GIS and Spatial Statistics: One World View or Two?

Michael F. Goodchild
University of California
Santa Barbara

Location as attribute

- The data table
  - Census summary table
- What value is location as an explanatory variable?
- Linking the table to a boundary file
  - enabling maps of summary data

Tract	Pop	Location	Shape
1	3786	*x*,*y*	
2	2966	*x*,*y*	
3	5001	*x*,*y*	
4	4983	*x*,*y*	
5	4130	*x*,*y*	
6	3229	*x*,*y*	
7	4086	*x*,*y*	
8	3979	*x*,*y*	

Abstraction of geographic space

- Cartograms

- Invariance under rotation, displacement
- Reconstruction from a distance matrix
- Reconstruction from ranked distances
  - ordered metric data (Coombs)

Space as a matrix

- ***W*** where w_{ij} is some measure of interaction
  - adjacency
  - decreasing function of distance
  - invariant under rotation, displacement
  - readily obtained from a GIS

Applications of the *W* matrix

- Spatial regression
  - add spatially lagged terms weighted by ***W***
  - Anselin's SPACESTAT
- Moran and Geary indices of spatial dependence

$$c = \frac{(n-1)\sum_i \sum_j w_{ij}(x_i - x_j)^2}{2\sum_i \sum_j w_{ij} \sum_i (x_i - a)^2}$$

The location-as-attribute world view

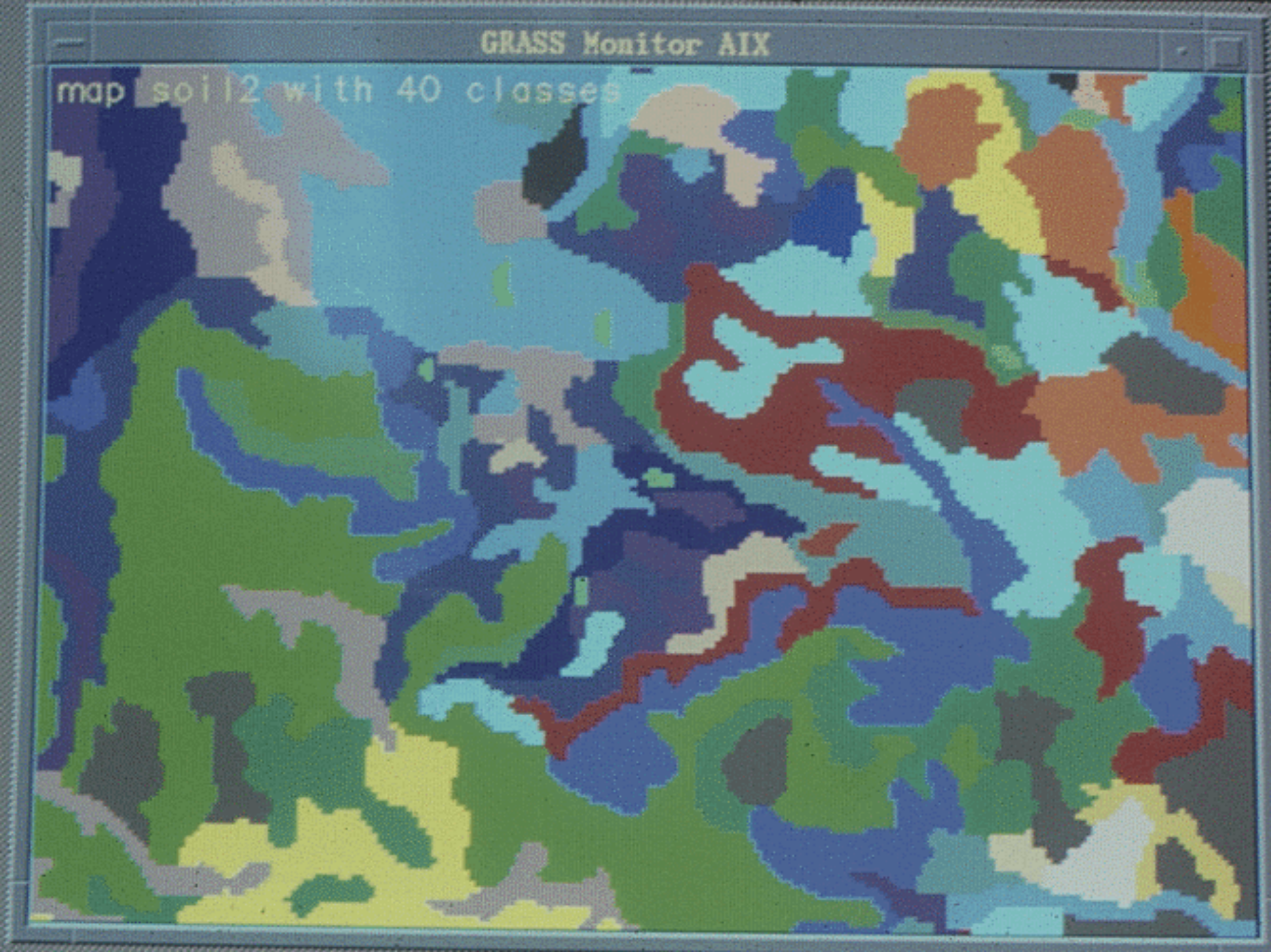
- Objective: scientific explanation, understanding of social processes
  - is location an explanatory factor?
- Relative location as expressed in the ***W*** matrix
  - a surrogate for spatial interaction
  - reflecting costs of transport, probability of interaction and acquaintance, probability of migration or travel, probability of seed dispersal

