Spatial Relationship Networks: Network Theory Applied to GIS Data

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Agenda

- GIS Database Production
- Associations
- Spatial Relationships
- Spatial Relationship Networks
- Ontology

GIS Database Production

- Image Derived.
- Field Collection.
- OPD – Other Peoples Data.

- Costly.
- Time Consuming.
- Never Complete.
- Never Detailed Enough.

1st Law of Geography

"Everything is related to everything else; however, closer things are more related."

Waldo Tobler, 1970

Our Premise…

It is possible to predict the existence of unknown features…

Based on
the locations of known features.

The Genesis of Cultural Features…

- The placement of cultural objects on the terrain is a conscious effort:
  - Relative to existing terrain features.

AND / OR

  - Relative to other cultural objects.

Basic Feature Database Augmentation…

- Human interaction with the environment…
  - Is often predictable.
  - It is often rule-based.
  - It is often based on laws, ordinances, and/or tradition.

Associations

- Commonly occurring co-existences.
- The basis of spatial analysis.
- When deconstructed:

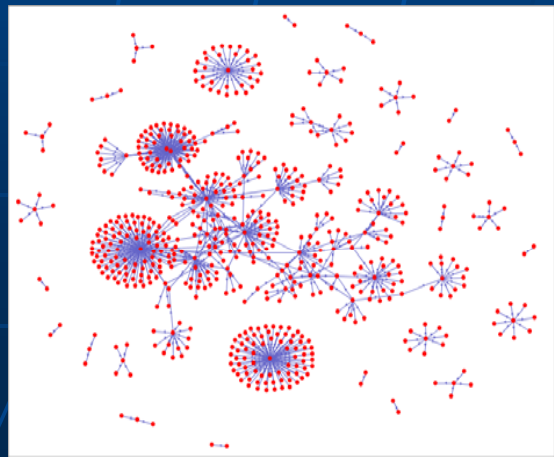
- Obvious
- Often Subtle
- Unperceived
- Regional
- Repeating
- Statistical

Spatial Relationships

- Topology
- Extended Spatial Relationships
  - Adjacency – inside, surround, connected
  - Proximity – near, far
  - Containment – inside, outside
  - Orientation – angular, parallel, perpendicular
  - Intersection – touches, connects, crosses
  - Surface Relations – above, below
  - Network Relations – nodes, links
  - Groupings – clusters, scattered
  - Shape Descriptions –circular, rectangular

Spatial Relationship Networks...

- By Identifying Commonalities.
  - Commonly Occurring Associations.
  - Their Spatial Relationships.
  - Probability of Occurrence.
- A Complex Logical Network Results.
- With an Inference Engine Predict New Feature Content.
- Probabalistic Feature Content.



Spatial Relationships

- A name and attributes.
- “Unambiguously” defined.
- Synonyms
- Named using IT style.
  - Formal name plus optional variable.
  - Differentiate from textual counterpart.

Spatial Relationship Classes

srLocationOf( )
srFrom( )
srToward( )
srAbove( )
srBelow( )
srOnTop( )
srBeneath( )
srOver( )
srUnder( )
srOff( )
srOn( )
srAdjacent( )
srAcrossFrom( )
srBetween( )
srAlong( )
srAlongside( )
srSide( )
srRightSide( )
srLeftSide( )
srAround( )
srAttached( )
srBackSide( )
srBehind( )
srFront( )

srAhead( )
srInFront( )
srAgainst( )
srFacing( )
srNear( )
srFar( )
srCongruent( )
srConnectedTo( )
srConnectWith( )
srDetached( )
srHasPart( )
srOutOf( )
srOutOf( )
srContains( )
srWithin( )
srPartOf( )
srSurround( )
srPartialSurround( )
srAmong( )
srConsistsOf( )
srInside( )
srOutside( )
srOrientation( )
srParallel( )

