Topology and Spatial Predicates Geog 516 Presentation #1

Rueben Schulz

Feb 2004

Overview

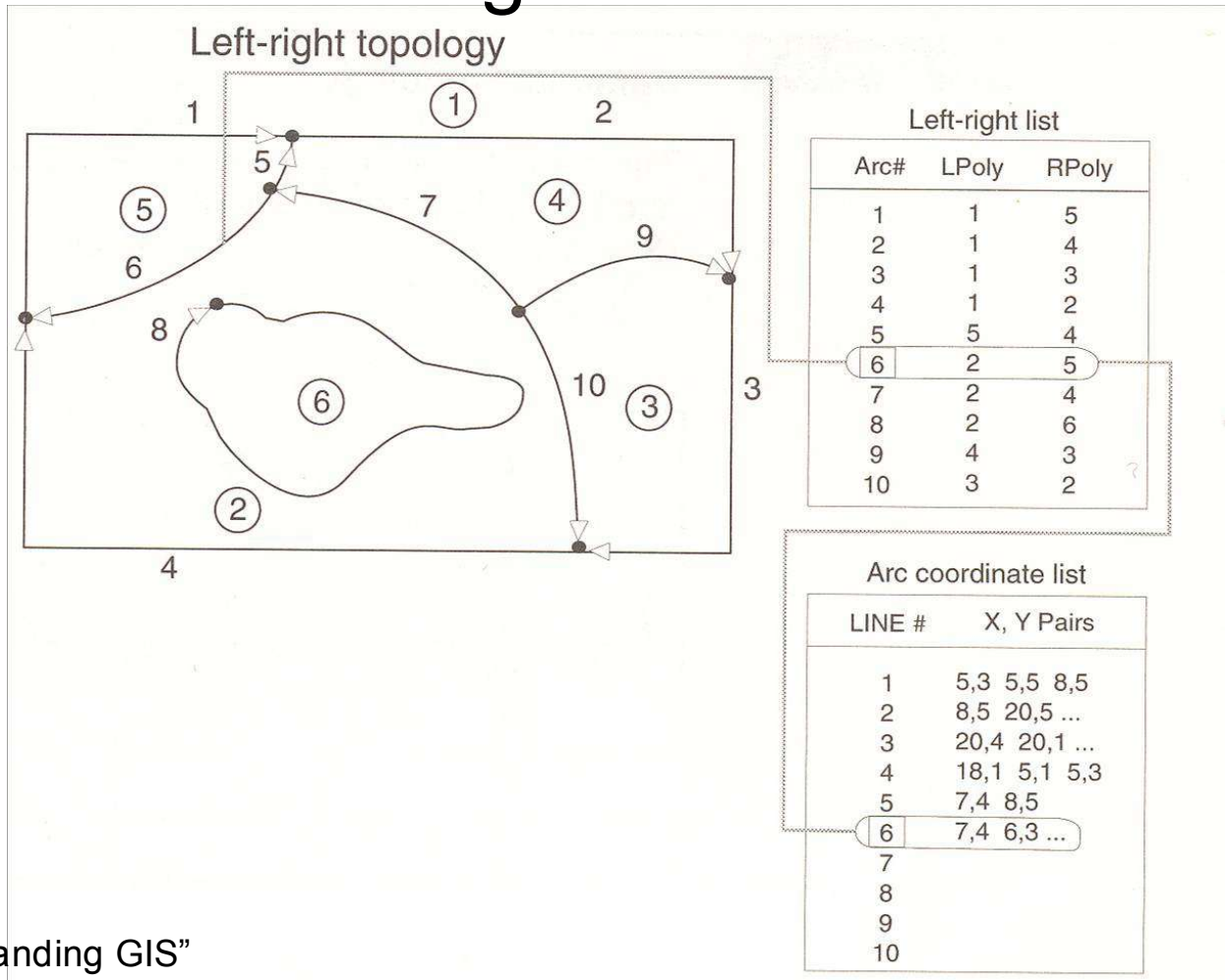
- Background on topology
- Current data format implementations
- New abstractions
  - Interior, Boundary and Exterior
  - 4 Intersection Method
  - 9 Intersection Method
  - Dimensionally Extended
  - Spatial Predicates
- Importance
- Examples
- Problems

Background

- Definitions of topology
  - Spatial relationship between geographic features
    - Connectivity
    - Contiguity
  - Topological data structure, allows features to share geometry
    - TIGER, DIME, ESRI Coverage
  - Set of tools to validate topology
    - Nodes at line intersections, polygons closed, etc.