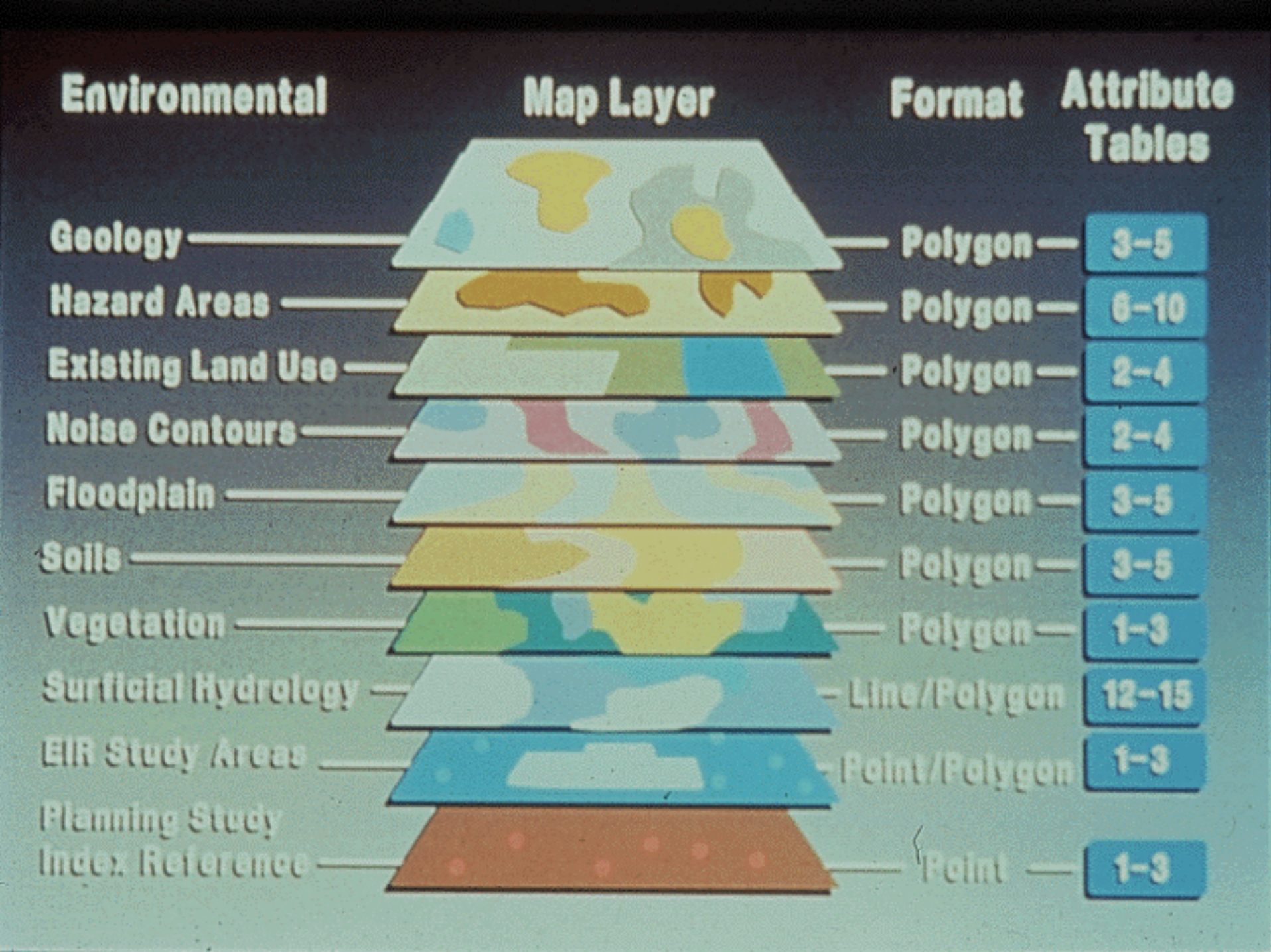
Geographic information systems

- Systems to acquire, store, transform, analyze, display, share, archive geographic information
- Geographic information
  - information about the specific characteristics of places on or near the Earth's surface
  - <***x***,***z***> where ***x*** is a location in space-time and ***z*** is some set of general properties

Origins of GIS

- The Canada Geographic Information System
  - circa 1965
  - support for the Canada Land Inventory
  - $20 million investment by the Government of Canada
  - justified by accurate cost-benefit analysis


GRASS Monitor AIX
map soil2 with 40 classes


Environmental
Map Layer
Format
Attribute Tables
Geology
Hazard Areas
Existing Land Use
Noise Contours
Floodplain
Soils
Vegetation
Surficial Hydrology
EIR Study Areas
Planning Study Index Reference
Polygon
Polygon
Polygon
Polygon
Polygon
Polygon
Polygon
Line/Polygon
Point/Polygon
Point
3-5
6-10
2-4
2-4
3-5
3-5
1-3
12-15
1-3
1-3

Objectives of GIS

- Mapping and inventory
  - representing the contents of the Earth's surface
  - using space (and time) as the organizing dimensions
- Design
  - formulation, evaluation of future scenarios
- Support for science
  - search for pattern, anomalies, hypotheses, explanation
  - integrating layers of data
  - geographic context

The impact of the Internet

- Communication of geographic knowledge as the new purpose
  - sharing what we know
  - geographic information as a public good
  - spatial analysis as added value, manipulation of the message
  - spatial data archives and clearinghouses, the National Spatial Data Infrastructure

Fundamental parameters of the communication paradigm

- Technical
  - bandwidth, speed, access, reliability
  - interoperability, semantics, understanding
- Media and formal structures
  - visual, auditory, tactile
  - speech, text, imagery, maps, tables…
  - facilitating or imposing