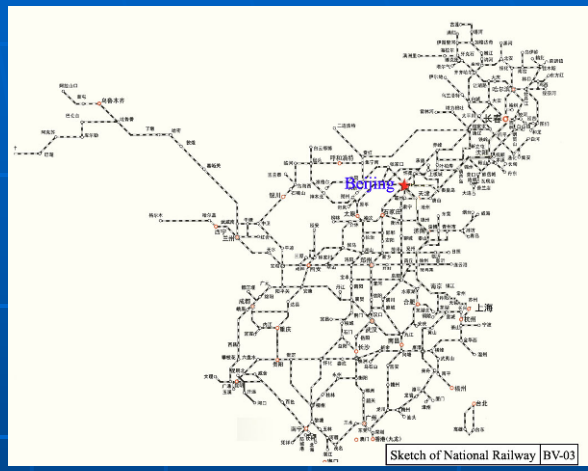
srParallelOutside( )
srParallelWithin( )
srParallelPartialWithin( )
srPerpendicular( )
srPerpendicularOutside( )
srPerpendicularWithin( )
srFacing( )
srIntersects( )
srTouches( )
srOverlaps( )
srThrough( )
srCrosses( )
srOnGround( )
srAboveGround( )
srUnderGround( )
srBranchOf( )
srTributaryOf( )
srTraverses( )
srInterconnecting( )
srCluster( )
srClusterRandom( )
srClusterLinear( )
srClusterNonRandom( )

Spatial Relationship – sRNear( )

- sRNear() - is a proximity spatial relationship defining the relative location in space of two objects. This relationship is often an ambiguous and inexact measure of proximity. The sRNear spatial relation can be defined as either:
  - An unknown linear value [e.g. **sRNear()**;
  - A discrete linear value in meters [e.g. **sRNear(10)** meaning a 10 meter separation];
  - Or as a range of values in meters [e.g. **sRNear(20-100)** meaning a 20 to 100 meter separation].

Spatial Relationship Networks

- **Blatant Spatial Networks**



- **Subtle Spatial Networks**

Ontology

- What exists? What is reality?
- A specification of a conceptualization.
  - Informal - Natural language
  - Formal - Logical language

  - Top-Level - Broad IT Concepts.
  - Domain - Objects, Things.
  - Task - Tasks and Activities.
  - Application - Link Task and Domain

SR Network Knowledge Base

- Define and record a broad set of association axioms and include:
  - Probability of occurrence.
  - Spatial relationships.
  - Probability of spatial relationships.
  - Regional characteristics.