Current Implementations

- Arc/Info Coverage data model



Source “Understanding GIS”

Motivation for a new, more complex system

- Abstraction away from implementation details
  - Currently ask for:
    - polygons left/right of an arc to get neighbours
    - node to/from a line to get connections
  - Want to work with natural languages for geographic queries
- Current model is not flexible for certain queries
  - Cannot easily query topological relationships between different datasets
  - Cannot easily query containment

Interior, Boundary and Exterior

- Points only have an interior

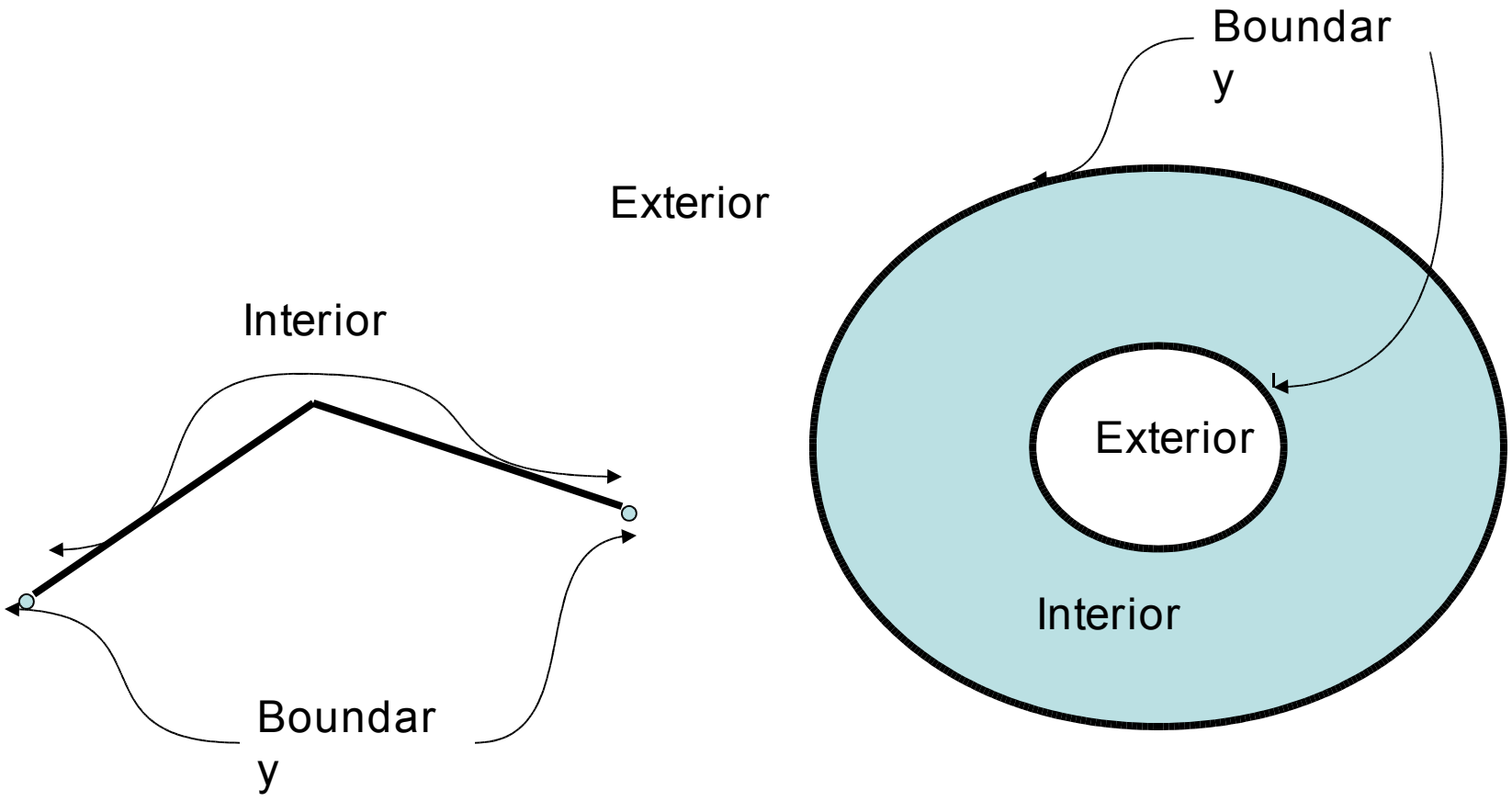


Image after Rob Hewlet, BCIT

Ways to quantify spatial relationships

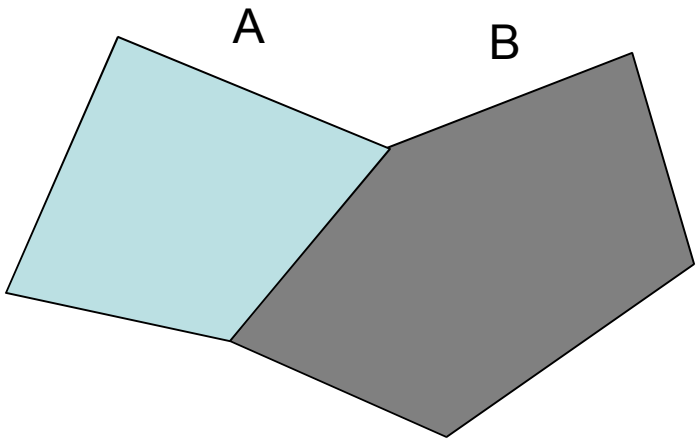
- Examine the interactions of the interiors, boundaries and exteriors of geometries
- 4 different methods
  - 4 Intersection Method
  - 9 Intersection Method
  - Dimensionally Extended
  - Spatial Predicates (Calculus Based Method)

4 Intersection Method (4IM)

