcher uses several image the problem will increase because the user use Eyes to giving the best interpretation but this problem was solved by preparing a colored optical

4-Equipment can help the researcher in the interpretation of multi spectral image

Scanning

The process of conversion of paper maps into digital format usable by computer is known as Scanning. It is used to convert an analog map into a scanned file, which is again converted to vector format through tracing. Scanning automatically captures map features, text and symbols as individual cells, or pixels and produces an automated image.

-The scanned file shows map features as raster lines (a series of connected pixels). And must be vectorized to complete the process of digitizing. Vectorization is converting raster lines into vector lines in a process known as tracing.

Based on the document, Scanning is mainly of two types:

Black and White Raster Scanning: It is the simplest type of scanning and can be used on line drawings, text or any one colored document. It is used in Archival Drawing Libraries, Electronic Document Distribution and Vectorization Templates.

Grey Scale and Color Raster Scanning: It is used for large size documents. Its applications include capturing images for use in desktop publishing, full color maps, aerial photography, Toposheets and cartographic base data for "high end" mapping system.

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Topic4 /Digital data

Photograph vs. Image

Photographs are recorded two-dimensionally on photosensitive emulsions that are either reflective (a print) or transmissive (a slide).

-The term **photograph** is reserved for images detected and recorded on film.

-The more generic term **image** is used for any pictorial representation of data.

-Thus, all photographs are images, but not all images are photographs.

Vector and Raster

Vector data model: [data models] A representation of the world using points, lines, and polygons. Vector models are useful for storing data that has discrete boundaries, such as country borders, land parcels, and streets

Raster data model: [data models] A representation of the world as a surface divided into a regular grid of cells. Raster models are useful for storing data that varies continuously, as in an aerial photograph, a satellite image, a surface of chemical concentrations, or an elevation surface.

Vector data attribute

Attribute	Explanation
Coordinate	Every object in a vector data set is based upon coordinates. They may consist of a Coordinate pair of numbers, representing distances along two orthogonal axes, or three numbers that include additionally the third ,dimension
Point	A point is the simplest unit in a vector data set, representing a zero-dimensional object by x,y- coordinates. A point is normally too small to be displayed on a map
Node	A node is the same as a point, with the difference that it either connects lines or that it represents the start or end point of a two or more Node line. The term vertex may be used equally
Line	A line is a one-dimensional object that is constructed by a set of ordered coordinates, what means that it starts and ends in a node. Normally, a line represents a feature that is too narrow to be displayed as a polygon , e.g. a street or a river, or a linear Object without any extension , e.g. a boundary or the route of an airplane. The terms arc or edge are used synonymously
Polygon	A polygon is an area that is surrounded by lines. It represents two-features with a concrete extension, such as a lake or dimensional Polygon an area of certain soil type, as well as undefined extensions, such as a political area

Raster data attribute

Attribute	Explanation
Spatial resolution	Defines the size or a raster cell, the smallest Identifiable discrete area of an Image. The smaller the cell-size, the finer Is the image quality Images with a very fine spatial resolution tend to be big in file size. Defined either In paper units (e g dpi (dots per inch) lines per mm) or map units (e g. meters)
Pixel Dimensions	Specified In number of pixels for image width by number of pixels for image height

Color depth	The range of color values available. Defined in bit ranges. An 8bit gray value image can store 256 different gray values A 16 bit gray value can hold up to 65536 values Other common color depths are 1 bit (monochrome 2colors). 2bit (CGA. 4 colors), 4bit (EGA. 16 colors), 24bit (3x8bit (RGB channels). true color 16.7 million colors, 32blt (usually the true color plus an 8bit alpha channel to store transparency values) The range of colors also depends on the data acquisition , e.g. the sensitivity of a scanner, digital camera or satellite based scanner Digital terrain models are often stored In 16bit images or text based files
Spectral resolution	Relevant to remote sensing data Specified In number of bands with a given spectral range (wave lengths). The popular Landsat 7 satellite e.g. suppol'1s 8 bands (3 visible 3 Infrared one thermal band and a panchromatic band In the visible light spectrum). Modern hyper spectral scanners often support 100 or more different bands.
Temporal resolution	Specifies how often a dataset is update
Print size	Specified In paper units (width by height), primarily relevant for printing or DTP. By using the pixel dimensions and the print size one can calculate the spatial resolution
Geo-referencing	Usually provided by either specifying a coordinate value In map units of one of the corner cells in an Image and the cell size. Or by specifying coordinates for diagonal corners of an image, or by specifying one corner coordinate and the Image width and

Pixel

-The basic building block of digital imagery is the pixel.

-Pixel is short for “picture element".

-Pixels have both spatial and spectral properties

-A pixel can, hold data values within the specified possible range or color depth of a raster image or data set. This data value can represent a color or grey value, depth or height, measurements or any other thematic value, such as an index to a land cover class.

-Raster cells are usually organized in a matrix (rows and columns). By specifying the coordinates of the raster origin and the spatial resolution of a raster cell, the spatial position of each cell within the raster grid can be easily calculated. To store multiband raster data one can either interleave the data by pixel (BIP), line (BIL) or per image (BSQ=Band Sequential).

What are digital data?

-The spatial aspect of a pixel defines an image's spatial resolution (the area of ground represented by the data values).

-The spectral aspect defines the intensity of interaction between EMR and the corresponding ground area in a particular band.

-In this context, a band is digital sensor sensitivity to a particular wavelength range.

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What are digital data?

-The spatial data structure of digital imagery is called raster.

-The basis of raster data is the individual grid cell.

