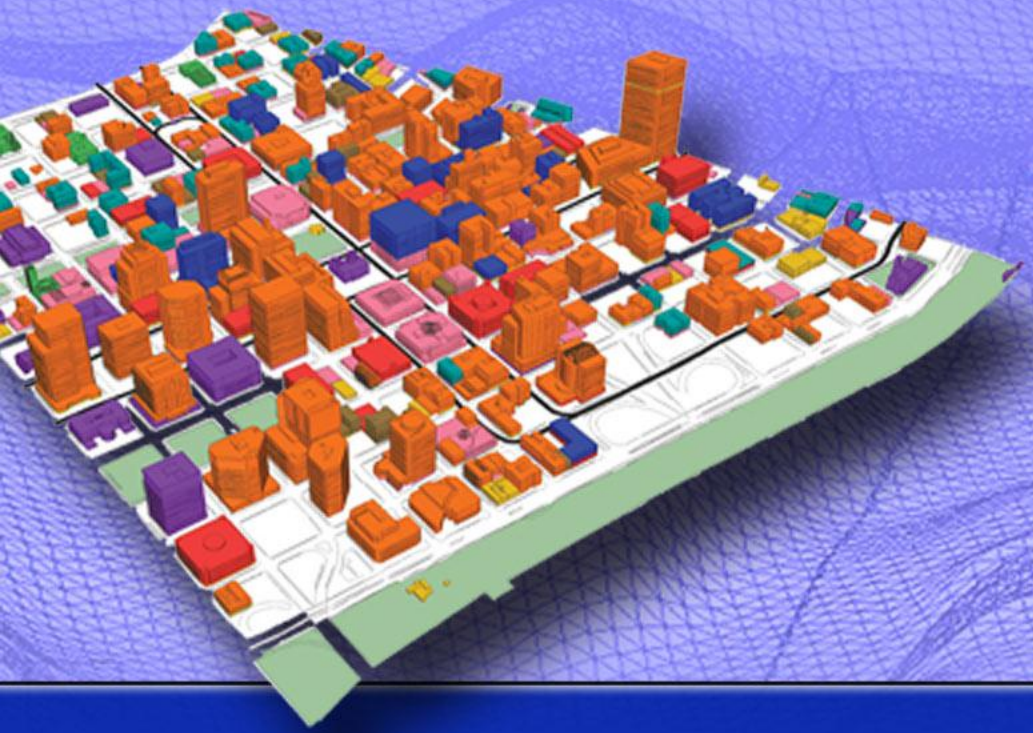
UNIVERSITY OF FLORIDA

The Neighborhood Configuration Model: a Framework To Distinguish Topological Relationships between Complex Volumes



Tao Chen & Markus Schneider

Outline

- Motivation of our research
- Existing Approaches
- Our approach: the neighborhood configuration model (NCM)
- Comparisons with the 9IM based models
- Conclusions and future work

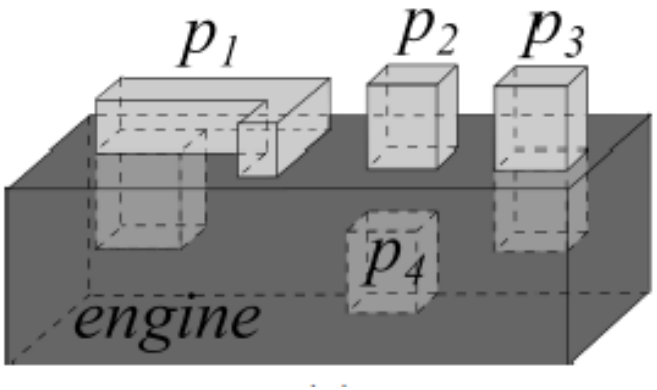
Motivation of Modeling 3D Topological Relationships

- The exploration of topological relationships between spatial objects is an important topic in fields like *artificial intelligence*, *cognitive science*, *geographical information systems* (*GIS*), *robotics*, and *spatial databases*.
- In spatial databases, the development of topological relationship models has been motivated by the need of formally defined topological predicates as filter conditions for *spatial selections* and *spatial joins* in spatial query languages and as a support for spatial data retrieval and analysis tasks.
- Most of the research work has been focusing on modeling topological relationships in the 2D space, while the work in the 3D space is rather limited.