- Looks at the interaction between the geometries interior and boundary; $2^4 = 16$ combinations
- 6 groups of relationships
  - area / area
  - line / area
  - point / area
  - line / line
  - point / line
  - point / point
- 43 possible relationships, 37 real relationships (converse relationships only counted once).

4 IM Example

- An Area / Area example
- Notation, a matrix of values with:
  - True = interaction
  - False = no interaction



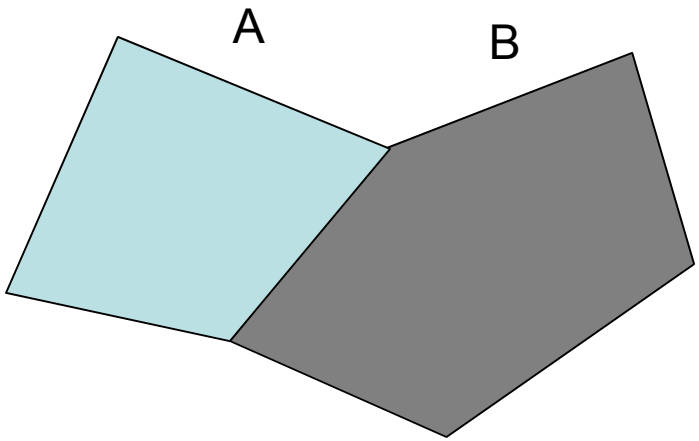
Geometry B

Geometry A

	I	**B**
I	F	F
B	F	T

9 Intersection Method (9IM)

- Looks at the interaction between the geometries interior, boundary and exterior; $2^9 = 512$ combinations
- 68 possible cases, 56 real



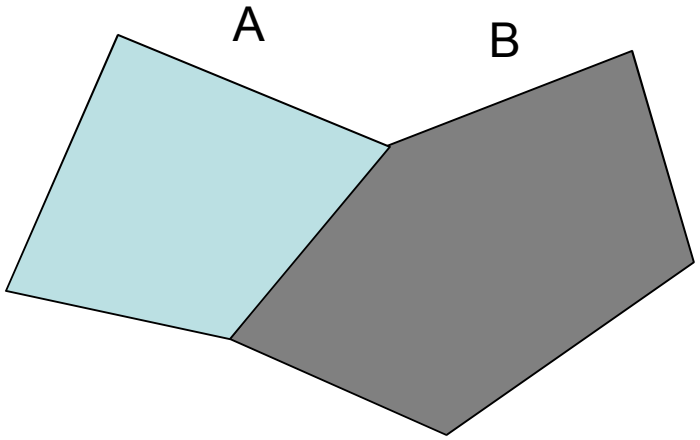
Geometry B

Geometry A

	I	**B**	**E**
I	F	F	T
B	F	T	T
E	T	T	T

Dimension Extended (DE)

- Also look at the dimension of the intersection: 0,1, 2 or -1 (no interaction)
- Can be applied to 4IM or 9IM
  - 61 possible cases, 52 real for DE-4IM
  - 87 possible case, 81 real for DE-9IM



