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

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<th>srParallelOutside()</th>
<th>srParallelWithin()</th>
<th>srParallelPartialWithin()</th>
<th>srPerpendicular()</th>
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<th>srPerpendicularWithin()</th>
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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

<table>
<thead>
<tr>
<th>Reference Object</th>
<th>Association Object</th>
<th>Association Probability</th>
<th>Spatial Relationships</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>SFRD</td>
<td>Mailbox</td>
<td>0.9</td>
<td>srBetween(Street)</td>
<td>0.99</td>
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<tr>
<td>SFRD</td>
<td>Mailbox</td>
<td>0.9</td>
<td>srFacing(Street)</td>
<td>0.99</td>
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<tr>
<td>SFRD</td>
<td>Street</td>
<td>0.8</td>
<td>srFacing(Street)</td>
<td>0.99</td>
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<tr>
<td>SFRD</td>
<td>Street</td>
<td>0.8</td>
<td>srInFront(Street)</td>
<td>0.99</td>
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<tr>
<td>SFRD</td>
<td>Street</td>
<td>0.9</td>
<td>srConnect(Driveway)</td>
<td>0.99</td>
</tr>
<tr>
<td>Mailbox</td>
<td>Street</td>
<td>0.99</td>
<td>srNear(1.0)</td>
<td>0.99</td>
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<tr>
<td>Mailbox</td>
<td>Driveway</td>
<td>0.8</td>
<td>srNear(3.0)</td>
<td>0.99</td>
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<td>Mailbox</td>
<td>Walkway</td>
<td>0.5</td>
<td>srNear(1.0)</td>
<td>0.99</td>
</tr>
</tbody>
</table>

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)

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

http://vissim.uwf.edu
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 $R_i$