Spatial Technology for The Survey and Monitoring of Invasive Species

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The Basic “Invasives” Problem

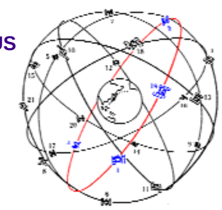
- **To survey, inventory, and monitor invasive plants, their invasion characteristics, document control treatments, and evaluate the results.**
- **In short, to *measure*, *document*, and *analyze*.**

Basic Tools

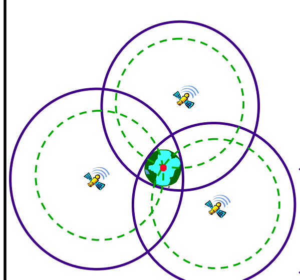
- **Measurement**
  - GPS **– *(Global Positioning System)***
    – A device for measuring geographic coordinates at any location on the earth.
- **Documentation and Analysis**
  - GIS **– *(Geographic Information System)***
    – A database for maintaining and analyzing spatial features and the relationships between features as they are defined through geographic coordinates or measurements.

Global Positioning System (GPS)

- **A constellation of 24 man-made “stars” (satellites) composed of very accurate atomic clocks put into an approximately 12 hour orbit at an altitude of 20,000km**
  (meaning that at least 6 satellites should be “viewable” at any time.)
- **The system is maintained by the US Department of Defense giving users access to “quality” measurements anywhere on (or near) the surface of the earth at any time of the day or night.**



How does GPS work?

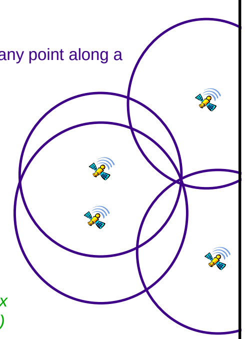


- **Satellites are at known points orbiting the earth**
- **Their range is defined by the difference in time between sending and receiving a signal**
- **Using resection trigonometry, the location of the receiver clock can be calculated**
- **Most error in the range intersection is due to error in the receiver clock**

Trigonometry

- **Quick Trigonometry review –**
  - One radius measurement locates me to any point along a circle
  - Two radius measurements narrows my position to only two points
  - A third radius will narrow the position to only one value
  - If the timing offset is consistent, a fourth radius measurement will compensate the errors

And remember, we should usually have six satellites available (in perfect conditions)



Accuracy

- **Basic Accuracy** (Post May 1,2000)
  - Uncorrected 10-30 meters (30-100')
- **WAAS (Wide Area Augmentation System)**
  - Realtime correction 0.5 –10 meters (2 – 30 ft)
  - Terrestrial based low cost, limited range, terrain obstructions
  - Satellite based has wide coverage but also high cost
- **DGPS (Differential GPS)**
  - Post Processing (<0.01m) 0.1 ft

Error Sources

Per Satellite :	Std GPS	DGPS
Satellite Clocks	1.5	0
Orbit Errors	2.5	0
Ionosphere	5.0	.4
Troposphere	.5	.2
Receiver Noise	.3	.3
Multipath	.6	.6
SA	30	0

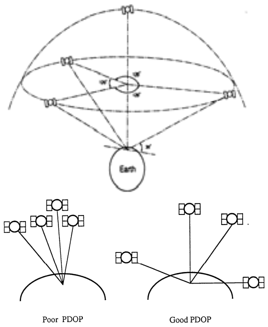
Typical Position Accuracies

Horizontal	50	1.3
Vertical	78	2.0
3-D	93	2.8

Source : Trimble

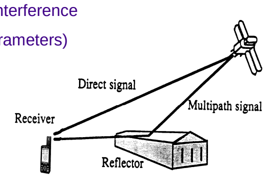
Measures of Precision

- **The symmetry of the satellites will control the level of precision**
- **These symmetry factors are known as**
  - GDOP
  - PDOP
  - VDOP



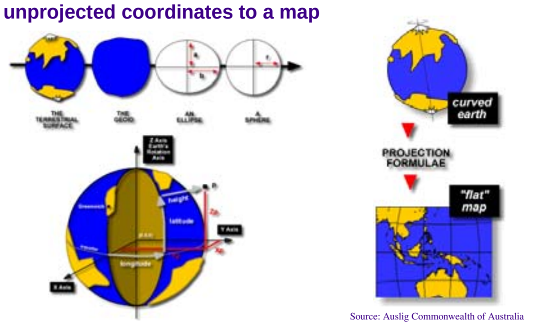
Reliability

- **Many factors can contribute to decrease reliability**
  - Receiver quality
  - Proximity to buildings or other obstructions (cliffs, etc.), tree canopy
  - Multipathing
  - Mircowave or other radio interference
  - Blunders (wrong setup parameters)
  - Weight of receiver unit
  - Power source