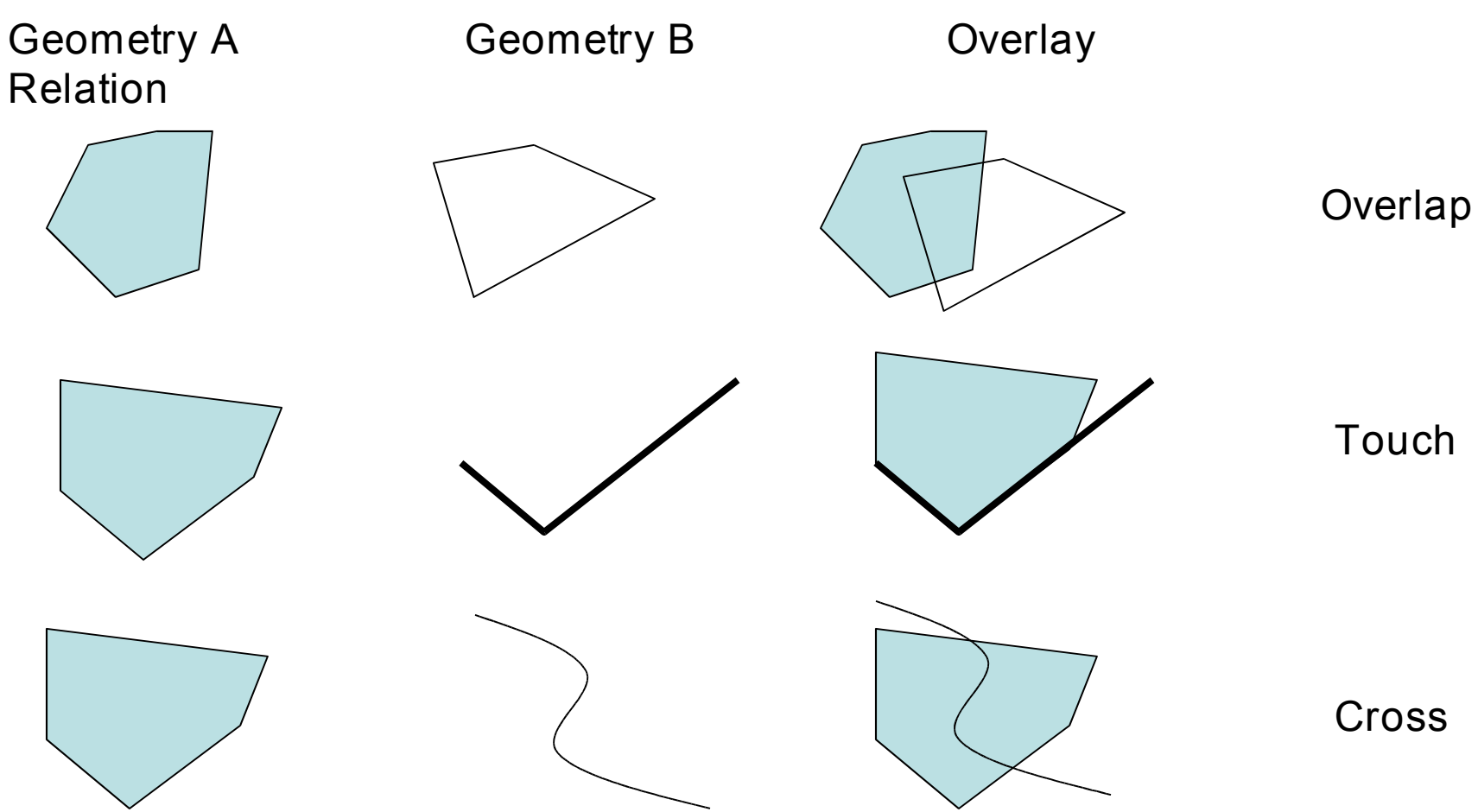
Geometry B

Geometry A	I	B
I	-1	-1
B	-1	1

Spatial Predicates: Calculus Based Method (CBM)

- Human brain does not deal well with 81 relations
- 9 predicates, return true/false
  - **Equals**
  - **Disjoint**
  - **Touch**
  - **Overlaps**
  - **Cross**
  - **Within**
  - **Contains** – opposite of within
  - Intersects – tests if there is any interaction at all (not disjoint)
  - Relate – test a specific DE-9IM relationship
- The first 7 predicates are are mutually