Spoken word

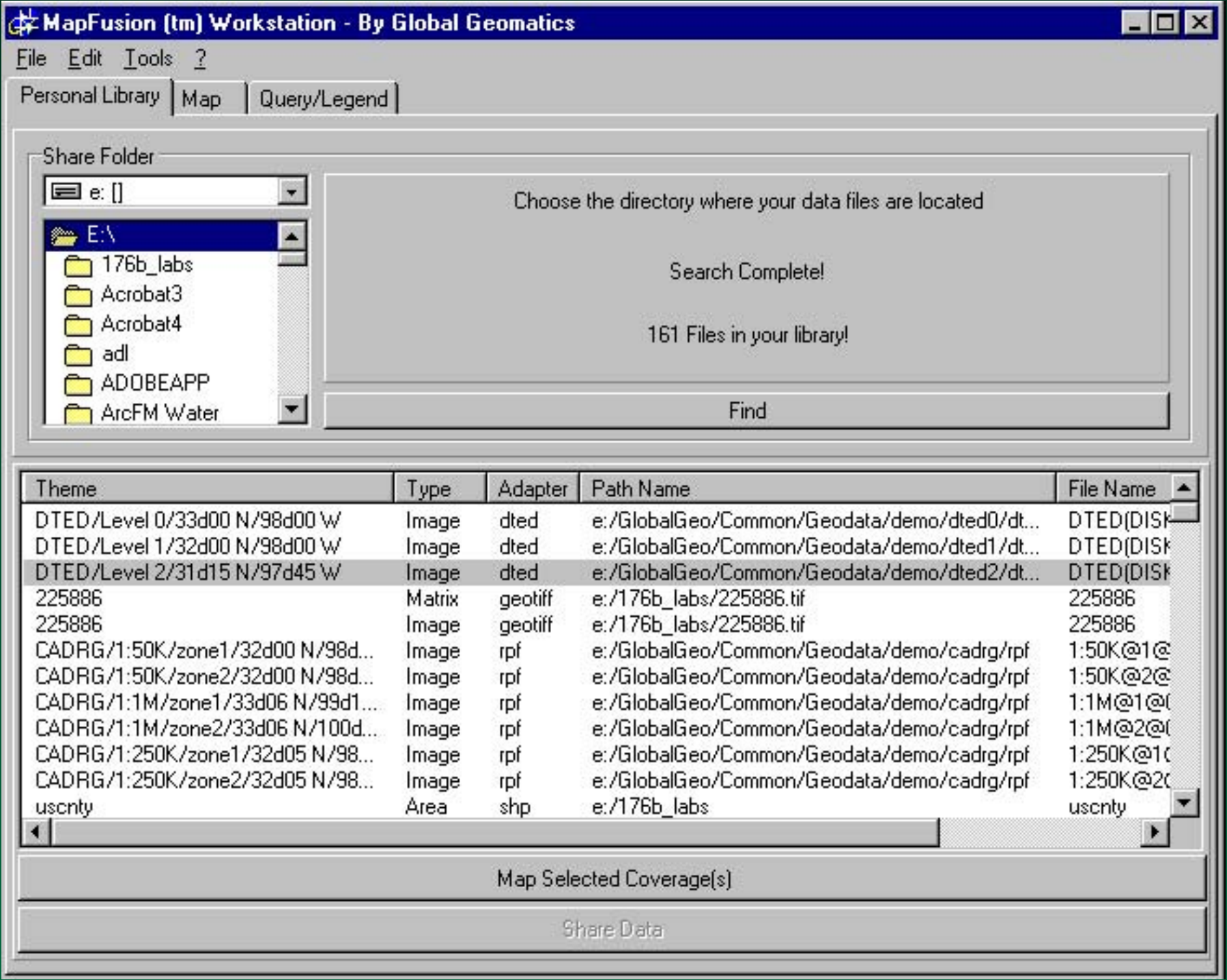
Text

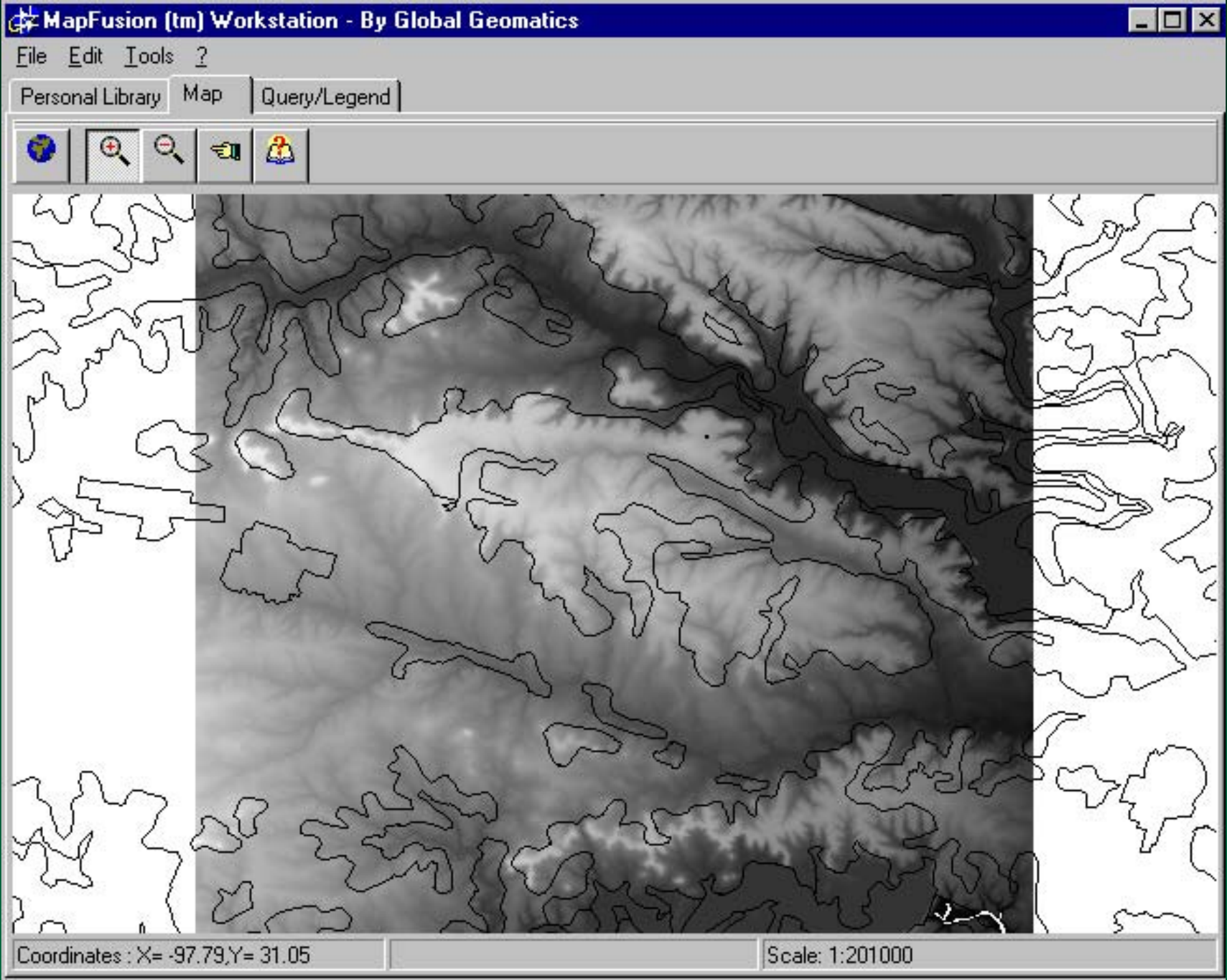
Picture

x, *y*, *T*

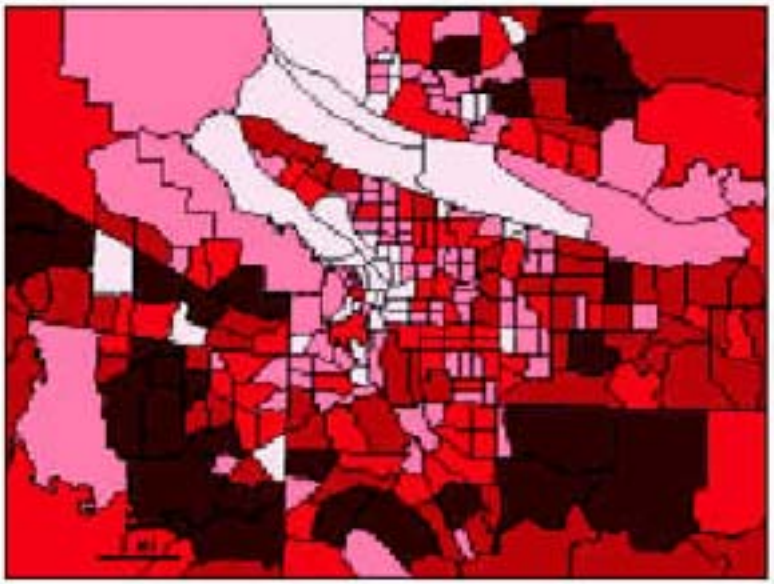
Interoperability

- Common understanding of meaning
  - semantics over syntax
  - ***x*** is more commonly understood than ***z***


MapFusion (tm) Workstation - By Global Geomatics
File Edit Tools ?
Personal Library
Map
Query/Legend
Share Folder
e: []
E:\
176b_labs
Acrobat3
Acrobat4
adl
ADOBEAPP
ArcFM Water
Choose the directory where your data files are located
Search Complete!
161 Files in your library!
Find
Theme
Type
Adapter
Path Name
File Name
DTED/Level 0/33d00 N/98d00 W
Image
dted
e:/GlobalGeo/Common/Geodata/demo/dted0/dt...
DTED/Level 1/32d00 N/98d00 W
Image
dted
e:/GlobalGeo/Common/Geodata/demo/dted1/dt...
DTED/Level 2/31d15 N/97d45 W