Transportability

- **Projections and datums are important when converting unprojected coordinates to a map**



Source: Auslig Commonwealth of Australia

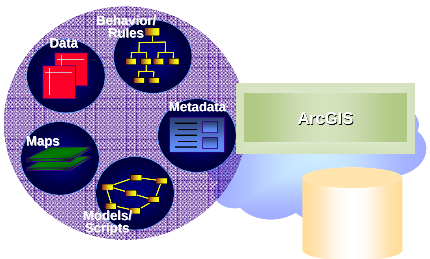
Useful Conclusions on GPS

- **Buy the best equipment that you can afford that will give you the level of reliable accuracy that you need**
- **Carefully plan (and execute) data collection trips**
  - Watch satellite geometry – PDOP, GDOP
- **Be sure to understand**
  - Datums and projections of data target
- **Be sure to check**
  - Cables, batteries, setup options
- **Be sure to avoid sources of interference**
  - Microwaves, buildings, cliffs, trees, etc.

Managing Real-World Objects

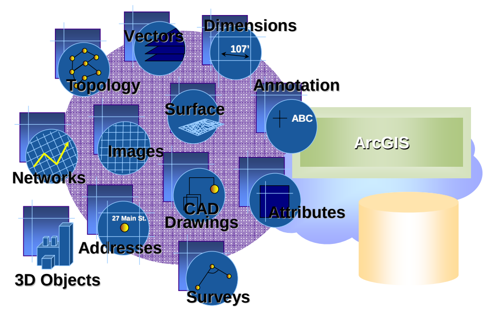
A GIS is more than just a database with coordinates…

Geodatabases Abstract Knowledge



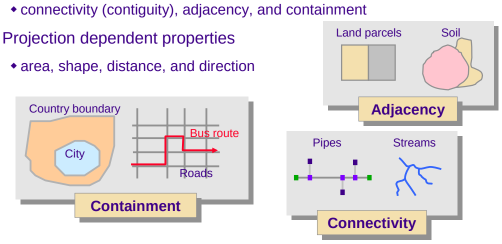
… GIS abstracts and serves a geospatial business logic through database tables!

Geodatabase Objects



Topology is About Relationships

- **A field of study focusing on the properties of shapes that remain constant when the shapes are deformed (e.g. through projections or datum transformations)**
  - Projection independent properties
    - connectivity (contiguity), adjacency, and containment
  - Projection dependent properties
    - area, shape, distance, and direction



Understanding Behavior

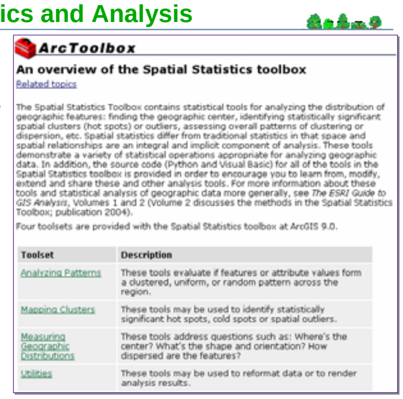
- **Topology gives us the syntax and vocabulary for defining what we learn through our research**
  - How strong is the species preference for steep slopes, for specific aspects, or soils? Why is it where it is?
  - How can we expect a species to response to treatments? How can spatial considerations affect the results?
  - What was my return on investment for a treatment? Where can I expect even better returns for my efforts?
- **Spatial Analysis, Geographic Business Logic, and Spatial Modeling gives us answers to questions, … … but only when we learn how to ask the questions!**

Data Modeling and Initiatives

- **SAMAB (SAIN) – a great start at collecting and disseminating descriptive spatial data**
- **NBII (ISIN) – a great forum for building on the sharing of spatial knowledge**
- **2003 *Biodiversity Modeling Workshop: Results and Recommendations* - "planning for the eventual shift from descriptive to functionally mechanistic models will be important to accurately depict both current and potential future species distributions."**

Spatial Statistics and Analysis

- **New collection of analytical tools that come standard with ArcGIS 9 licenses**



ArcToolbox

An overview of the Spatial Statistics toolbox

Related topics

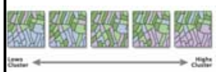
The Spatial Statistics Toolbox contains statistical tools for analyzing the distribution of geographic features: finding the geographic center, identifying statistically significant spatial clusters (hot spots) or outliers, assessing overall patterns of clustering or dispersion, etc. Spatial statistics differ from traditional statistics in that space and spatial relationships are an integral and implicit component of analysis. These tools demonstrate a variety of statistical operations appropriate for analyzing geographic data. In addition, the source code (Python and Visual Basic) for all of the tools in the Spatial Statistics toolbox is provided in order to encourage you to learn from, modify, extend and share these and other analysis tools. For more information about these tools and statistical analysis of geographic data more generally, see *The ESRI Guide to GIS Analysis*, Volumes 1 and 2 (Volume 2 discusses the methods in the Spatial Statistics Toolbox; publication 2004).