Limitations are:

1-Each grid cell can only contain one number.

2-The size of raster data sets is large, because each cell in an image must have a value recorded and stored.

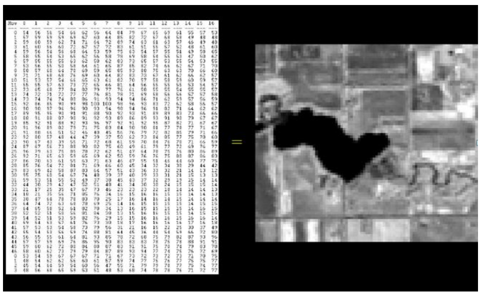
The BIG advantage to using digital data:

1-Numbers in the arrays can be added, subtracted, multiplied, divided, – and subjected to statistical manipulations not otherwise possible.

2-Therefore, digital representation greatly increases the ability to – examine, display, and analyze data.

3-Thus, by assigning gray-scale values to DNs in a linear array, digital arrays can visually represent the surface of the Earth.

4-Numeric arrays for several spectral channels can be combined to produce color images.



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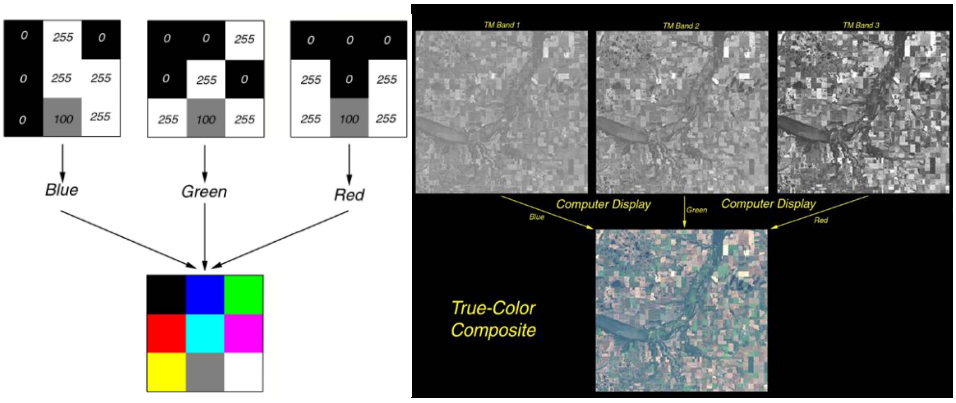

Data bit ranges

-Energy reflected or emitted from an Earth scene is continuous. That is, there are an infinite number of levels that could be recorded

-A digital sensor must detect such energy and convert measurements into discrete levels.

-Radiometric resolution refers to the sensitivity of the instrument, or how many signal levels (DNs) can be recorded by each pixel.

-DNs are recorded in pixels as a series of binary digits known as “bits".

-Radiometric resolution is determined by the number of bits available.

-e.g., 16-bit instruments have higher radiometric resolution than 8-bit sensors (that is, 16-bit instruments can sense more levels of EMR reflected or emitted from a scene).

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-6-bit = 64 brightness levels (0-63)

-7-bit = 128 brightness levels (0-127)

-8-bit = 256 brightness levels (0-255)

-16-Bit = 65,536 brightness levels (0-65,535)

-32-bit = 4,294,967,296 brightness levels

-Each bit records an exponent of a power of 2, with the value of the exponent determined by the position of the bit in a data sequence.

-e.g., 8-bit data has 8 binary digits available to record DNs. The 8 values record, in sequence, successive powers of 2. A binary digit of “1” signifies that a specific power of 2 is to be evoked. A “0” means that it is not.

Example 1: The 8-bit binary sequence 11111111=

27 + 26 + 25+ 24 + 23 + 22 + 21 + 20=

128 + 64 + 32 + 16 + 8 + 4 + 2 + 1 =255

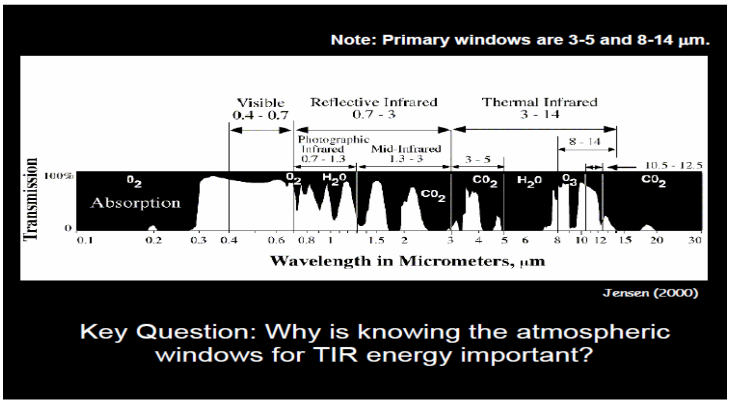
-So, 8-bit sensors can record 256 different

levels of brightness (0-255).

Topic5 /Bands

-Each of the sensor's bands is sensitive to surface brightness is a distinct portion of the electromagnetic spectrum.

-Thus, separate analog signals are generated and digital conversions performed by a sensor for each band.



The wavelengths are approximate; exact values depend on the particular satellite's instruments:

Blue, 450-515..520 nm, is used for atmosphere and deep water imaging, and can reach depths up to 150 feet (50 m) in clear water.

Green, 515..520-590..600 nm, is used for imaging vegetation and deep water structures, up to 90 feet (30 m) in clear water.

Red, 600..630-680..690 nm, is used for imaging man-made objects, in water up to 30 feet (9 m) deep, soil, and vegetation.