A Basic Residential Example

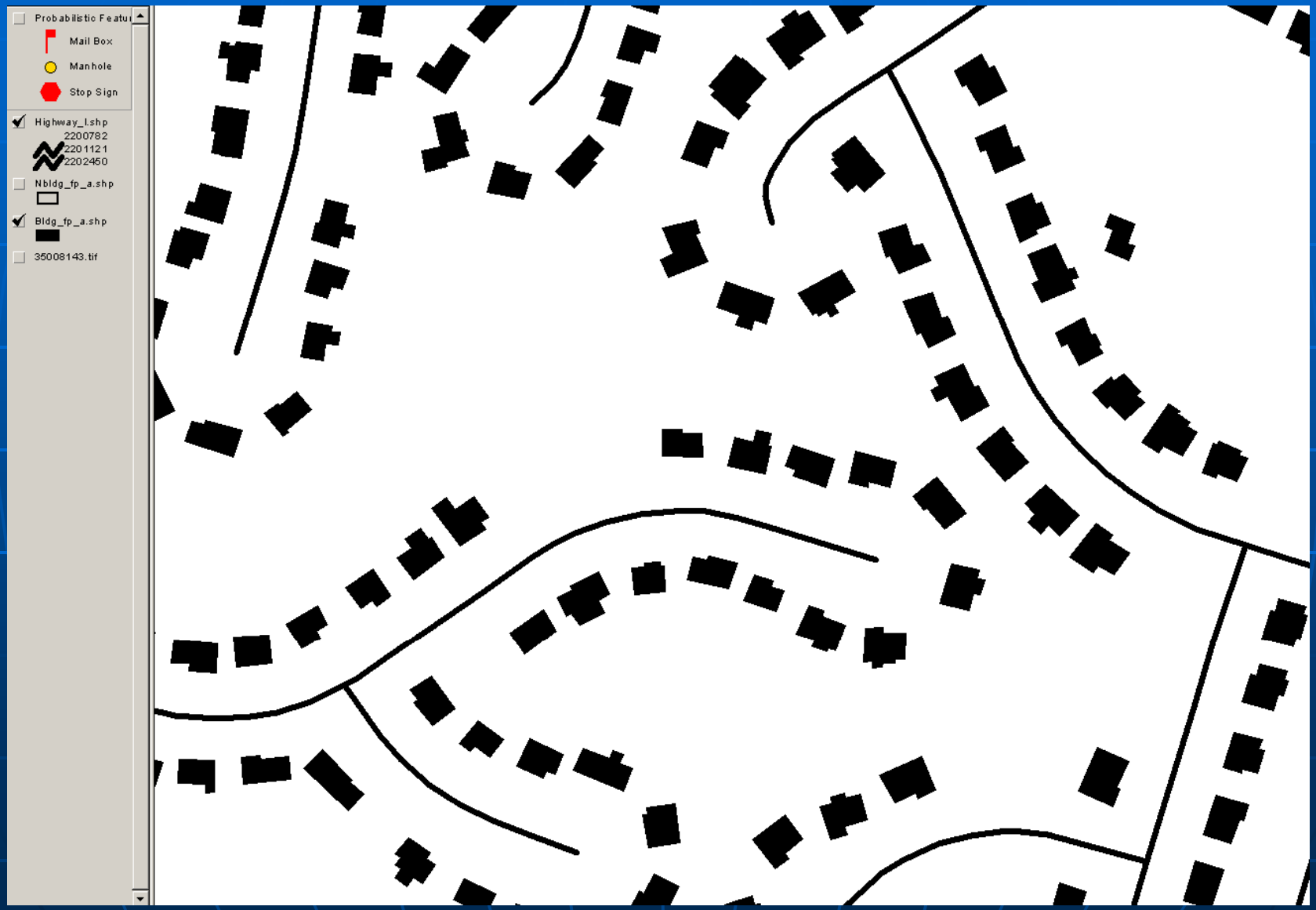
Reference Object	*Association Object*	*Association Probability*	*Spatial Relationships*	*Probability*
SFRD	Mailbox	0.9	srBetween(Street)	0.99
SFRD	Mailbox	0.9	srFacing(Street)	0.99
SFRD	Street	0.8	srFacing(Street)	0.99
SFRD	Street	0.8	srInFront(Street)	0.99
SFRD	Street	0.9	srConnect(Driveway)	0.99
Mailbox	Street	0.99	srNear(1.0)	0.99
Mailbox	Driveway	0.8	srNear(3.0)	0.99
Mailbox	Walkway	0.5	srNear(1.0)	0.99

