# A Strategy for Drawing a Conceptual Neighborhood Graph Schematically

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**Abstract.** Conceptual neighborhood graph is a network diagram that schematizes a set of spatial/temporal relations. This paper proposes a strategy for arranging the relations in a diagrammatic space such that the graph highlights the symmetric structure of the relation set.

## 1. Introduction

*Conceptual neighborhood graph* (*CNG*) [1] is a diagram in which spatial/temporal relations (or potentially any set of concepts in a certain domain) are networked based on their similarity. A number of CNGs has been developed for various relation sets (e.g., [1-6]) and its usefulness for schematizing relations has been reported repeatedly, because well-designed CNGs highlight the symmetric structures of the relation sets. However, how to design such schematic CNGs is not well discussed except the definitions of neighbors. Thus, this paper proposes a strategy for arranging the relations in a diagrammatic space such that the CNG becomes schematic.

## 2. A Drawing Strategy

In a CNG, each node corresponds to a relation and each link indicates a pair of *conceptual neighbors*. Typically, two relations are considered conceptual neighbors if an instance of one relation can be transformed into an instance of another relation by a continuous transformation (e.g., sliding a part of one object). The nodes (i.e., relations) are arranged in a diagrammatic space under the following conventions:

- the number of crossing links becomes as small as possible;
- the nodes are arranged in a linear or reticular pattern as much as possible; and
- the pairs of symmetric relations are located at symmetric locations.

As for the third convention, for instance, in the CNG for topological relations between two simple regions embedded in a spherical surface $\mathbf{C}^1$ (Fig. 1d) [4], every pair of symmetric relations, derived from each other by exchanging the interior and exterior of one region (e.g., Fig. 1a), is located symmetrically with respect to the horizontal axis. Similarly, in the CNG for topological relations between a directed line (arrow) and a region [6], every pair of relations, derived from each other by exchanging the line's direction, is located symmetrically with respect to the middle-height plane. If the relations are modeled by the 9-intersection [7] or its relative models (e.g., [3, 5, 6]), such symmetric pairs of relations are represented by similar patterns of icons with two exchanged rows or columns (Fig. 1a) and thus the pairs are easily identified.

Based on this observation, we propose the following strategy for drawing a CNG:

**Step 1**: Determine neighbors among the given set of relations $R$ (Fig. 1b). Under the 9-intersection or its relative models, the candidates for such neighbors are determined computationally based on the similarity of the relations' iconic patterns [2, 5, 6].

**Step 2**: Determine one or two concepts of symmetry $C_i$ (e.g., exchanging the interior and exterior of one region, exchanging the line's direction, etc.).

**Step 3**: For each $C_i$, identify $R$'s subset $R_i$ that is self-symmetric with respect to $C_i$. Then, among the relations in $\bigcap R_i$ , identify the relation $r^*$ that has the largest number of neighbors, and put $r^*$ at (0, 0, 0). In our example, $r^*$ is *overlap* relation (Fig. 1c), since this relation holds even if we exchange the interior and exterior of each region.

**Step 4**: Locate the relations in $R_1\backslash\{r^*\}$, if they exist, on the $x$-axis at $(a, 0, 0)$ ($a\in\mathbf{Z}$), such that the length of each link between the relations in $R_1$ becomes two. Leave the relations without any link. In a similar way, locate the relations in $R_2\backslash\{r^*\}$ on the $y$-axis, if they exist. In our example, both $R_1\backslash\{r^*\}$ and $R_2\backslash\{r^*\}$ are empty.

**Step 5**: Locate all other relations at $(a, b, 0)$ ($a, b\in\mathbf{Z}$), such that:

- each relation is located at equal distance from its neighbors, whenever possible;
- the remaining relations in $R_1$ and $R_2$ are located on $x$- and $y$- axes, respectively;
- symmetric relation pairs with respect to $C_1$ and $C_2$ are located symmetrically with respect to $x$- and $y$-axes, respectively (e.g., *meet* and *covers* relations in Fig. 1c).

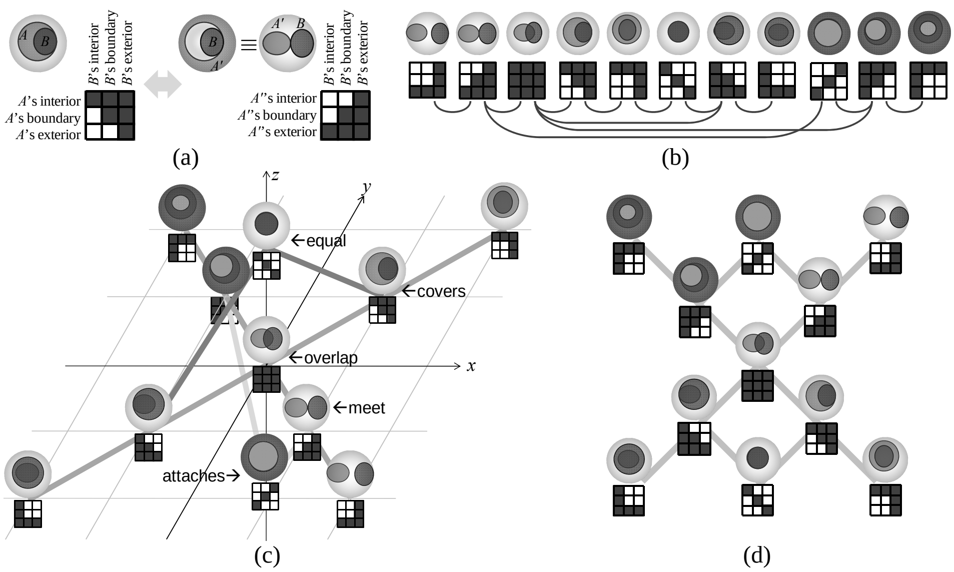


**Fig. 1.** (a) Icons of two symmetric relations, (b) neighboring pairs of relations, and (a-b) CNGs for topological relations between two simple regions in $\mathbf{C}^2$ before and after Step 7.

**Step 6**: If two or more relations are located at the same point, then relocate them to ($a$, $b$, $c$) ($c \in \boldsymbol{Z}$) such that the links do not intersect with each other and the links' total length becomes the smallest. In our example, *equal* and *attaches* relations, which are placed originally at (0, 0, 0) in Step 5, are relocated to (0, 0, ±1) by this rule (Fig. 1c).
**Step 7**: If preferable, reduce the dimension of the CNG by continuous transformation while avoiding the creation of intersecting links as much as possible. In our example, we obtain the two-dimensional CNG in Fig. 1a from the CNG in Fig. 1b by rotating its right half ($x > 0$) by 180 degree and its middle vertical plane ($x = 0$) by 90 degree.

## 3. Conclusions

This paper proposed a strategy for arranging relations in a CNG by which symmetric properties of the relation set are highlighted. We already confirmed the applicability of this strategy to various sets of topological relations, including 13 interval relations in a linear time frame [8], 16 interval relations in a cyclic time frame [3], 8 region-region relations in $\mathbf{R}^2$ [7], 11 region-region relations in $\mathbf{C}^2$ [4], 26 arrow-region relations in $\mathbf{R}^2$ [6], and 80 arrow-arrow relations in $\mathbf{R}^2$ [5] (a slight technique necessary), as demonstrated in our poster. It is left for a future research to examine the applicability of this strategy to other sets of relations, including more complicated topological relations (e.g., those between two regions with holes) and non-topological relations (e.g., directional relations). In addition, given an arbitrary set of relations, their neighborhood information, and all symmetric pairs among them, how to design a schematic CNG in a fully automated way is an interesting future challenge.

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