Near infrared, 750-900 nm, is used primarily for imaging vegetation.

Mid-infrared, 1550-1750 nm, is used for imaging vegetation, soil moisture content, and some forest fires.

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Far-infrared, 2080-2350 nm, is used for imaging soil, moisture, geological features, silicates, clays, and fires.

Thermal infrared, 10400-12500 nm, uses emitted instead of reflected radiation to image geological structures, thermal differences in water currents, and fires, and for night studies.

Radar and related technologies are useful for mapping terrain and for detecting various objects and flood.

Example

Landsat Multi Spectral Scanner (MSS)

Landsat MSS 1,2,3 Spectral band	Landsat MSS 4,5 Spectral Bands	Wavelength	Useful for mapping
Band 4 - green	Band 1 - green	0.5 - 0.6	Sediment-laden water, delineates areas of shallow water
Band 5 - red	Band 2 - red	0.6 - 0.7	Cultural features
Band 6 – Near infrared	Band 3 - Near infrared	0.7 – 0.8	Vegetation boundary between land and water, and landforms
Band 7 - Near infrared	Band 4 - Near infrared	0.8-1.1	Penetrates atmospheric haze best, emphasizes vegetation, boundary between land and water, and landforms

Landsat 8 operational lnd imager (OLI) and therml infrared sensor (TIRS)

Landsat 8 operational land imager (OLI) and thermal infrared sensor (TIRS)		
Band 1 – coastal aerosol	0.43-0.45	coastal and aerosol studies
Band 2 - blue	0.45 – 0.51	Bathymetric mapping, distinguishing soil from vegetation and deciduous from coniferous vegetation
Band 3 - green	0.53 - 0.59	Emphasizes peak vegetation, which is useful for assessing plant vigor

Band 4 - red	0.64 - 0.67	Discriminates vegetation slopes
Band 5 - Near nfrared (NIR)	0.85-0.88	Emphasizes biomass content and shorelines

Band 6 –short wave infrared (SWIR)1	1.57 - 1.65	Discriminates moisture content of soil and vegetation; penetrates thin clouds
Band 7 –short wave infrared (SWIR)2	2.11-2.29	Improved moisture content of soil and vegetation and thin cloud penetration
Band 8 - Panchromatic	0.50 - 0.68	15 meter resolution, sharper image definition
Band 9 - Cirrus	1.36 - 1.38	Improved detection of cirrus cloud contamination
Band 10 - TIRS 1	10.60 – 11.19	100 meter resolution, thermal mapping and estimated soil moisture
Band 11 - TIRS 2	11.5 - 12.51	100 meter resolution, improved thermal mapping and estimated soil moisture

Topic6 /Types of Digital images

Types of Digital images

Types of Digital Images The images types we will consider are:

1) Binary

2) gray-scale

3) Color

4) Multispectral

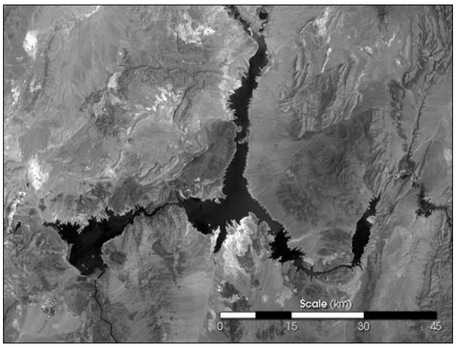
1-Binary images

Binary images are the simplest type of images and can take on two values, typically black and white, or 0 and 1. A binary image is referred to as a 1-bit image because it takes only 1 binary digit to represent each pixel.

-These types of images are frequently used in applications where the only information required is general shape or outline, for example optical character recognition (OCR). Where every pixel above the threshold value is turned white (`l), and those below it are turned black (`0'). In the figure below, we see examples of binary images.

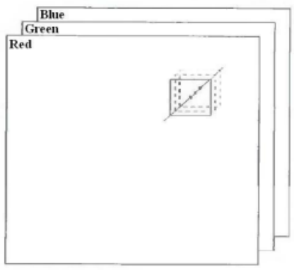
2- Gray Scale Image

Gray Scale Image are refer to as monochrome (one color) images. They contain gray-level information, no color information. **The number of bits used for each pixel determines the number of different gray levels available.** The typical gray-scale image contains 8bits/pixel data, which allows us to have 256 different gray levels. The figure below shows examples of gray-scale images.



3- Color images

Color images can be modeled as three-band monochrome image data, where each band of data corresponds to a different color. The actual information stored in the digital image data is the gray-level information in each **spectral band.** Typical color images are represented as red, green, and blue **(RGB images).** Using the 8-bit monochrome standard as a model, the corresponding color image would have 24-bits/pixel (8-bits for each of the three color bands red, green, and blue). The figure illustrates a representation of a typical RGB color image.



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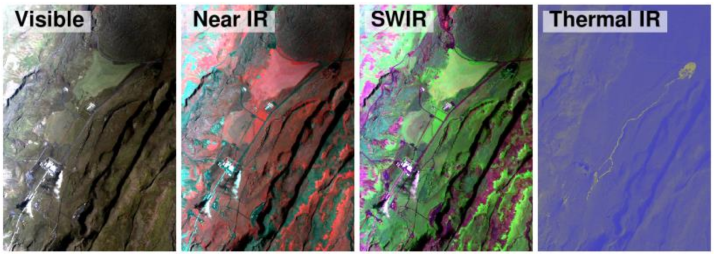
4- Multispectral images

Multispectral images typically contain information outside the normal human perceptual range. **This may include infrared, ultraviolet, X-ray, acoustic, or radar data. These are not images in the usual sense because the information represented is not directly visible by the human system.** However, the information is often represented in visual form by mapping the different spectral bands to RGB components.