Image
dted
e:/GlobalGeo/Common/Geodata/demo/dted2/dt...
225886
Matrix
geotiff
e:/176b_labs/225886.tif
225886
Image
geotiff
e:/176b_labs/225886.tif
225886
CADRG/1:50K/zone1/32d00 N/98d...
Image
rpf
e:/GlobalGeo/Common/Geodata/demo/cadrg/rpf
1:50K@1@
CADRG/1:50K/zone2/32d00 N/98d...
Image
rpf
e:/GlobalGeo/Common/Geodata/demo/cadrg/rpf
1:50K@2@
CADRG/1:1M/zone1/33d06 N/99d1...
Image
rpf
e:/GlobalGeo/Common/Geodata/demo/cadrg/rpf
1:1M@1@
CADRG/1:1M/zone2/33d06 N/100d...
Image
rpf
e:/GlobalGeo/Common/Geodata/demo/cadrg/rpf
1:1M@2@
CADRG/1:250K/zone1/32d05 N/98...
Image
rpf
e:/GlobalGeo/Common/Geodata/demo/cadrg/rpf
1:250K@1
CADRG/1:250K/zone2/32d05 N/98...
Image
rpf
e:/GlobalGeo/Common/Geodata/demo/cadrg/rpf
1:250K@2
uscnty
Area
shp
e:/176b_labs
uscnty
Map Selected Coverage(s)
Share Data