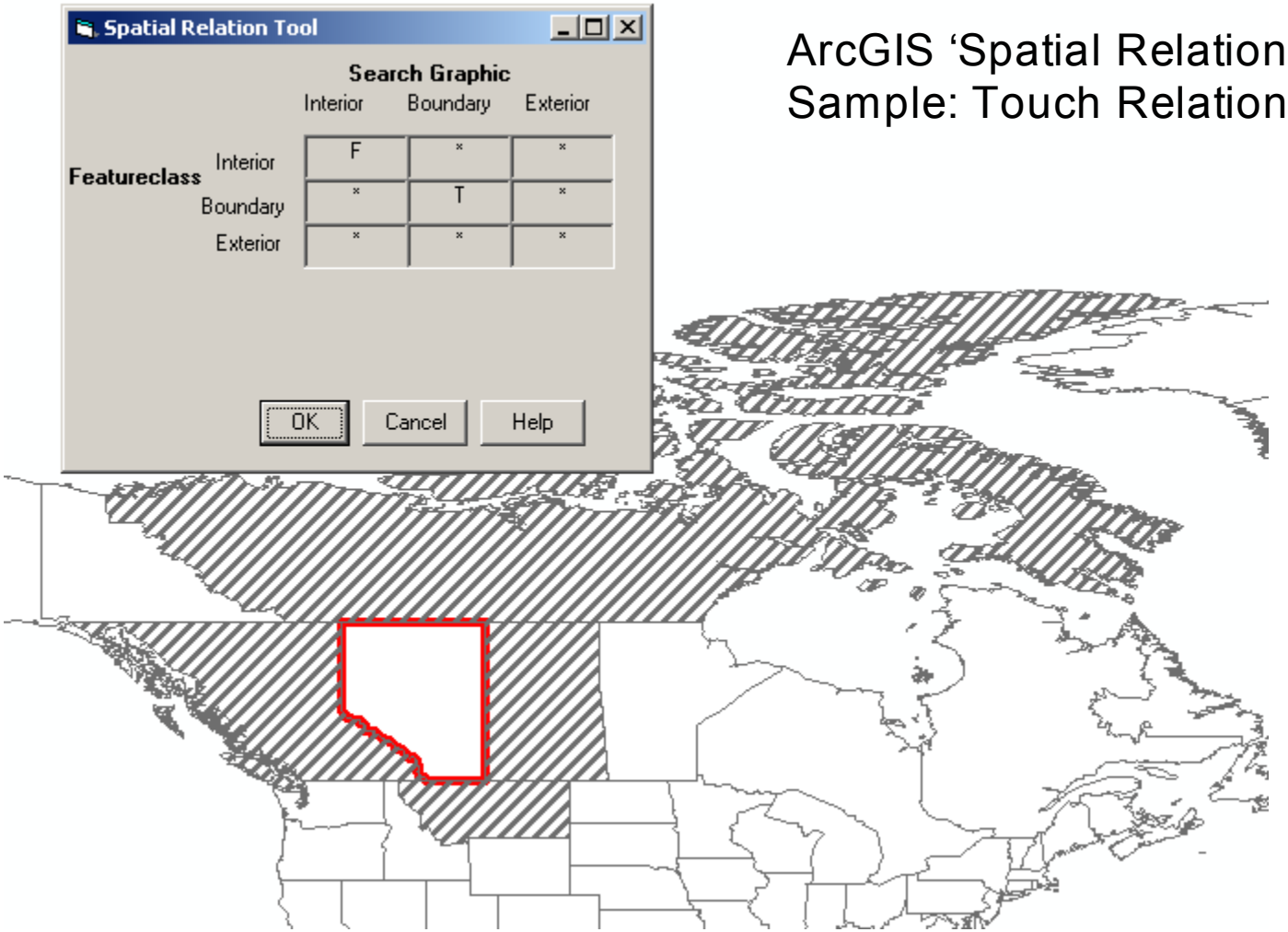
CBM Example


Geometry A
Relation
Geometry B
Overlay
Overlap
Touch
Cross

Importance

- OpenGIS Consortium (OGC) specification
- Implemented in:
  - ESRI ArcGIS and ArcSDE
  - Oracle Spatial
  - IBM DB2 Spatial Extender
  - Java Topology Suite (JTS)
  - PostGIS with GEOS support
- Predicates used to extend SQL to create a spatial query language

Examples



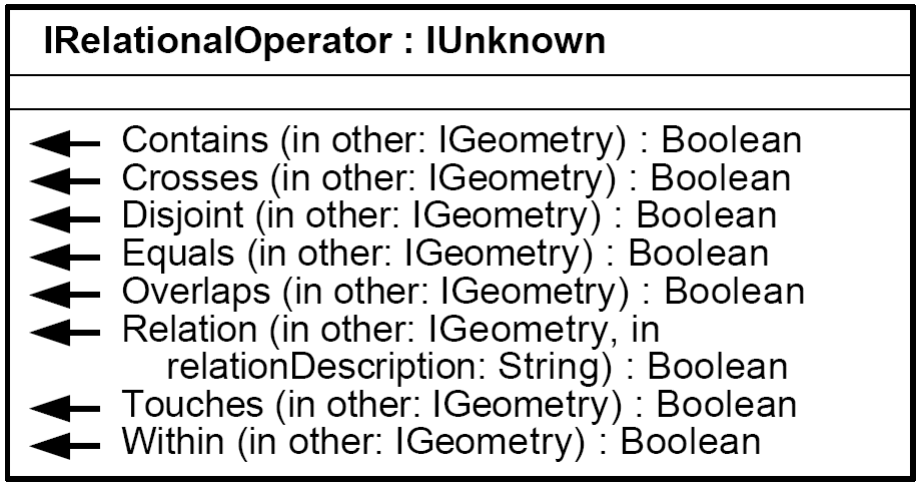
ArcGIS 'Spatial Relation Tool'
Sample: Touch Relation