Topic7 /Data model

Data Modeling

-In information theory, data model is a description of the rules by which data is defined, organized, queried, and updated within an information system. The abstractions of a real-world must be **formalized** in a data model.

-The data model shows the computer how best to **store** the geographic information (**geometry and attributes**) in a database.

-Data model will try to **simplify aspects of the real world**, but there are limitations and may lead to oversimplifying or misrepresenting of geographical data and feature.

-In order for geographic data to be represented **digitally**, a geographic **data model** has to be chosen.

1-1Data Abstraction

-To simplify the idea of a real-world object or features the relevant information need to be abstracted and finally entered into the computer.

-Traditional maps are abstractions of the real world, a sampling of important elements portrayed on a sheet of paper with symbols to represent physical objects.

-Digital surface model is an abstraction or approximation of a surface. Because a surface contains an infinite number of points, some subset of points must be representing the surface.

There are three levels of abstraction which are:

1-Conceptual data model

2-Logical data model

3-Physical data model

1-2 Topology

-A **distinguishing** feature that the **spatial relationships** between **spatial entities** will be coded in the database. This coding is termed topologically coding.

Coordinate strings without topology with associated feature codes were called **"spaghetti"** files because **there was not any relationship** between any two coordinate strings formally encoded in the database. For example, the GIS system would not "know" **if two lines intersect or not or whether they had common end points.** These relationships could be seen by the human eye if a plot were to be made or alternatively could be calculated (often a time consuming process).

Typical of this type of geographic data file are those produced by computer-aided drafting systems (CAD) files.

Topology is employed in order to

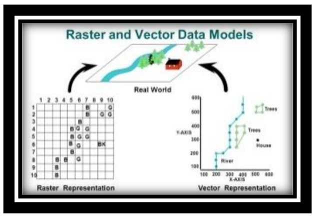
1-Constrain how features share geometry. For example, adjacent polygons such as parcels have shared edges, street centrelines and census blocks share geometry, adjacent soil polygons share edges, etc

2-Define and enforce data integrity rules (e.g., no gaps should exist between polygons; there should be no overlapping features, and so on).

3-Support topological relationship queries and navigation (e.g. to navigate feature adjacency and connectivity).

4-Support advance editing tools (tools that enforce the topological constraints of the data model).

5-Construct features from unstructured geometry (e.g. to construct polygons from lines).



Vector data not only contains the geometry of a point; depending on the model, it can also include topology or neighborhood relations, e.g. areas next to a line or start and end point of a line. Vector model support both **spaghetti and topological model.**

Spaghetti model

The spaghetti model is a simple model that stores the data in an unstructured way. This model just stores the name of every object, followed by the coordinates the object is composed of. Since the objects are not related to each other, no topological information is included and the consistency cannot be verified. The spaghetti data model has a simple structure; every object is described independently of the others. The same coordinate may appear several times; therefore it needs large amounts of storage space. On the other hand, an advantage of this data structure is the possibility to modify every object without affecting the others.

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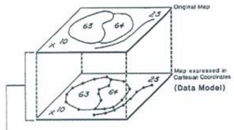

Data Structure

Feature	Number	Location
Point	10	X,Y (Single Point)
Line	23	$X_1Y_1, X_2Y_2, \ldots\ldots X_nY_n$ (String)
Polygon	63	$X_1Y_1, X_2Y_2, \ldots\ldots X_1Y_1$ (Closed Loop)
	64	$X_1Y_1, X_2Y_2, \ldots\ldots X_1Y_1$ (Data Structure)

Topological model

-Topology refers to knowledge about relative spatial positioning of features i.e. knowledge about how features are connected and which features are adjacent to each other. It distinguishes GIS data models from non-topological data models supported by many CAD, mapping and graphics systems.

Topological relationships between geometric entities traditionally includes:

1- Connectivity: which geographic features connect to others or which geographic features intersect each other.

2- Adjacency: geographic features are adjacent (contiguous) to others

3-Containment: which geographic features are contained within a polygon.

4- Proximity: which geographic features are near others.

5- Direction: the relative position between features.

Spatial relationships between objects:

Types of topological relationship

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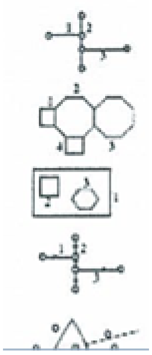


