Errors in GIS

GEOG 300, Lecture 14

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Error and Uncertainty

- Uncertainty
  - A lack of sureness about something… the same as a lack of knowledge
    - lack of knowledge about level of error
      - Indicates the extent of unreliability
- Error
  - degree of doubt in a measurement
  - e.g. 5% error (calculated by difference between known & measured values)

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Error and Uncertainty

- UNCERTAINTY…
  - To you the scientist:
    - A statement of knowledge
    - Useful information on the limits
- UNCERTAINTY…
  - To the general public and decision makers:
    - Sign of weakness
    - Lack of trust and confidence
    - Confusing

Propagation of Errors

- In GIS applications we combine data from different sources.
  - The data have uncertainties associated with them.
    - How can you state the effect of these uncertainties to the final result?
    - What impact does error in each data layer have on the final result?

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Propagation of Errors

- Example:
  - Find the most likely locations where human settlement will infringe on the Agricultural Land Reserve.
    - The data for the study area are available in a raster format
    - You have identified about 10 factors likely to influence infringement e.g.
      - agricultural productivity (dollars per hectare)
      - Existing settlements (presence or absence)
      - Parcel size (number of owners per hectare)

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Propagation of Errors

- Example:
  - the factors can be combined, or cascaded, to a single measure of ***likelihood*** on a scale of 0 through 10
    - the cascading rules could group factors into composites such as "social impact", "agricultural impact" and then weight each group relative to the others
    - the rules used in cascading include weighted addition: likelihood = w1x1 + w2x1
      - as well as simple conditions:
      - likelihood = 0 if settlement = "present"
      - and reclassifications:
        - likelihood = 3 if factor A has value of X

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Propagation of Errors

- Error Analysis
  - Sources of errors in the above example?
    - Input data
    - relative importance of factors
  - It quickly becomes evident that rigorous analytical methods are needed to ascertain errors in the final outputs.

"the ultimate arbiter of cartographic error is the real world, not a mathematical formulation"

Nicholas R. Chrisman

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Propagation of Errors

- Errors propagate due to the multiplication of numerical error and initial measurement error.
- Estimating the degree of an error is an important area of research in GIS and computational science.

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Error Analysis

- Error Analysis:
  - Some Methods
    - Sensitivity Analysis
      - Used to determine how different values of an input variable(s) impact the output.
      - Described as the study of how uncertainty in the output of a model can be attributed to different sources of uncertainty in the inputs
    - Validation
      - Used to determine how close the results match up to data in the real world

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Error Analysis

- Error Analysis:
  - Cross-validation
    - remove one data value at a time and predict its associated value using the values at the rest of the locations

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Error Mitigation

- Techniques to mitigate sources of errors?
  - Quality Control in measurements
  - Develop standards
  - …
- Consider spatial location differences between imagery
  - Are there errors or just expected differences

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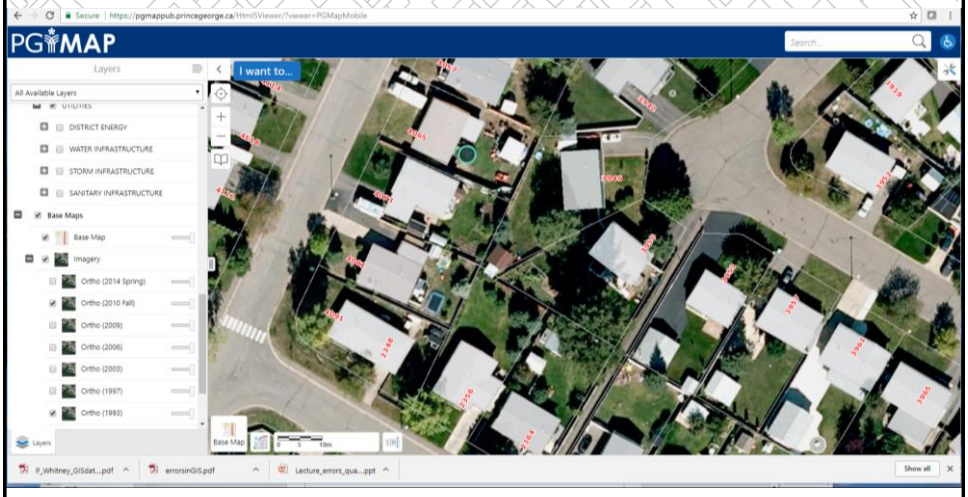

