Qualitative Spatial Reasoning over Line-Region Relations

Leena and Sibel

Knowledge Representation
Seminar Presentation

Agenda

9-Intersection

Snapshot Model

Smooth-Transition Model

Evaluation

Summary

Agenda

9-Intersection

Snapshot Model

Smooth-Transition Model

Evaluation

Summary

Agenda

9-Intersection

Snapshot Model

Smooth-Transition Model

Evaluation

Summary

Smooth-Transition Model

Example

A pair of line-region relations that are conceptual neighbors (one can be obtained from the other via a "smooth transition")

Counterexample

A pair of line-region relations that **not** are conceptual neighbors

Formalization

A smooth transition occurs by moving around the line's

1. **boundary nodes**

   Q: Do they intersect with the same region part?
   Transition Rule 1 **if** Yes
   Transition Rule 2 **if** No

2. **interior**

   Transition Rule 3 **to** extend the intersection area *and*
   Transition Rule 4 **to** reduce it

What this means for the 9-intersection:
An entry or its adjacent entries gets changed from $\varnothing$ to $\neg\varnothing$ or v.v.

Formalization Extent of a Line Part

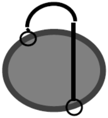
Definition (Extent of a line part i)

- Denoted by $\#M[i, \_]$
- Count of intersections betw. line part i and the region parts
- $\#M[i, \_]$ in the interval $[0 \ldots 3]$

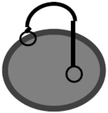
Transition Rule 1

If the line's two boundaries intersect with the **same** region part, then extend the intersection to either of the adjacent region parts:

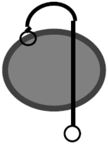
$$\#M[\delta, \_] = 1 \Rightarrow \forall i(M[\delta, i] = \neg\varnothing) : M_N[\delta, \mathrm{adjacent}(i)] := \neg\varnothing$$



$$\begin{pmatrix} \neg\varnothing & \neg\varnothing & \neg\varnothing \\ \varnothing & \neg\varnothing & \varnothing \\ \neg\varnothing & \neg\varnothing & \neg\varnothing \end{pmatrix} \xrightarrow{M[\partial,^{\circ}] := \neg\varnothing} \begin{pmatrix} \neg\varnothing & \neg\varnothing & \neg\varnothing \\ \neg\varnothing & \neg\varnothing & \varnothing \\ \neg\varnothing & \neg\varnothing & \neg\varnothing \end{pmatrix}$$



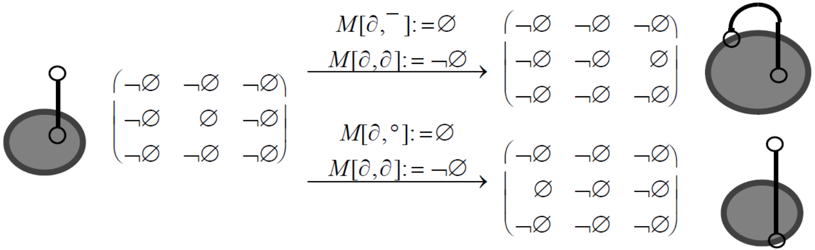
$$\begin{pmatrix} \neg\varnothing & \neg\varnothing & \neg\varnothing \\ \varnothing & \neg\varnothing & \varnothing \\ \neg\varnothing & \neg\varnothing & \neg\varnothing \end{pmatrix} \xrightarrow{M[\partial,^{-}] := \neg\varnothing} \begin{pmatrix} \neg\varnothing & \neg\varnothing & \neg\varnothing \\ \varnothing & \neg\varnothing & \neg\varnothing \\ \neg\varnothing & \neg\varnothing & \neg\varnothing \end{pmatrix}$$



Transition Rule 2

If the line's two boundaries intersect with two **different** region parts then move either intersection to the adjacent region part:

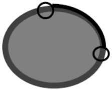
$$\#M[\delta, \_] = 2 \Rightarrow \forall i(M[\delta, i] = \neg\varnothing) :$$
$$M_N[\delta, i] := \varnothing \textbf{ and } M_N[\delta, \text{adjacent}(i)] := \neg\varnothing$$



Transition Rule 3

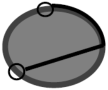
Extend the line's interior-intersection to either of the adjacent region parts:

$$\forall i(M[^\circ, i] = \neg\varnothing) : M_N[^\circ, \mathrm{adjacent}(i)] := \neg\varnothing$$



$$\begin{pmatrix} \varnothing & \neg\varnothing & \varnothing \\ \varnothing & \neg\varnothing & \varnothing \\ \neg\varnothing & \neg\varnothing & \neg\varnothing \end{pmatrix}$$

$$\xrightarrow{M[^\circ,^\circ]:=\neg\varnothing} \begin{pmatrix} \neg\varnothing & \neg\varnothing & \varnothing \\ \varnothing & \neg\varnothing & \varnothing \\ \neg\varnothing & \neg\varnothing & \neg\varnothing \end{pmatrix}$$



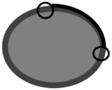
$$\xrightarrow{M[^\circ,^-]:=\neg\varnothing} \begin{pmatrix} \varnothing & \neg\varnothing & \neg\varnothing \\ \varnothing & \neg\varnothing & \varnothing \\ \neg\varnothing & \neg\varnothing & \neg\varnothing \end{pmatrix}$$

Transition Rule 4

Reduce the line's interior intersection on either of the adjacent region parts.