Examples Con't

- Oracle Spatial SQL

```
SELECT Roads.Name
FROM Provinces, Roads
WHERE Provinces.Name = 'British Columbia'
AND SDO_RELATE(Provinces.Geometry,
Roads.Geometry,
'mask=ANYINTERACT querytype = WINDOW') = 'TRUE';
```

- ArcObjects IRelationalOperator Interface



Problems

- Data Uncertainty
  - A lake digitized twice will not be Equal, though logically it should be
- *Ad Hoc* solution is to buffer geometries and then test the buffers
  - Ex. Test if boundary of geometry A is Within a 10m buffer of geometry B's boundary
- More rigorous solution is the concept of broad boundary
  - Boundary represented as a wide line/area
  - Not currently implemented

References

- Clementini, E., P.D. Felice, and P., van Oostrom, A Small Set of Formal Topological Relationships Suitable for End-User Interaction, in D. Abel and B. C. Ooi (Ed.), Advances in Spatial Databases - Third International Symposium. SSD-93. LNCS 692. Pp. 277-295. Springer-Verlag. Singapore (1993).
- Clementini E. and P.D. Felice, A Comparison of Methods for Representing Topological Relationships, Information Sciences - Applications: An International Journal 3 (3), 149-178, 1995.
- Egenhofer M.J. and J. Herring, Categorizing binary topological relationships between regions, lines and points in geographic databases, Tech. Report., Department of Surveying Engineering, University of Maine, Orono, ME 1991.
- Egenhofer M.J., Topological Reasoning in Geographic Space: http://www.spatial.maine.edu/~max/topReasoning.html
- ArcGIS: Working with Geodatabase Topology, An ESRI White Paper, 2003.
- Understanding GIS: The ArcInfo Method, ESRI Press, 1998.
- IBM DB2 Spatial Extender: Users Guide and Reference, Version 8.
- OpenGIS Specifications 99-049: Simple Feature Specification for SQL (SFS), OpenGIS Consortium, Inc, May 5, 1999.

Appendix

- Details about each spatial predicate
- Partially based on notes from BCIT
- Notation for DE-9IM
  - T = interaction
  - F = no interaction
  - * = interaction does not matter
  - 0,1, 2 = dimension of interaction

Appendix

- DE-9IM's given below test geometry A against geometry B.
  - Eg. for a Within Relation; testing if A is Within B.

Geometry B

Geometry A

	I	B	E
I	*	*	*
B	*	*	*
E	*	*	*

Equals

- Geometries must be identical
  - Same dimension
  - Same geometry type
  - Same number of vertices
  - All x,y coordinates must be identical

	I	**B**	**E**
I	T	*	F
B	*	*	F
E	F	F	*

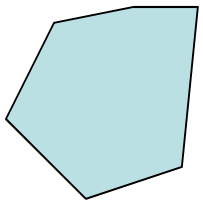
Geometry A

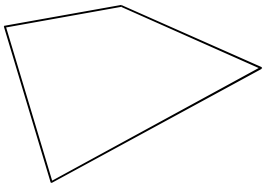
Geometry B

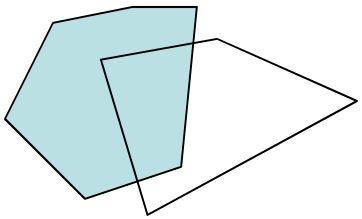
Overlay

Result

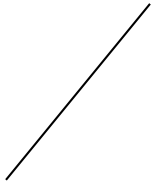
True

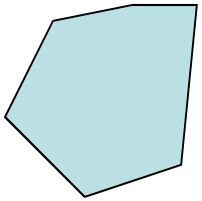


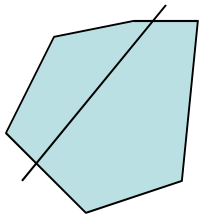




False







False

Disjoint

- Overlay of the two geometries is an empty set
- Does not need to be the same geometry type