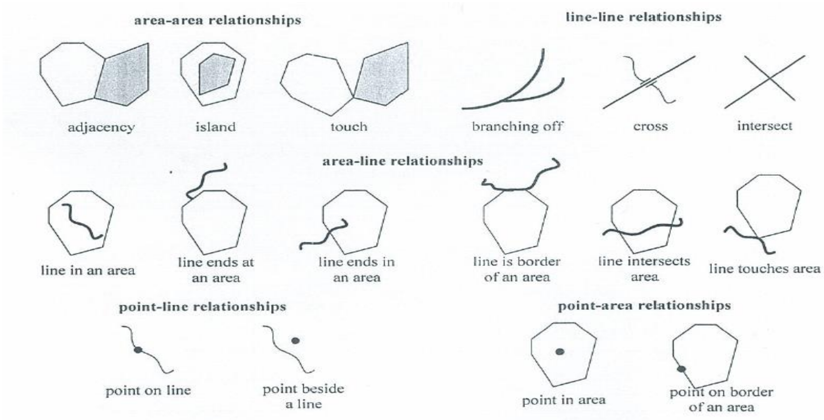
Connectivity

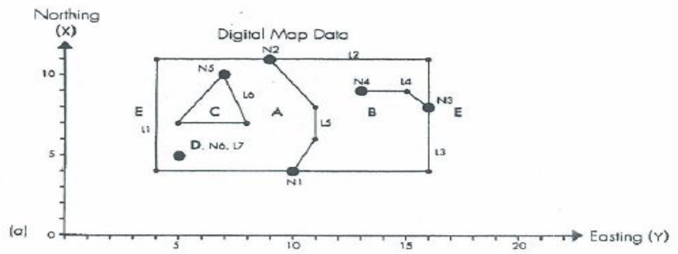
Adjacency

Containment (nestedness , insideness)

Relative Direction

Proximity





(b) POLYGON TOPOLOGY

Polygon	Links
A	L1, L5
B	L2, L3, L5
C	L6
D	L7
E	L1, L2, L3

(c) NODE TOPOLOGY

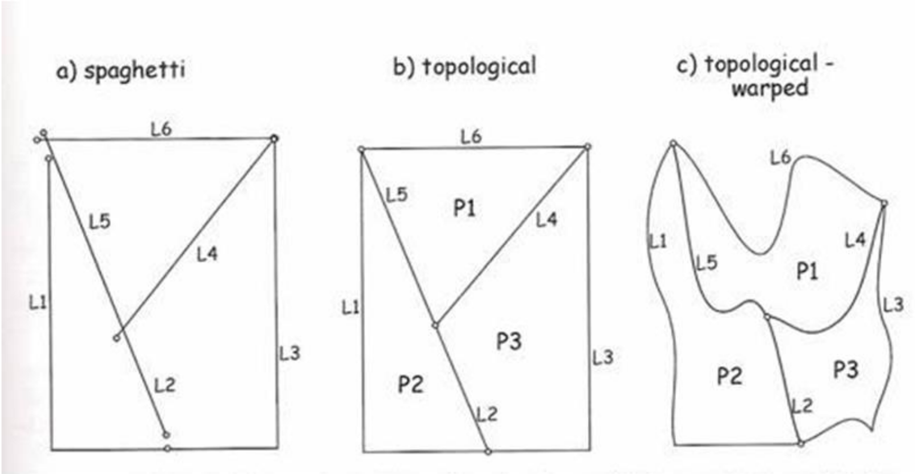
Node	Links
N1	L1, L3, L5
N2	L1, L2, L5
N3	L2, L3, L4
N4	L4
N5	L6
N6	L7

(d) LINK TOPOLOGY

Links	Start node	End node	Left polygon	Right polygon
L1	N1	N2	E	A
L2	N2	N3	E	B
L3	N3	N1	E	B
L4	N3	N4	B	B
L5	N2	N1	B	A
L6	N5	N5	A	C
L7	N6	N6	A	A

(e) LINK COORDINATES

Link	Coordinates			
L1	4,10	4,4	11,4	11,9
L2	11,9	11,16	8,16	
L3	8,16	4,16	4,10	
L4	8,16	9,15	9,13	
L5	11,9	8,11	6,11	4,10
L6	10,7	7,8	7,5	10,7
L7	5,5			



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Topic8 /Surface Data model

The earth's surface is a continuous phenomenon. Elevation and terrain variables are important at some point in almost 'everyone's life. Elevation and slope determines flood zones and watershed boundaries as well as hydrologic networks. Terrain is also an integral part of determining transportation networks and 'Site suitability for a variety of applications. There are various ways of representing such Surfaces in digital form using a finite amount of storage. **Digital terrain surface models (DTM/DSM)** are used as a way of representing surfaces. Although used interchangeably the terminology can be misleading if it is not used properly:

Digital Terrain Model (DTM) is used to refer to any digital representation of a terrain (meaning ground and not including the infrastructures on the surface). Sometime digital ground model **(DGM)** is used for small areas

Digital elevations Model or DEM' most often it is used to refer specially to raster or regular grid of spot heights. **Digital surface model (DSM)** is used to represent digital representation of all features on the surface including the infrastructures.

Within a GIS, DTM are most valuable as a basis for the extraction of terrain-related attributes and features. The objective of DTM interpretation is the derivation of geomorphometric parameters like slope values, interpretation of landform features ("terrain positioning") and derivation of drainage networks.

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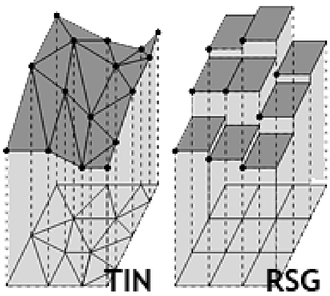
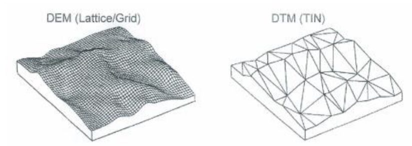
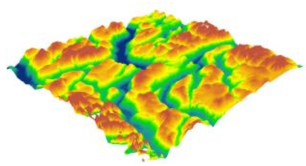
Surface models are normally stored in either **TIN or lattice Format**. Lattice models of terrain arp like other raster data models. Height values are kept in a regular grid. This structure makes algorithms for modeling slope, aspect, run-off, visibility etc very simple. A TIN (Triangular Irregular Network) model is a continuous mesh of triangles. These vary in size according to need based on the roughness of the terrain. Large triangles are sufficient for flat or smoothly sloping country. Small triangles can model highly variable terrain. This makes TIN modeling accurate and efficient. Slopes, aspects and run-off can be computed directly from TIN models