3D Topological Predicates in Spatial Databases

Q3: Determine the parts that both attach to the surface of the engine body from outside and penetrate the engine body.

```
SELECT p.pname FROM parts p, machine m
WHERE  m.type='engine' and p.body meets_from_outside m.body and
       p.body overlaps m.body
```



Q1 result: p_2

Q2 result: p_1, p_2, p_4

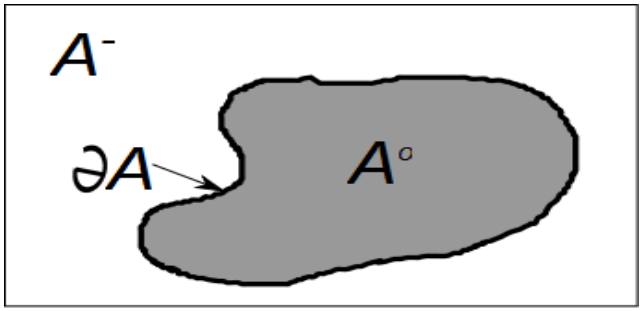
Q3 result: p_1

Existing Approaches

- Goal: to clarify, identify, and classify as many topological relationships as possible between two 3D spatial objects
- Current approaches
  - the *9-Intersection Matrix* (*9IM*) based models [Egenhofer1990a]
  - the *Dimension Model* (*DM*) [Zlatanova 2002]
    (*dependent on discrete representation*)

The 9-Intersection Matrix (9IM) Model

- Three basic components: *interior*, *boundary*, and *exterior*

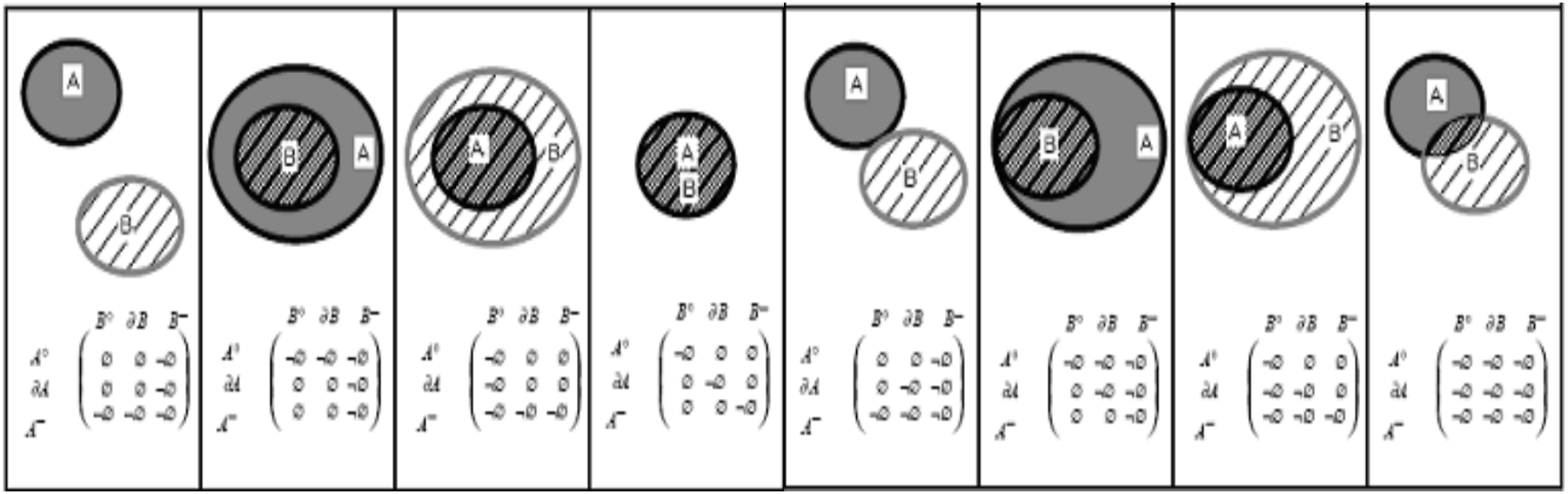


- Representing the topological relationships between two spatial objects in a 9-element matrix