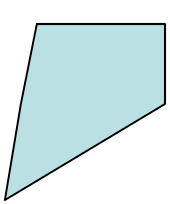
	I	**B**	**E**
I	F	F	*
B	F	F	*
E	*	*	*

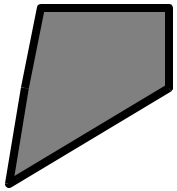
Geometry A

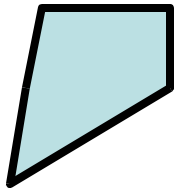
Geometry B

Overlay

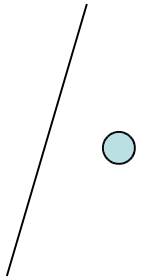
Result







False



True

Touch

- Boundaries from both geometries intersect, but both interiors cannot.
- A single geometry's interior can intersect with the others boundary
  - Ex. A point intersecting with a polygon or line's boundary

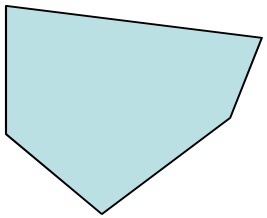
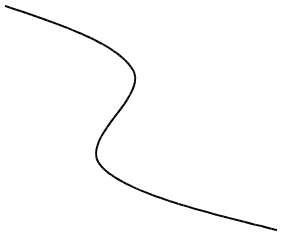
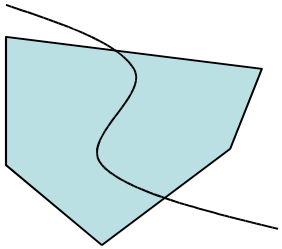
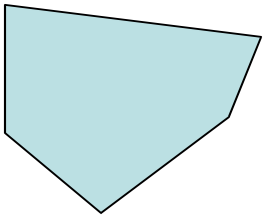
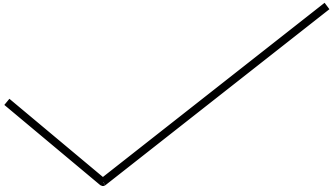
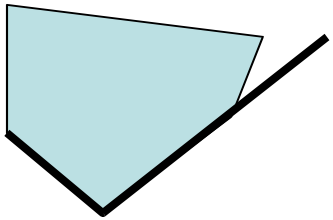
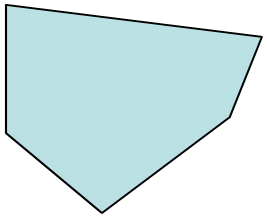
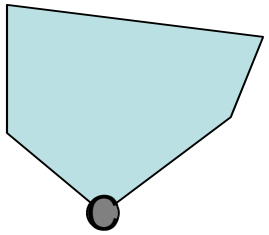
	I	B	E
I	F	T	*
B	*	*	*
E	*	*	*

Or

	I	B	E
I	F	*	*
B	T	*	*
E	*	*	*

Or

	I	B	E
I	F	*	*
B	*	T	*
E	*	*	*

Geometry A	Geometry B	Overlay	Result
			False
			True
			True

Overlaps

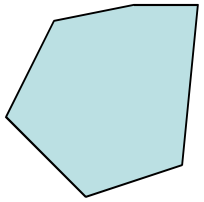
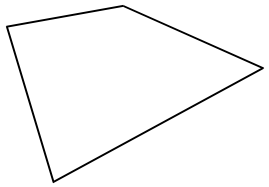
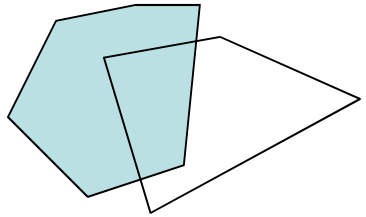
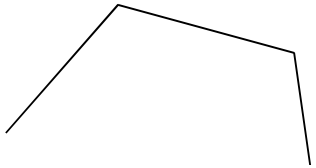
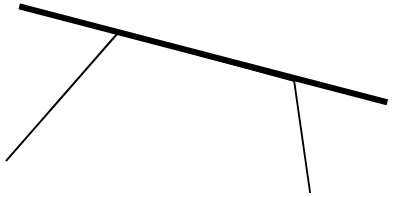
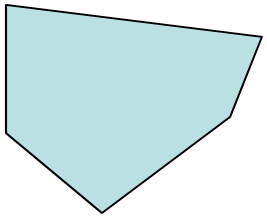
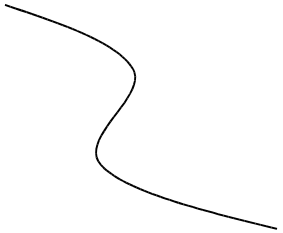
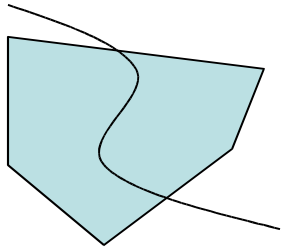
- Geometries must be of the same dimension
- Intersection of the geometries must result in a geometry of the same dimension, but not equal to either input geometry.
- Does not work with points (would be equal)