MapFusion (tm) Workstation - By Global Geomatics
File Edit Tools ?
Personal Library
Map
Query/Legend
Coordinates : X= -97.79,Y= 31.05
Scale: 1:201000

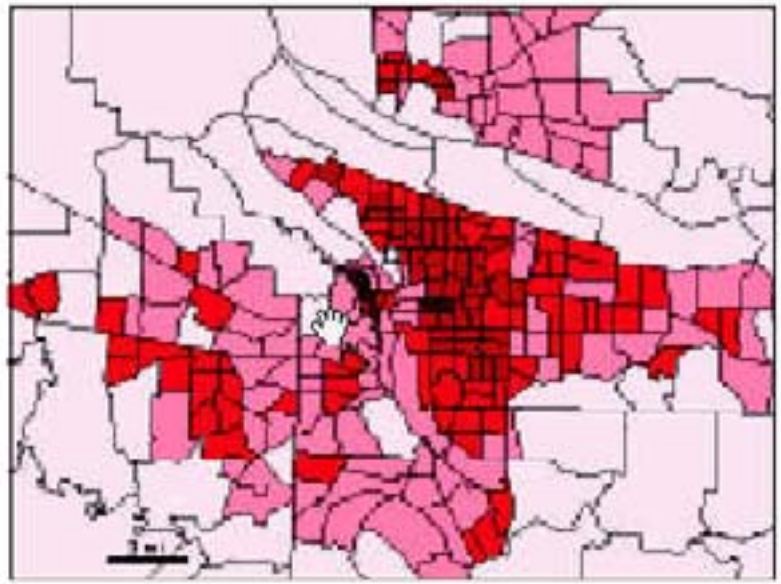
If you want to know approximately how many people each census tract has, map total population.



132 - 2224
2225 - 3900
3901 - 5507
5508 - 7732
7733 - 12611

Census tracts by total population.

If you want to know where most of the people are concentrated. map population density.



8 - 1882
1883 - 4409
4410 - 6906
6907 - 11111
11112 - 21334

Census tracts by people per square mile.

The Modifiable Areal Unit Problem

- Openshaw and Taylor
  - 99 counties of Iowa
  - % Republican voters, % over 65
- 48 regions: -.548 to +.886
- 12 regions: -.936 to +.996
- Solutions:
  - manipulate to determine range
  - strengthen theoretical framework

The GIS data types

- Discrete geographic features
  - points, lines, areas
  - the contents of maps
  - with associated attributes
  - countable
  - conceived as tables with associated feature geometry
- ESRI shapefiles