2010 Imagery

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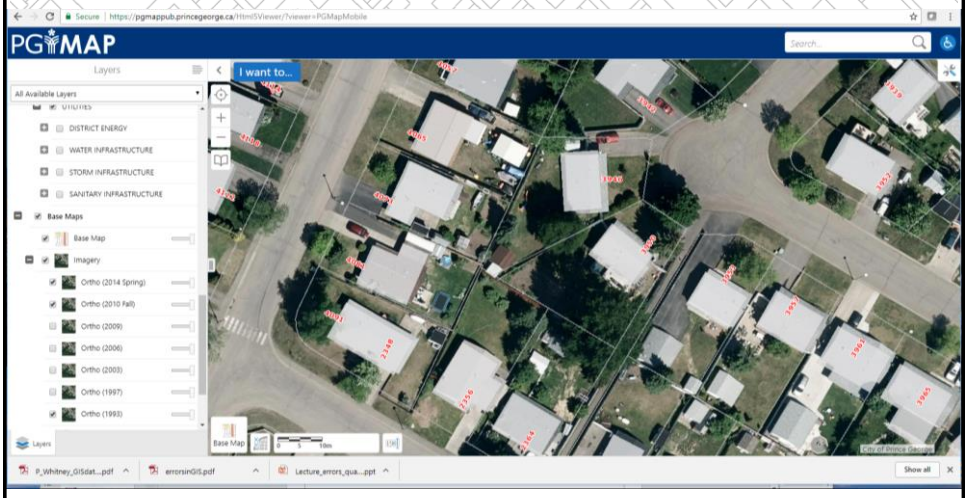

2014 Imagery

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RMSE

- **Root Mean Square Error (RMSE)**
  - A measure of the differences between predicted values (results) and the values actually observed (real world).
  - The RMSE represents the standard deviation of the differences between predicted values and observed values

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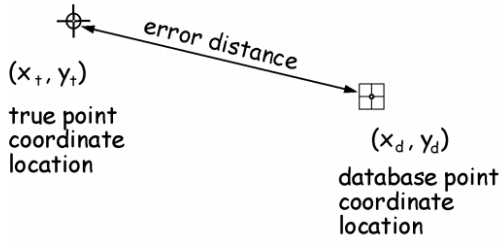
RMSE

- **Root Mean Square Error (RMSE)**

One needs measured coordinates and true coordinates



The lower the error distance, the more the accuracy

$$\text{error distance} = \sqrt{(x_t - x_d)^2 + (y_t - y_d)^2}$$

RMSE

- $RMSE = \sqrt{\frac{e_1^2 + e_2^2 + e_3^2 \ldots e_n^2}{n}}$

e = error distance
n = number of observations

- Try it
  - https://www.dropbox.com/s/fb0e7g07an08bgb/rmse_sample_data.xlsx?dl=0

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Some not good practices

- Bad Analysis Practices
  - Overstating the accuracy of the results
    - Data accuracy/quality
      - Vector
      - Raster
    - Area proportion overlays
    - Mixed scales
    - Attribute accuracy
  - Ignoring topological errors

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MAUP

- The Modifiable Areal Unit Problem (MAUP)
  - “a problem arising from the imposition of artificial units of spatial reporting on continuous geographical phenomena resulting in the generation of artificial spatial patterns”
  - Geographical boundaries are imposed.
    - They do not relate in any meaningful sense to the variables of interest.
  - Data are aggregated from source observations to zones or output areas which have no special meaning in terms of the underlying geographical process of phenomenon.

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MAUP

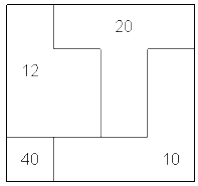
100	200	400	100
200	300	500	100
400	200	100	100
300	100	200	100

Total population in 16 areas

10	20	20	20
5	10	20	10
15	15	20	10
40	10	10	10

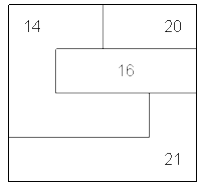
Percentage unemployment

(A)



Percentage unemployment aggregated to four areas

(B)



Percentage unemployment aggregated to four areas

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http://www.restore.ac.uk/geo-refer/91023cwors00y00000000.php

Ecological Fallacy

- Ecological Fallacy:
  - The interpretation of statistical data where inferences about individuals are deduced from data for the group to which those individuals belong.
  - Relationships observed for groups do not necessarily hold for individuals, and vice versa
  - For instance, assume that you measured the average weight of moose in Jasper, you cannot expect that the next moose you see is of the same weight.

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Coordinate adjustments	*Generalization*
rubber sheeting/transformations	linear alignment
projection changes	line simplification
datum conversions	addition/deletion of vertices
rescaling	linear displacement
Feature Editing	*Raster/Vector Conversions*
line snapping	raster cells to polygons
extension of lines to intersection	polygons to raster cells
reshaping	assignment of point attributes
moving/copying	to raster cells
elimination of spurious polygons	post-scanner line thinning
Attribute editing	*Data input and Management*
numeric calculation and change	digitizing
text value changes/substitution	scanning
re-definition of attributes	topological construction / spatial indexing
attribute value update	dissolving polygons with same attributes
Boolean Operations	*Surface modelling*
polygon on polygon	contour/lattice generation
polygon on line	TIN formation
polygon on point	Draping of data sets
line on line	Cross-section/profile generation
overlay and erase/update	Slope/aspect determination
Display and Analysis	*Display and Analysis*
cluster analysis	class intervals choice
calculation of surface lengths	areal interpolation
shortest route/path computation	perimeter/area size/volume computation
buffer creation	distance computation
display and query	spatial statistics
adjacency/contiguity	label/text placement

Common Sources of Errors in GIS Analysis

All Analyses?

Hunter, G. J., and Beard, K. Understanding error in spatial databases. The Australian Surveyor 37, 2 (1992), 108–119. 433

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