$$\begin{pmatrix} A^\circ \cap B^\circ \neq \varnothing & A^\circ \cap \partial B \neq \varnothing & A^\circ \cap B^- \neq \varnothing \\ \partial A \cap B^\circ \neq \varnothing & \partial A \cap \partial B \neq \varnothing & \partial A \cap B^- \neq \varnothing \\ A^- \cap B^\circ \neq \varnothing & A^- \cap \partial B \neq \varnothing & A^- \cap B^- \neq \varnothing \end{pmatrix}$$

The 9-Intersection Matrix (9IM) Model

- 8 topological relationships between two simple regions distinguished by 9IM



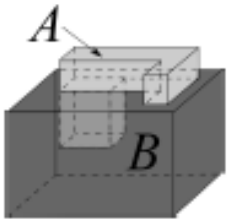
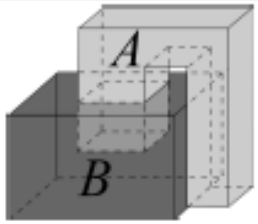
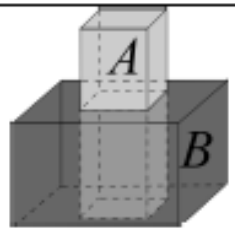
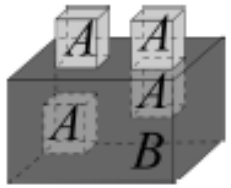
The 9-Intersection Matrix (9IM) Model

- 9IM for 3D data [Egenhofer 1995, Zlatanova 2000]

	simple 3D point	simple 3D line	simple surface	simple volume
simple 3D point	2	3	3	3
simple 3D line	3	33	29	19
simple surface	3	29	41	19
simple volume	3	19	19	8

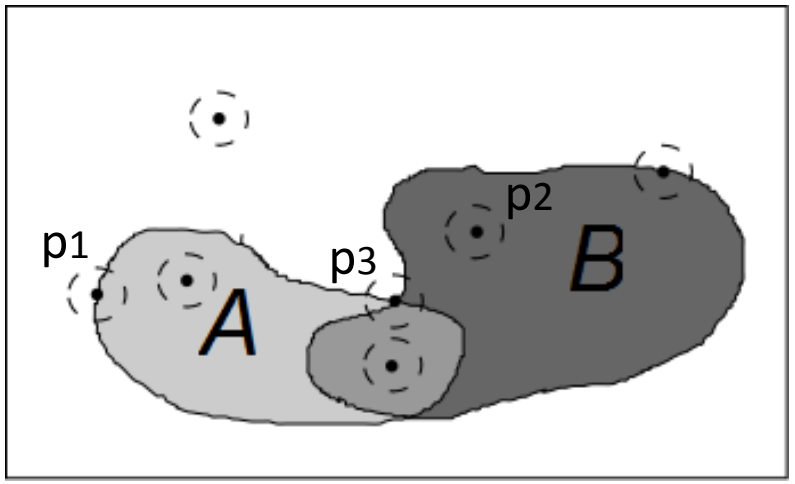
Problems with Current Models

- Problems with the 9IM
  - Since the 9IM is originally designed for 2D spatial objects, some 3D features are not captured
  - The 9IM ignores the complex interaction between the basic components (*high granularity problem*)
  - Insufficient for complex spatial objects