$$\#M[\circ,\_] = 2 \Rightarrow \forall i(M[\circ,i] = \neg\varnothing) : M_N[\circ,i] := \varnothing$$
$$\#M[\circ,\_] = 3 \Rightarrow \forall i(i \neq \delta) : M_N[\circ,i] := \varnothing$$

$$\begin{pmatrix} \varnothing & \neg\varnothing & \neg\varnothing \\ \varnothing & \neg\varnothing & \varnothing \\ \neg\varnothing & \neg\varnothing & \neg\varnothing \end{pmatrix} \xrightarrow{M[\circ,\partial]:=\varnothing} \begin{pmatrix} \varnothing & \neg\varnothing & \varnothing \\ \varnothing & \neg\varnothing & \varnothing \\ \neg\varnothing & \neg\varnothing & \neg\varnothing \end{pmatrix}$$



$$\xrightarrow{M[\circ,^{-}]:=\neg\varnothing} \begin{pmatrix} \varnothing & \varnothing & \neg\varnothing \\ \varnothing & \neg\varnothing & \varnothing \\ \neg\varnothing & \neg\varnothing & \neg\varnothing \end{pmatrix}$$

Additional Consistency Constraints

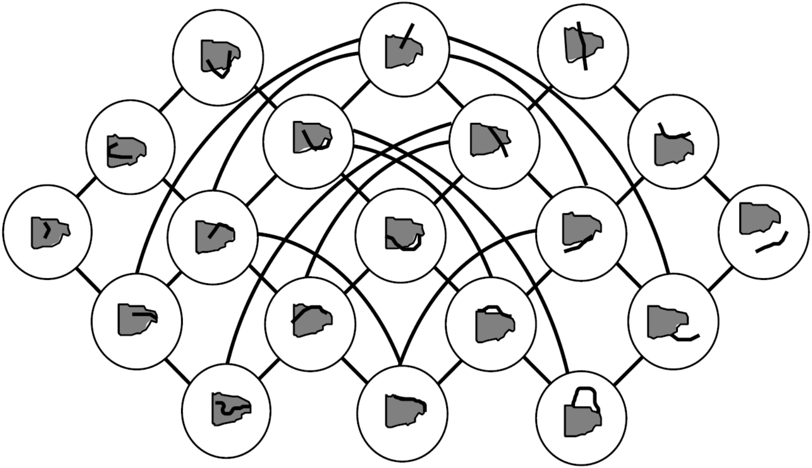
1. If the line's interior intersects with the region's interior *and* exterior, then the line's interior must also intersect with the region's boundary.

$$M[^\circ, ^\circ] = \neg\varnothing \textbf{ and } M[^\circ, ^-] = \neg\varnothing \Rightarrow M[^\circ, \delta] := \neg\varnothing$$

2. If the line's boundary intersects with the region's interior (exterior) then the line's interior must intersect with the region's interior (exterior) as well.

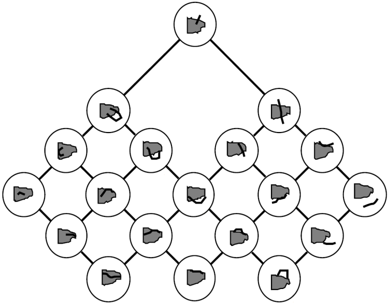
$$M[\delta, ^\circ] = \neg\varnothing M[^\circ, ^\circ] := \neg\varnothing$$
$$M[\delta, ^-] = \neg\varnothing M[^\circ, ^-] := \neg\varnothing$$

Resulting Neighborhood Graph

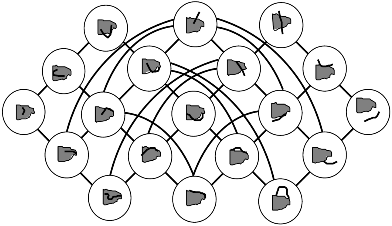


Comparison

Snapshot Model



Smooth-Transition Model



Agenda

9-Intersection

Snapshot Model

Smooth-Transition Model

Evaluation

Summary

Experiment

Setup

- 38 diagrams each of which showed a line and a region, said to be a road and a park respectively
- 2 geometrically distinct placements of the road corresponding to each of the 19 topologically distinct relations

Task

- group spatial relations between line and region, road and park (parks were all the same size and shape)
- arrange the sketches into several groups, such that you would use the same verbal description for the spatial relationship between the road and the park for every sketch in each group

Experiment (cont.)

Goal

- analyse how the subjects formed groups of similar relations
- check similarity with presented conceptual neighborhood models

Participants

The 40 drawings were then printed on individual cards, and were shown to 12 native speakers of English, 12 native speakers of Chinese, 3 native speakers of German, and one native speaker of Hindi. With one exception, the instructions were given and responses were recorded in the native language of the subject. In English,

Results

- The pairs that were neighbors by both snapshot and smooth-transition models were grouped from 0 to 78 times, with a mean of 33.6.
- Those pairs that were neighbors for smooth transitions-but not snapshots- were grouped between 0 and 66 times, with a mean of 17.3 (15.4 per cent).
- The two pairs that were snapshot neighbors-but not smooth transition neighbors- were grouped 10 and 16 times (mean = 14; 11.6 per cent).
- Perhaps most significant, however, is the fact that the 131 pairs that were neighbors by neither the snapshot model nor the smooth transitions were grouped an average of only 6.0 times by the subject (5.3 per cent of the maximum).
- Sixty pairs were never grouped by any of the 28 subjects nor any of the four possible stimulus pairs. The most frequently-grouped pair in this category was 54 times (48 per cent), but only 20 stimulus pairs with neither smooth

Agenda

9-Intersection

Snapshot Model

Smooth-Transition Model

Evaluation

Summary

Summary

- Introduced two models for the conceptual neighborhood of line-region relations (Snapshot model + Smooth transition model)
- Found out in human-subject experiments that: ...

References