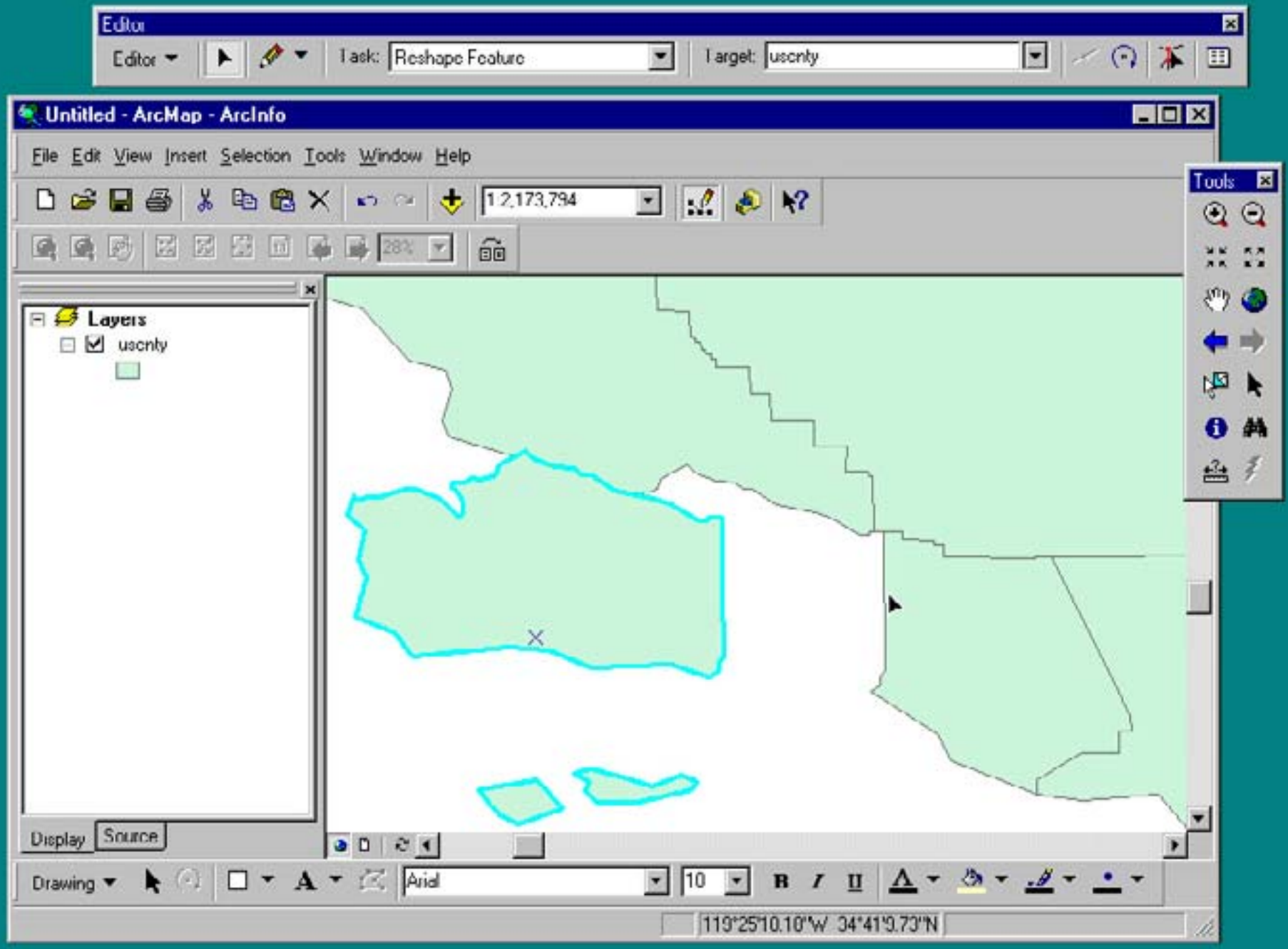
Scottish Munros

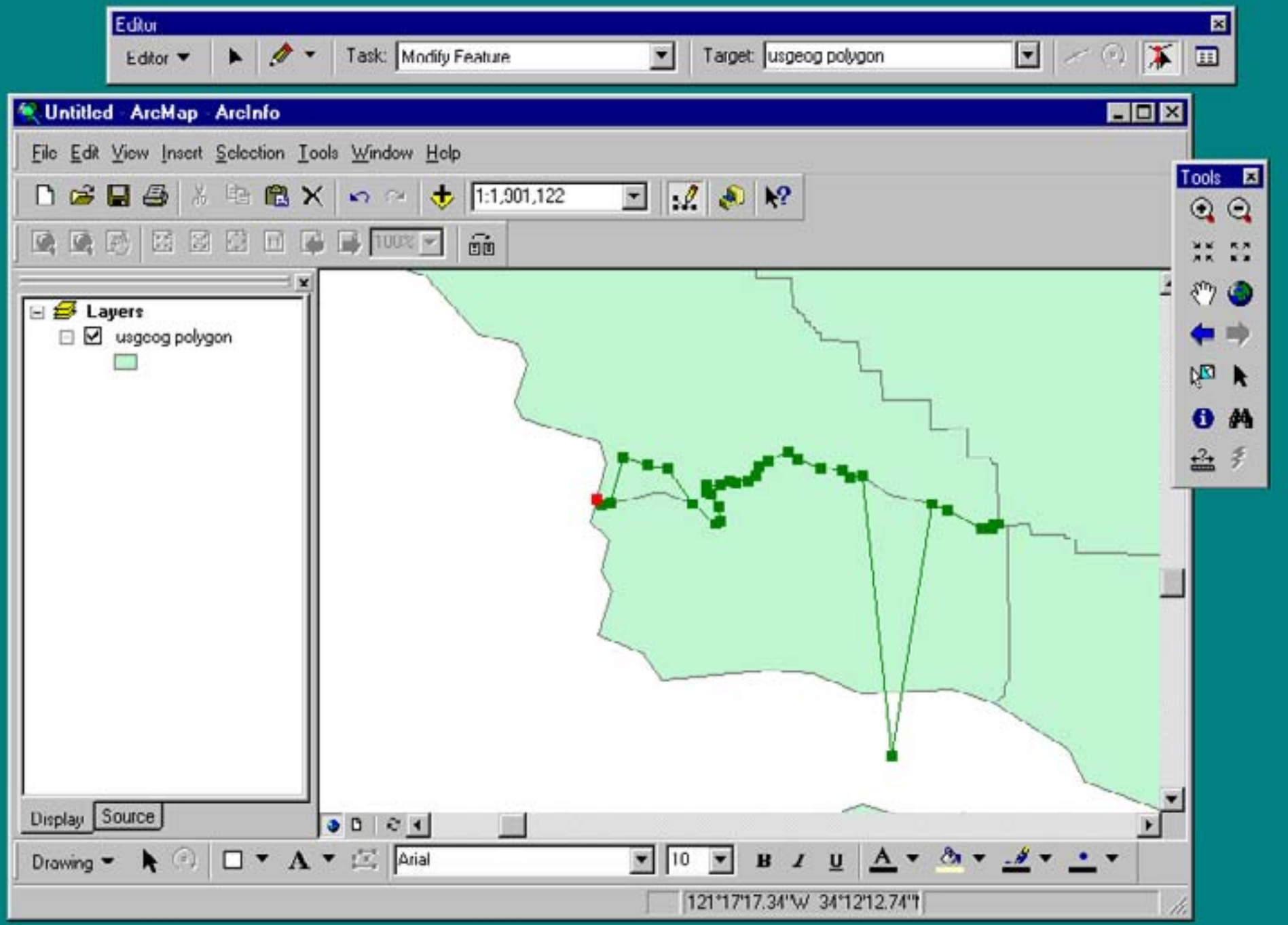
1.. Ben Hope
2.. Ben Klibreck
3..Ben More Assynt
4..An Teallach
5..Seana Bhraigh
6..Ben Wyvis
7..Slioch
8..Sgorr Ruadh
9..Moruisg
10..Sgurr na Ruaidhe
11..Bia Bheinn
12..Sgurr na Lapalch
13..Ben Attow
14..The Saddle
15..Creag a' Mhaim
16..Ladhar Bheinn