				
9IM	$\begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix}$	$\begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix}$	$\begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix}$	$\begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix}$

Our Approach: the Neighborhood Configuration Model (NCM)

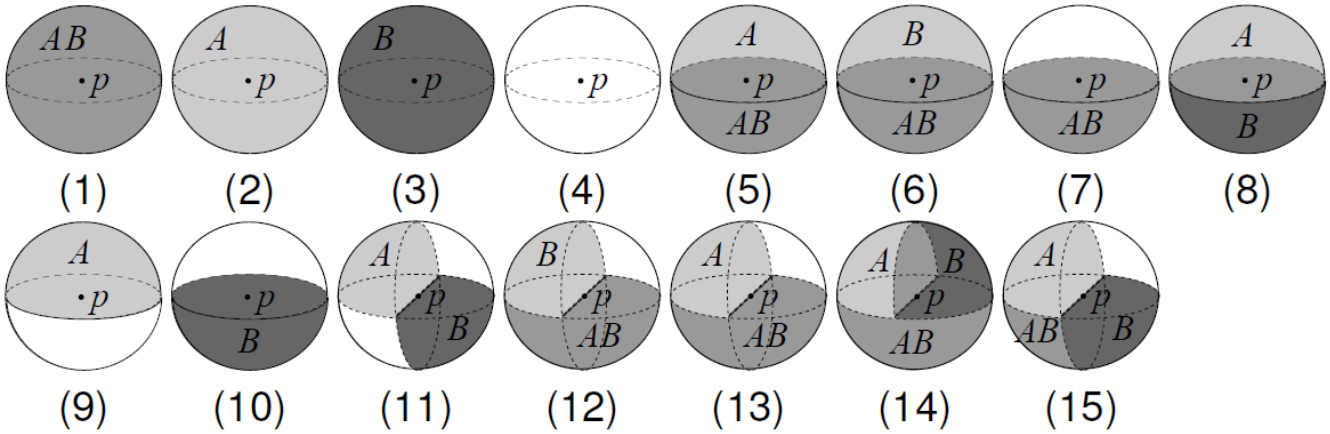
- Basic idea: to evaluate the *neighborhood configurations* of all points in a scenario that involves two spatial objects
- A two-step approach
  - Step1: exploring all possible neighborhood configurations
  - Step2: encoding topological relationships with neighborhood configuration flags



- Step1: exploring all possible neighborhood configurations
  - A total of 4 ownerships for any point in a scenario involving two 3D spatial objects

$$\text{(i) } q \in A \wedge q \notin B,\ \text{(ii) } q \notin A \wedge q \in B,\ \text{(iii) } q \in A \wedge q \in B,\ \text{(iv) } q \notin A \wedge q \notin B$$

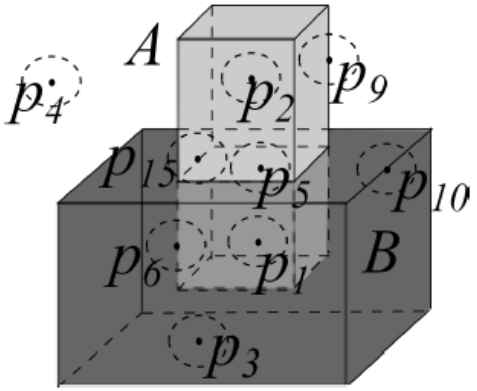
  - A total of 15 neighborhood configurations



- Step2: encoding topological relationships with neighborhood configuration flags

$$FV(A, B, i) = \begin{cases} 0 \text{ if } & F[i] \text{ yields false for } A \text{ and } B \\ 1 \text{ if } & F[i] \text{ yields true for } A \text{ and } B \end{cases}$$

$$TRE(A, B) = (FV(A, B, 0)\ FV(A, B, 1)\ \ldots\ FV(A, B, 14))$$



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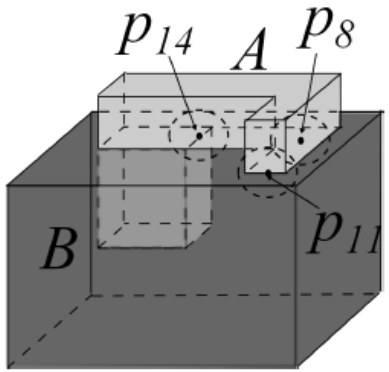