SFRD = Single-Family Residential Dwelling

The Area Of Interest

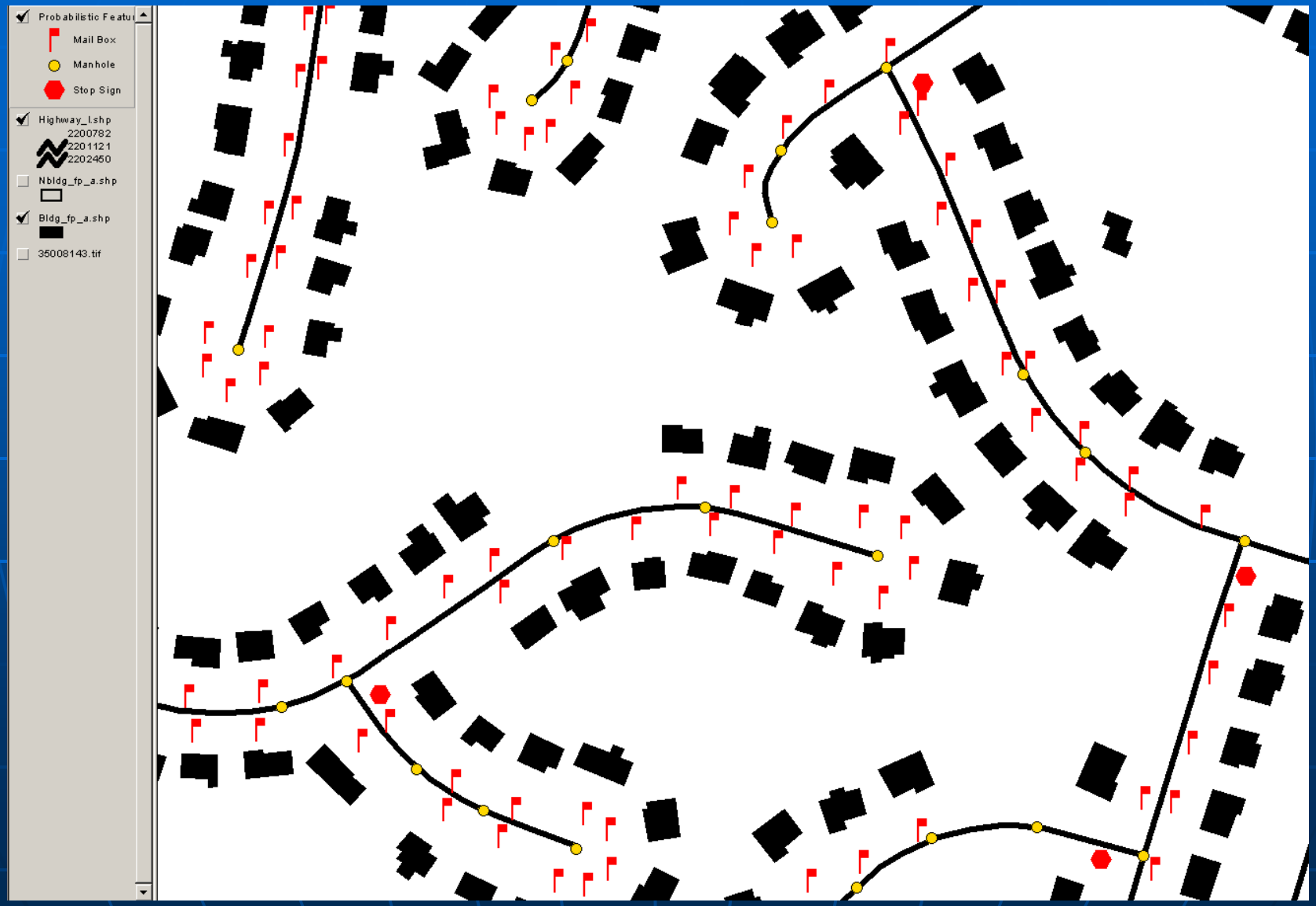
Photo courtesy of http://seamless.usgs.gov

Existing Feature Data



Data courtesy of Loudoun Co. Virginia

Probabilistic Feature Augmentation



Probabilistic Feature Augmentation

Photo courtesy of http://seamless.usgs.gov

Probabilistic Feature Augmentation

Applications...

- Augment Existing Spatial Data.
- Automated Image Extraction.
- Automated Image Interpretation.
- Automated Data Fusion
- Automated Intel Analysis.

Probabilistic Feature Databases

- GIS Production
- Gaming & Simulation.
- Environmental Data.
- Urban Area Analysis.
- Modeling Complex Systems.
- Image Interpretation.
- Data Fusion.

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Backups…

The Visual Objects Taxonomy (VOT)

- <u>A domain ontology of “terrain features”</u>
  - +200 heritage data structures.
  - 4-Tiered Hierarchical Data Structure.
  - 18,000 Unique Concepts.
  - “Unambiguous” Definitions.
  - <u>Basic</u> Relationships.

http://vissim.uwf.edu

Ontology - Formal Definition

An ontology O_i is a 4-tuple $<T_i, P_i, R_i, A_i>$ where:

i the domain of the ontology

T_i a set of terms $t\ i$ of $O\ i$

P_i a set of properties of term $t_i \in T_i$

R_i a set of relations between t_i and $t_x \in T_i$

A_i a set of axioms characterizing each relation of R_i

Spatial Relationship Ontologies

An ontology O_i is a set of axioms $<T_i, P_i>$ and $<R_i, A_i>$ where:

i	the domain of the ontology
T_i	a set of terms t_i of O_i
P_i	a set of properties of term $t_i \in T_i$
R_i	a set of relations between t_i and $t_x \in T_i$
A_i	a set of axioms characterizing each relation of R_i