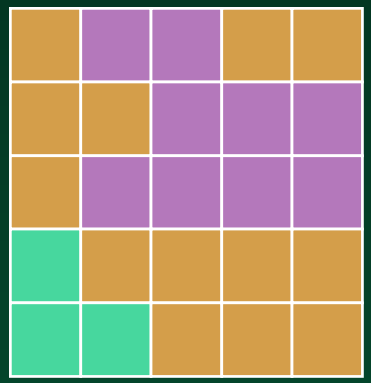
17..Coireachan
18..Ben Nevis
19..Ben More
20..Ben Starav
21..Braeriach
22..Ben Avon
23..Meall Chuaich
24..Mt Keen
25..Deinn Dearg
26..Glas Maol
27..Driesh
28..Schiehallion
29..Ben Chonzie
30..Den Lawers
30..Ben Challum
32..Ben Lomond

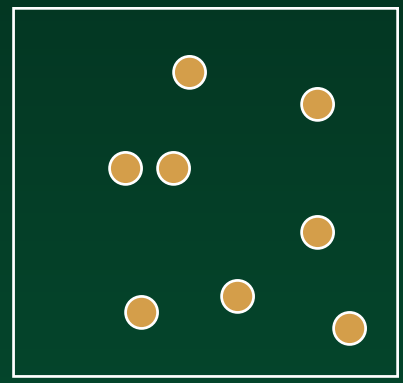
Fields

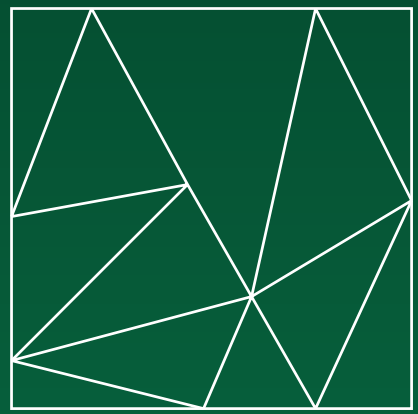
- Geography as a collection of continuous variables
  - measured on nominal, ordinal, interval, ratio scales
  - vector fields of direction and magnitude
  - exactly one value per point
  - $z=f(\mathbf{x})$
  - population density, land ownership, zoning

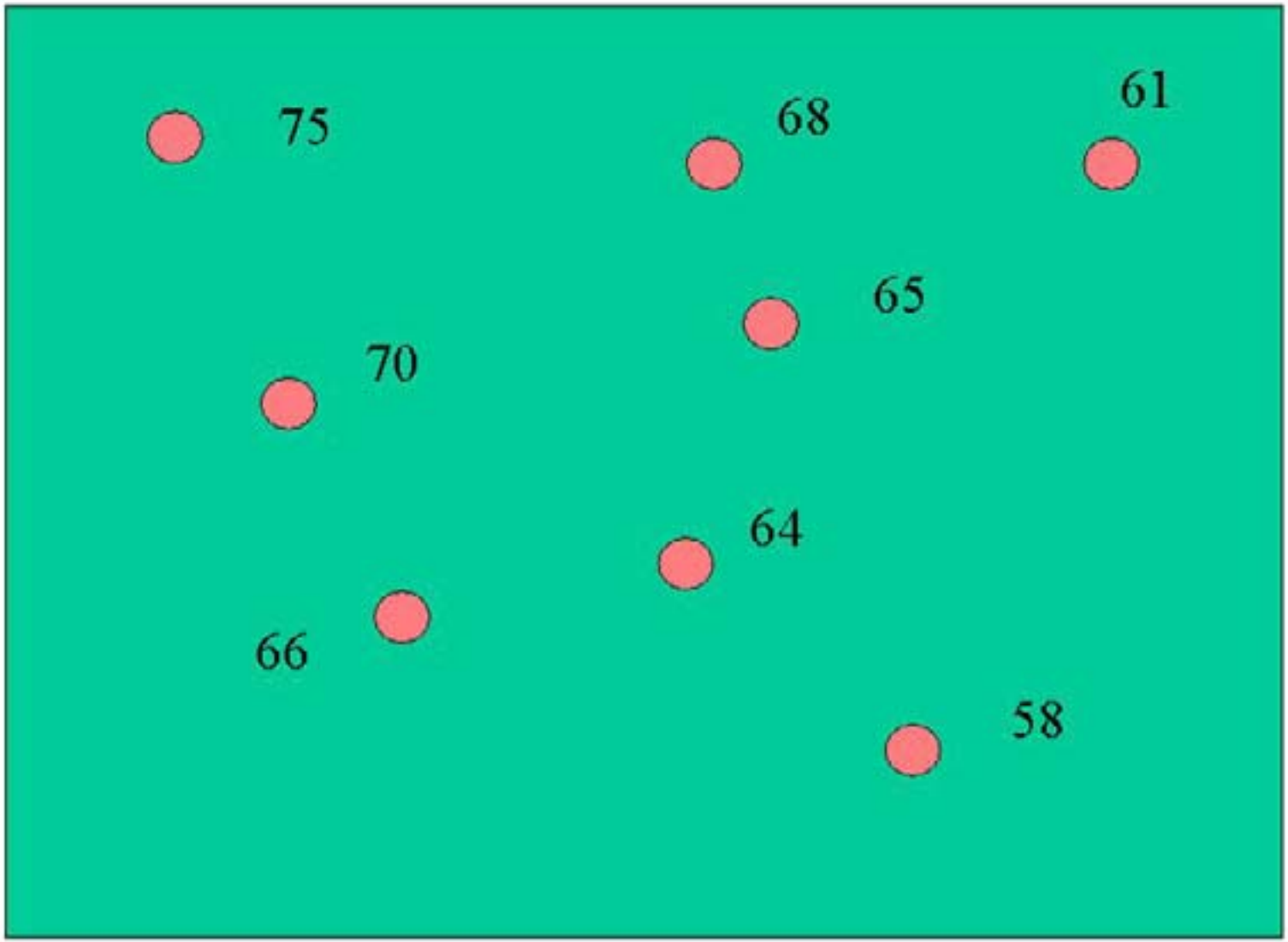

Editor
Editor
Task:
Reshape Feature
Target:
uscnty
Untitled - ArcMap - ArcInfo
File Edit View Insert Selection Tools Window Help
1:2,173,794
Tools
Layers
uscnty
Display
Source
Drawing
Arial
10
119°25'10.10"W 34°41'0.73"N