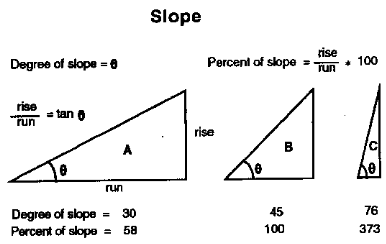


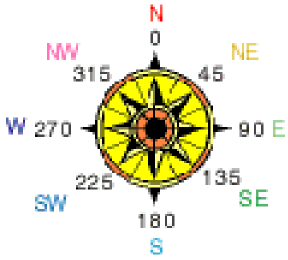


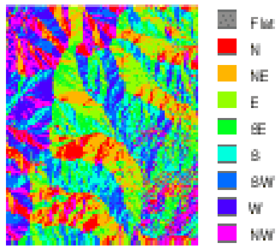


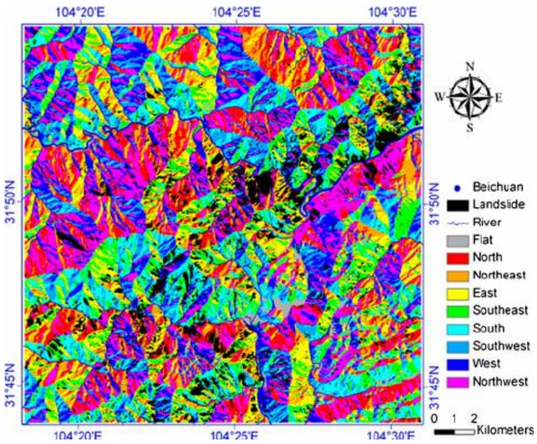
Slope & Aspect

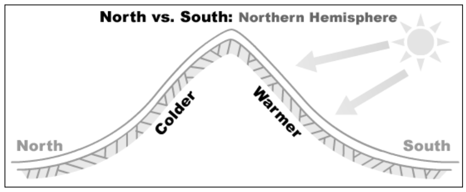
The expression TIN means Triangulated Irregular Network and is used for the digital modeling of a surface. The points of a TIN are distributed irregularly and meshed by triangles what results in an adaptive modeling of the surface. The more complex the surface the more points are needed. In exchange, a regular surface may be modeled by just a few points. This model is much more precise than the usual raster surface models, called Digital Elevation Model (DEM) in which points are represented regularly. Small summits, ridges and valleys may be visualized in a TIN but hardly in a DEM.





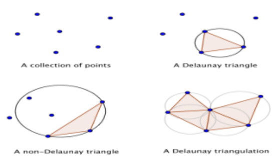






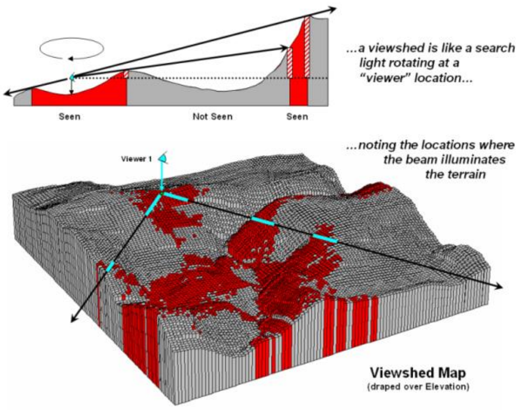
Triangulation

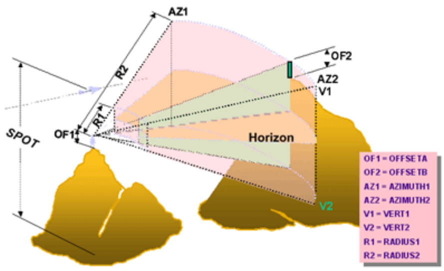
The TIN model represents a surface as a set of contiguous, non-overlapping triangles. Within each triangle the surface is represented by a plane. The triangles are made from a set of points called mass points. Delaunay triangulation is a proximal method that satisfies the requirement that a circle drawn through the three nodes of a triangle will contain no other node. Delaunay triangulation has several advantages over other triangulation methods: • The triangles are as equiangular as possible, thus reducing potential numerical precision problems created by long skinny triangles. • Ensures that any point on the surface is as close as possible to a node • The triangulation is independent of the order the points are processed.

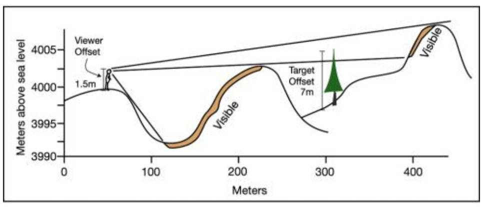


Viewshed Analysis

Viewshed identifies the point/place that can be seen from one or more observation points or lines. Sometimes it is taken as Line of Sight (LOS) Analysis. Viewshed is useful when you want to know how visible objects might be—for example, "which locations on the landscape will the towers be visible if they are placed in this location?" or "what will the view be from this place?" It can be applied to the design of a forest fire watchtower, the selection of scenic spots, the evaluation of visual impact of observation tower, and others.