Four toolsets are provided with the Spatial Statistics toolbox at ArcGIS 9.0.

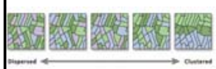
Toolset	Description
Analyzing Patterns	These tools evaluate if features or attribute values form a clustered, uniform, or random pattern across the region.
Mapping Clusters	These tools may be used to identify statistically significant hot spots, cold spots or spatial outliers.
Measuring Geographic Distributions	These tools address questions such as: Where's the center? What's the shape and orientation? How dispersed are the features?
Utilities	These tools may be used to reformat data or to render analysis results.

Analyzing Patterns

Average Nearest Neighbor Distance	The average nearest neighbor distance tool calculates the average nearest neighbor distance based on feature centroids. Available with any ArcGIS license.



High/Low Concentration	Measures concentrations of high or low values for a study area. Available with any ArcGIS license.



Spatial Autocorrelation	Measures spatial autocorrelation based on feature locations and attribute values. Available with any ArcGIS license.

Mapping Clusters

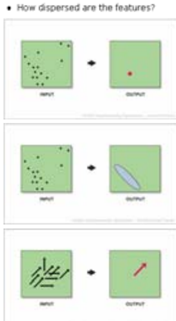
Cluster and Outlier Analysis	Given a set of weighted data points, identifies those clusters of points with values similar in magnitude, and those clusters of points with very heterogeneous values. Available with any ArcGIS license.

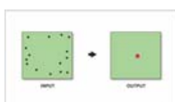
Hot Spot Analysis	Calculates Getis-Ord Gi* statistic for hot spot analysis. Available with any ArcGIS license.

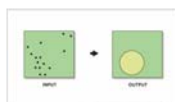
Measuring Geographic Distributions

The Measuring Geographic Distributions toolset addresses questions such as:

- Where's the center?
- What's the shape and orientation of the data?
- How dispersed are the features?





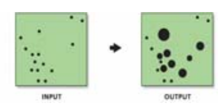


Tool	Description
Central Feature	Identifies the most centrally located feature in a point, line, or polygon feature class. Available with any ArcGIS license.
Directional Distribution	Measures whether a distribution of features exhibits a directional trend (whether features are farther from a specified point in one direction than in another direction). Available with any ArcGIS license.
Linear Directional Mean	Identifies the general (mean) direction for a set of vectors. Available with any ArcGIS license.
Mean Center	Identifies the geographic center (or the center of concentration) for a set of features. Available with any ArcGIS license.
Standard Distance	Measures the degree to which features are concentrated or dispersed around the points (or feature centroids) in an input feature class. Available with any ArcGIS license.

Utilities

These utility scripts perform a variety of data conversion and rendering tasks. They were designed for use in conjunction with other tools in the spatial statistics toolbox. The following table lists the tools available and provides a brief description of each.

Tool	Description
Calculate Areas	Creates a field with AREA values for each feature in a polygon feature class. Available with any ArcGIS license.
Collect Events	Creates a weighted point feature class from incident/event point data. Available with any ArcGIS license.
Count Rendering	Applies graduated circle rendering to a count type field of a point feature class. Available with any ArcGIS license.
Export Feature Attributes to ASCII	Given an input feature class and field, this tool creates an X, Y, <field value> ASCII text file. Available with any ArcGIS license.
Z Score Rendering	Applies a "cold to hot" graduated color rendering to a field of Z Scores. Available with any ArcGIS license.



Useful Conclusions on GIS

- **Think of a GIS as a method of utilizing a database to model everything you know about a species or a treatment, not just a way to build a "map"**
  - Learn to "model" instead of just how to "store" data
- **Let the computer do the "work" of maintaining databases and analyzing relationships while you "think" of useful questions**
  - Learn the language of GIS instead of being caught up in technology
- **Share your data, but be sure it is useful by creating appropriate metadata**
  - Learn to share "information" and "knowledge" instead of raw data