Editor
Editor
Task: Modify Feature
Target: usgeog polygon
Untitled - ArcMap - ArcInfo
File Edit View Insert Selection Tools Window Help
1:1,901,122
Tools
Layers
usgeog polygon
Display
Source
Drawing
Arial
10
121°17'17.34"W 34°12'12.74"N








75
68
61
65
70
64
66
58

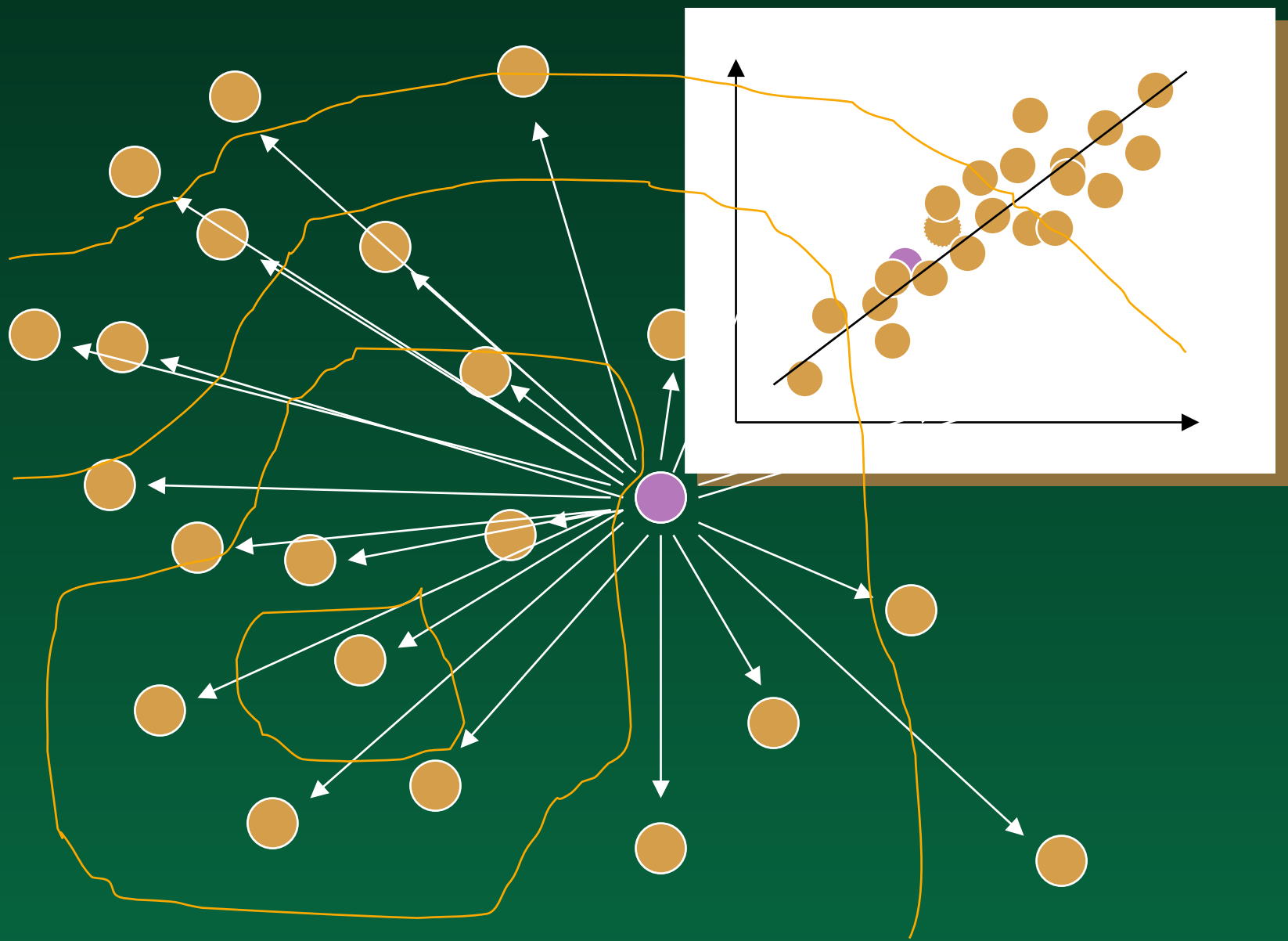
The location-as-continuum world view

- Discrete objects result from human interpretation
- Social processes respond to both fields and discrete objects
- Reporting zones lump the continuum in arbitrary ways

Spatial heterogeneity

- Uncontrolled variance over the Earth's surface
- There is no average place
- Results depend explicitly on bounds
- Places as samples
- Consider the model:

  $y = a + bx$



Spatial dependence

- The First Law of Geography (Tobler)
  - all things are related but nearby things are more related than distant things
- Acceptance of the null hypothesis of no spatial dependence is always a Type II error
- Hell is a place with no spatial dependence

Integrating GIS and spatial statistics

- Role of space
  - an organizing dimension for information
  - a source of context and linkage
  - an explanatory variable
  - a problem
- Terminology
  - lattice, support, drift, topology, layer, coverage, region
- Software as glue
  - within what conceptual framework?