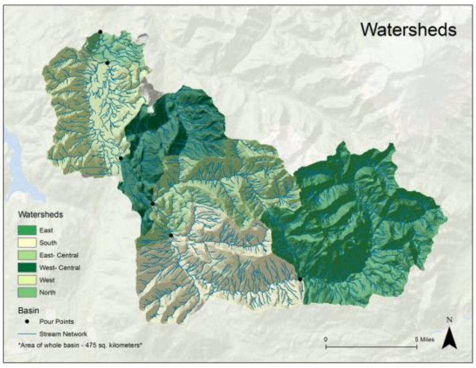


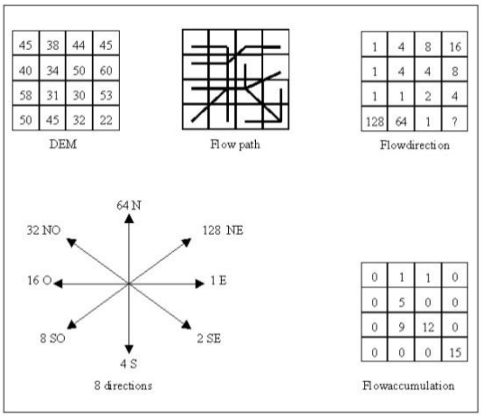


A single Line of Sight (LOS) in a particular direction, with examples of viewer and target offsets. Collectively, all of the LOS from a given location make up its viewshed.

Watershed Analysis

Watershed Analysis • A watershed is an area that drains water and other substances to a common outlet as concentrated drainage. Other common terms for a watershed are basin, catchment, or contributing area. This area is normally defined as the





Total area flowing to a given outlet, or pour point. These areas are the output of the Watershed function. The boundary between two watersheds is referred to as a watershed boundary or drainage divide.

An outlet, or pour point, is the point at which water flows out of an area. This is the lowest point along the boundary of the points above which the contributing area is determined. Source cells may be features such as dams or stream gauges, for which you want to determine characteristics of the contributing area. "Sink" or "Pit" should first be filled.

Watershed. The cells in the source raster are used as pour

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Topic9 /Geo-coding

Introduction

Consider the following examples

-You have a spreadsheet showing the addresses of all of the locations in your area that give free Flu shots and you want to create an interactive map for your patients.

-You want to map the all of the HUD homes in Virginia, but once you select the homes you want, you get a spreadsheet download. (http://www.hudhomestore.com/Home/Index.aspx)

Same problem as before: spreadsheets do not contain spatial data

What is geocoding?

-Similar to an attribute join of a standalone table to an attribute table of a spatial data set, except

It can use multiple fields to match records

It can match records that are similar but not exactly the same

-The spatial data set is called the **reference layer**

Geocoding applications

-911 emergency response

-Map Quest and Google Earth

-Finding locations of customers

-Marketing analysis

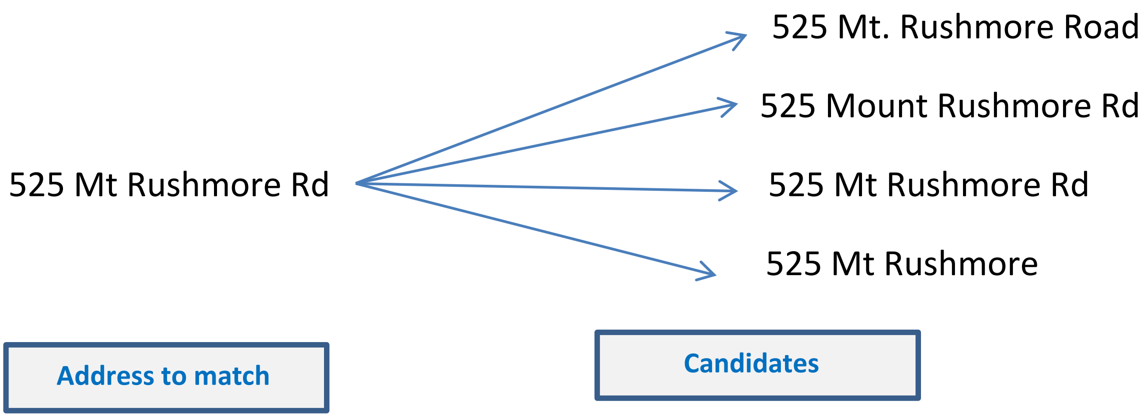
-Mapping distribution of crimes

-Mapping township/range descriptions

"Fuzzy" matching

-Joins and queries are based on exact matches

-Geocoding is able to match records when values may be close but not identical



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Using geocoding to join

Relies on scoring candidates, not exact matching

FID	Shap	CITY_FIPS	CITY_NAME	STAT	STATE_NAME
0	Point	05280	Bellingham	53	Washington
1	Point	35050	Havre	30	Montana
2	Point	01990	Anacortes	53	Washington
3	Point	47560	Mount Vernon	53	Washington
4	Point	50360	Oak Harbor	53	Washington
5	Point	53380	Minot	38	North Dakota
6	Point	40075	Kalispell	30	Montana
7	Point	86220	Williston	38	North Dakota

Case does not match

Same name in multiple states

OID	CITY	STATE	YRS	JAN	FEB
0	BIRMINGHAM	AL	30	5.45	4.21
1	HUNTSVILLE	AL	30	5.52	4.95
2	MOBILE	AL	30	5.75	5.1
3	MONTGOMERY	AL	30	5.04	5.45
4	ANCHORAGE	AK	30	0.68	0.74
5	ANNETTE	AK	30	9.67	8.05
6	BARROW	AK	30	0.12	0.12
7	BETHEL	AK	30	0.62	0.51

These two tables can't be joined, but they can be matched.