Both geometries Multi-Points or Areas

	I	B	E
I	T	*	T
B	*	*	*
E	T	*	*

Both geometries Lines

	I	B	E
I	1	*	T
B	*	*	*
E	T	*	*

Geometry A	Geometry B	Overlay	Result
			True
			True
			False

Cross

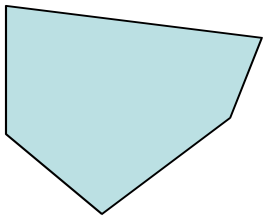
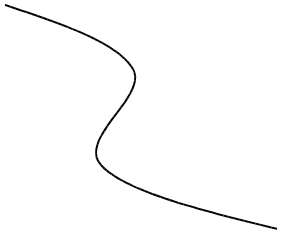
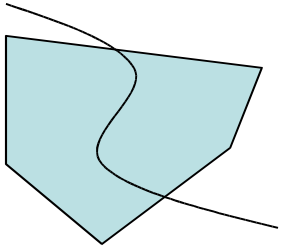
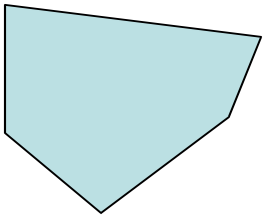
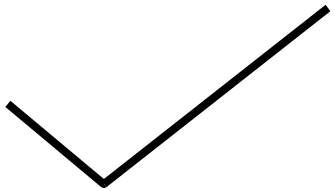
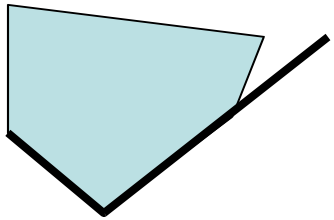
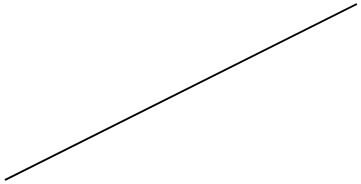
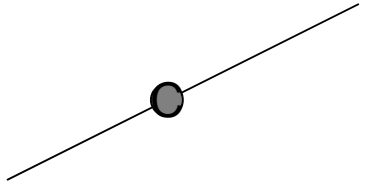
- Intersection of two geometries results in a shape that is one less than the maximum dimension of both geometries
- Based on interiors intersecting
- Points cannot cross (would be equal)

First geometry point or line and second area or
First geometry point and second line

	I	B	E
I	T	*	T
B	*	*	*
E	*	*	*

Both geometries lines

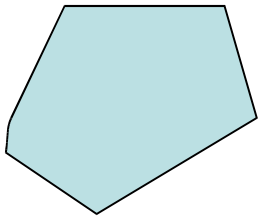
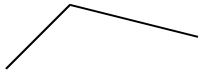
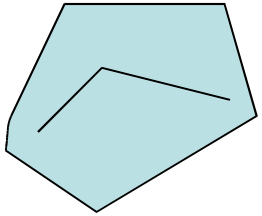
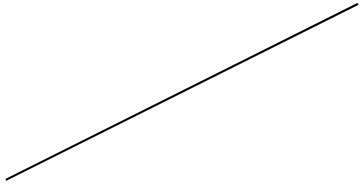
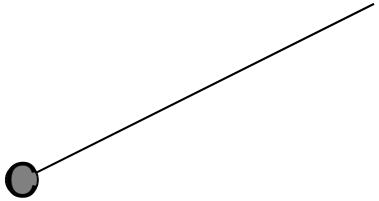
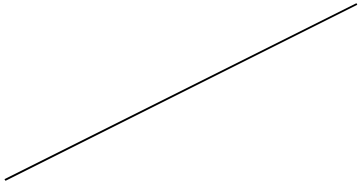
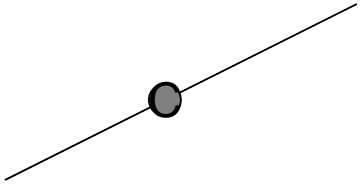
	I	B	E
I	0	*	*
B	*	*	*
E	*	*	*

Geometry A	Geometry B	Overlay	Result
			True
			False
			False

Within

- One geometry completely within another geometry
- Touching allowed for lines and polygons
- Touching not allowed for points
  - must be an interior on interior interaction

	I	**B**	**E**
I	T	*	F
B	*	*	F
E	*	*	*

Geometry A	Geometry B	Overlay	Result
			True
			False
			True

Contains

- The opposite of Within
  - If A is within B, then B contains A