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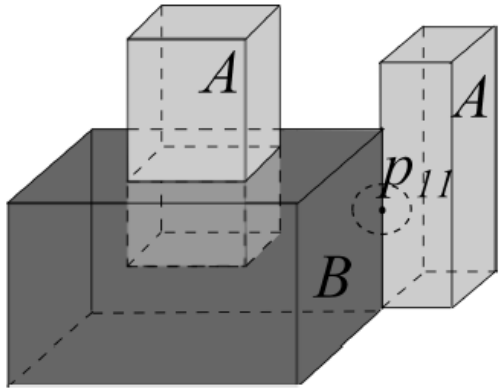

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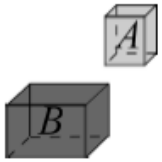
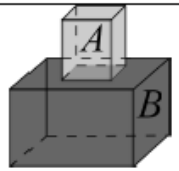
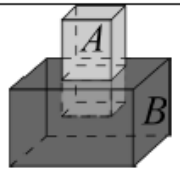
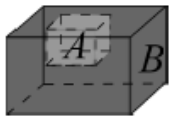
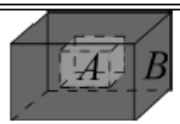
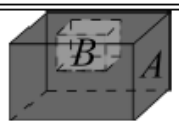
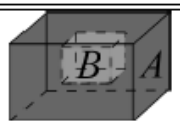
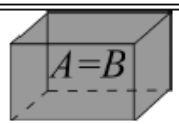
Comparison with the 9IM

- Our NCM approach is able to distinguish all 8 topological relationships that can be distinguished by the 9IM approach.

				
9IM	$\begin{pmatrix} 0 & 0 & 1 \\ 0 & 0 & 1 \\ 1 & 1 & 1 \end{pmatrix}$	$\begin{pmatrix} 0 & 0 & 1 \\ 0 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix}$	$\begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix}$	$\begin{pmatrix} 1 & 0 & 0 \\ 1 & 1 & 0 \\ 1 & 1 & 1 \end{pmatrix}$
NCM	(011100001100000)	(011100011110000)	(111111001100001)	(101101100101000)
				
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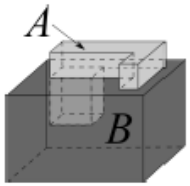
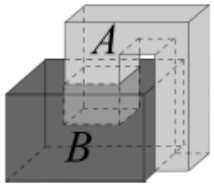
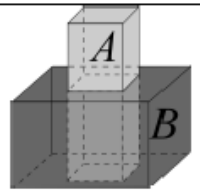
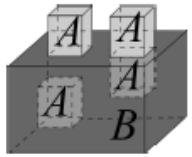
NCM	(101101000100000)	(110110101000100)	(110110001000000)	(100100100000000)

Comparison with the 9IM

- Our NCM approach is able to distinguish more relationships that cannot be distinguished by the 9IM approach.

				
9IM	$\begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix}$	$\begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix}$	$\begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix}$	$\begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix}$
NCM	(111111011110011)	(111111011110001)	(111111101101001)	(111111111111001)

Conclusions and Future Work

- Conclusions
  - We have proposed a novel approach called the *neighborhood configuration model* (NCM) for distinguishing topological relationships between two complex volume objects in the 3D space
  - The NCM approach provides a more fine-grained classification of topological relationships between two complex volume objects than the 9IM approach
- Future work
  - Extend the NCM approach to other complex types like lines and surfaces.
  - Design a proper set of topological predicates based on the NCM as selection and join conditions in spatial queries.

Thank you !

Questions?