Match an address to a street

RESTAURANT	ADDRESS
Cajun Caf,	2200 N Maple Av
Cajun Express	1301 Omaha St
Canyon Lake Chophouse	2720 Chapel Ln
Carini's	324 St Joseph St
Casa Del Rey	1902 Mount Rushmore Rd
Chili's Grill and Bar	2125 Haines Ave
China Buffet	750 Mountain View Rd
Colonial House Restaura	2501 Mount Rushmore Rd
Courthouse Coffee Shop	315 St Joseph St
Culver's	2121 W Main St

Address table

Reference layer

The reference layer contains information about the street names and address ranges.

Each address in a table is matched to a location on a particular street.

Creates a point layer of addresses.

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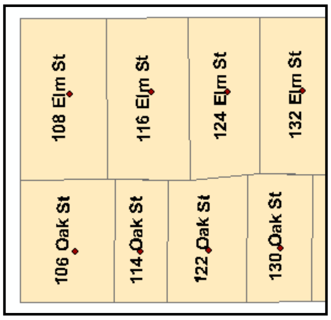
Matching addresses to points or polygons



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Culver's	2121 W Main St

Parcel reference layer

Detailed View: Must have

A **reference layer,** which is a shapefile or feature class containing features with attributes for matching

An **address locator** set up for the reference layer with rules and options

A **table** with address records to be matched

Reference layer

NORTHLAND DR 3120

Streets

PREFIX_DIR	PRE_TYPE	STREET_NAM	STREET_TYP	SUFFIX_DIR	LEFT_FRADD	LEFT_TOADD	RIGHT_FRAD	RIGHT_TOAD
		NORTHLAND	DR		3301	3345	0	0
		CEDAR BEND	DR		[illegible]	[illegible]	[illegible]	[illegible]
		NORTHLAND	DR		3051	3225	0	0
		PRESCOTT MANOR	WAY		[illegible]	[illegible]	[illegible]	[illegible]
		CARENTAN	DR		7701	7709	7700	7708
N	IH	35	SVRD	NB	0	0	3213	3223
N	IH	35	SVRD	NB	0	0	3201	3211
		E 32ND ST TO N IH 35	RAMP		0	0	0	0
		DECKER	LN		10714	10806	10715	10807
		DESSAU	RD		10206	10214	0	0
		DECKER	LN		10808	11016	10809	11017

Point, line, or polygon features with attributes on which matching will be based

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Address locator and geocoding

-Addresses to be matched are parsed into separate components (number, street name, etc).

-Each component is compared to the same fields in the reference layer

-Candidates are scored based on closeness of matches (0-100)

-80-100 is a good match

Address locator components

-**Prefix direction**. 124 East Main St.

-**Prefix type**. 345 Highway 85.

-**Number**. 123 Maple St.

-**Street name**. 123 Maple St.

-**Street type**. 123 Maple St. or 15 Elm Ct.

-**Suffix direction**. Florman St. E or 87th St. North.

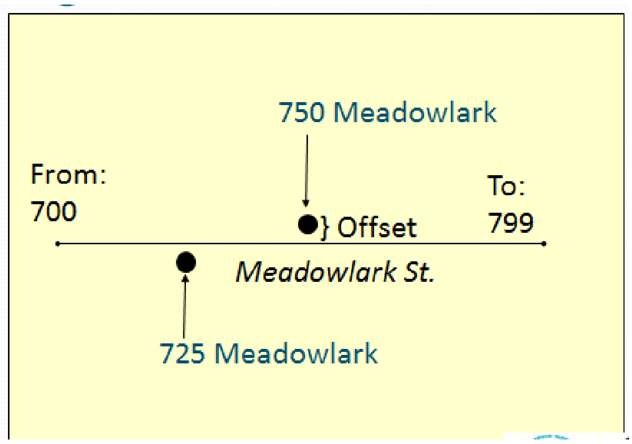
-**City, State, Zip code**. Optional.

How addresses are parsed

Address	Pre fix Dir	Prefix Type	Num-ber	Street	Type	Suffix Dir
123 Maple Road			123	MAPLE	RD	
15 Center St. East			15	CENTER	ST	E
314 Hwy 85 N		HWY	314	85		N
234 E. St. Patrick St.	E		234	SAINT PATRICK	ST	

Notice that parsing includes converting to upper case

Placing addresses



Address Locators

-Matching engine set up for a specific reference layer

-Stores a snapshot of the reference data

-Once created can be used again

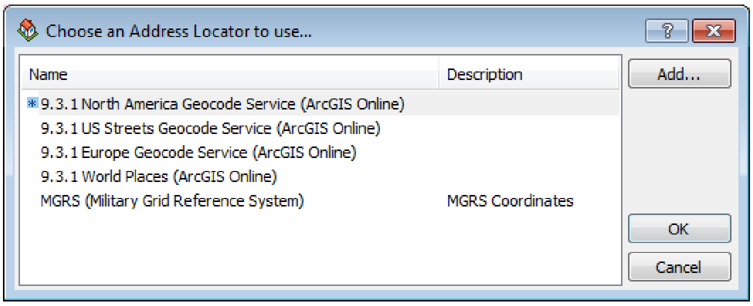
Online Locators

-ArcGIS Online now has several locators.

-May not be as accurate as those created in ArcGIS desktop.

-For quick access and easy access to large areas.

-Online can be sloooowwwww….



Geocoding Steps in Desktop

-Create an Address Locator

-Add the address locator previously created

-Choose the address table

-Match the addresses in batch mode

-Review the matched/unmatched addresses

-If necessary, rematch addresses in batch or interactive mode

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