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Topology in Composite Spatial Terms

John D. Kelleher
Technological University Dublin, john.d.kelleher@tudublin.ie

Robert J. Ross
Technological University Dublin, robert.ross@tudublin.ie

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John D. Kelleher and Robert J. Ross

Artificial Intelligence Research Group
School of Computing
Dublin Institute of Technology

1 Introduction

People often refer to objects by describing the object's spatial location relative to another object, e.g. *the book on the right of the table*. This type of referring expression is called a **spatial locative expression**. Spatial locatives have three major components: (1) the **target** object that is being located (*the book*), (2) the **landmark** object relative to which the target is being located (*the table*), and (3) the description of the spatial relationship that exists between the target and the landmark (*on the right of*).

In English spatial relationships are often described using **spatial prepositions**. The set of English prepositions that describe static relationships between a target and a landmark can be divided into two sets: (1) those that denote **topologically** defined relationships, e.g. *at*, *on*, *in*, and (2) those that describe directional relationships, e.g. *left of*, *right of*, *front of*. Interestingly, the topological and directional spatial prepositions are often combined into **composite spatial terms**: *at the right of, on the right of*. This raises the question of what motivates the uses of one topological preposition over another in the planning of composite spatial terms.

Contribution: This paper describes an experiment that investigates the semantic distinctions marked by the use of different topological prepositions in composite directional spatial terms.

2 Related Work

Previous psycholinguistic work on directional spatial descriptions [5, 3] has focused on the semantics of the directional prepositions; for example, *above, below, left of, right of*. This work has found a consistent relationship between the directional preposition used and the region around the landmark that can be acceptably described using that preposition. The term **spatial template** is often used to describe these acceptability regions. There are three regions of acceptability in the spatial template of directional prepositions: good, acceptable and bad. These regions are symmetric around the canonical direction described by the preposition with acceptability approaching 0 as the angular deviation from the canonical direction approached 90 degrees. Topological prepositions, by contrast, are often defined in terms of functional [1] or topological [4] relations (e.g., **disconnted**, **externally connected**, etc., see [2]). The difference in the semantics
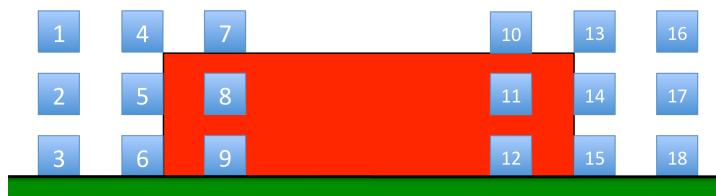
Fig. 1. The positions of the 18 locations where the target object (small blue box) appeared relative to the landmark object (large red box).

of regionally defined directional and topological prepositions is problematic in so far as it is not clear how the two types of semantics should be integrated when modeling composite spatial terms.

3   Experiment

The experiment examined how people's judgment of the appropriateness of composite spatial terms in describing a spatial configuration changed as the topological preposition in the composite spatial terms changed. A trial consisted of a participant being presented with an image containing two objects and an English sentence of the form *the blue box is X the Y the red box*. The X was replaced by one of the topological prepositions *at*, *on*, *in*, *to*[1] and the Y was replaced by one of the directional prepositions *left of*, *right of*. For example: *the blue box is at the right of the red box*. Each trial image contained a small blue box and a large red box. In all trial the blue box was used as the target object and the red box was used as the landmark. In each trial image the target object was positioned in 1 of 18 locations. The possible target locations are illustrated in Figure 1. These locations were chosen so that the topological relationship (e.g., **disconnected**, **externally connected**, etc.) between the target and the landmark object varied depending on the target position. The target positions 1 through 9 were used in the trials where the directional term used in the linguistic stimulus was *left of* and the target positions 10 through 18 were used in the trials when the directional term used in the linguistic stimulus was *right of*. This resulted in 72 trials: 4 topological relations * 2 directional terms * 9 target positions.

In each trial the sentence was presented under the image. Subjects were instructed that they would be shown sentence-picture pairs and were asked to rate the appropriateness of the sentence to describe the image on a 7-point Likert scale: with 1 denoting not acceptable, 4 denoting neutral, and 7 denoting perfectly acceptable. Trials were presented in a random order to control for sequence affects. Trials were self-paced and the experiment lasted about 10 minutes in total. 19 participants took part in the experiment.

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[1] Traditionally *to* is not considered a topological prepostion. Our results, however, indicate that its semantics does have topological semantics.

Table 1. Mean acceptability ratings for the 18 target positions for *at*, *on*, *in*, and *to*.

Preposition	Target Positions					
at	5.000	5.091	2.500	2.357	5.125	5.250
	5.091	5.692	2.636	2.545	5.583	5.385
	5.500	5.750	3.091	2.917	5.538	5.467
on	5.091	4.769	2.750	2.000	4.923	5.067
	5.500	5.438	2.636	2.769	5.417	4.929
	5.300	5.500	1.846	2.545	5.083	5.333
in	2.545	2.385	1.583	1.143	2.500	3.000
	3.300	2.929	4.900	4.917	2.444	2.231
	3.556	2.000	5.000	4.462	2.917	2.667
to	5.667	5.125	1.909	2.667	5.200	5.667
	5.833	5.231	1.778	1.778	5.636	5.706
	6.000	5.692	1.286	1.800	5.875	5.786

4 Results

In analysing the results we assume that the semantics of the directional terms *left of* and *right of* are symmetric. This assumption is backed up by previous research on directional terms [5, 3]. Under this assumption we merged data for trials that only differed in the directional term used. Following this, we computed the mean acceptability rating for each target position and topological preposition. Table 1 lists the mean acceptability ratings for each of the 18 target positions for each of the topological prepositions.

5 Analysis and Conclusions

The results presented in Table 1 show that toplogical prepositions when used in composite descriptions do generally follow their paradigmatic topological uses, as reported in [4]. Specifically, the topological preposition *in* is sensitive to inclusion: its acceptability increases in target positions 8, 9, 11, and 12. And, the topological preposition *at* is sensitive to contact: generally, its acceptability is high in the target position where contact with the landmark occurs, namely positions 4, 5, 6, 7, 10, 13, 14, and 15. Interestingly, however, these topological meanings are deviated from in a number of ways. If we examine the acceptability ratings as a function of relative distance from the landmark center, see Figure 2, it is evident that the acceptability of *in* and *at* does not decrease in the same way with distance from the landmark as would be the case for their purely topological counterparts. In particular, the acceptability of *in* increases slightly as distance from the landmark increases, while the acceptability of *at* does not notably decrease. One possible cause for this is that as distance increases the place picked out by the preposition as its anchor ceases to be a portion of the landmark, but rather becomes a newly construed area that is disjoint from the landmark.
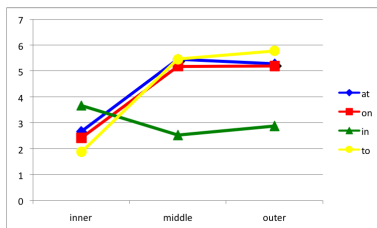
Fig. 2. Mean acceptability ratings by column by distance from landmark center.

In general, such devivations from the core toplogical meaning are also observed in the case of the term *on*. From the results, we see that contrary to a purely topological interpretation, the acceptability of locations 7 and 10 (i.e., directly above and touching the landmark) are rated poorly. A likely cause for this could be that prepositional phrases such as *on the right of* can be interpreted as having an idiomatic meaning that is equivalent to *to the right of*. In this case, it is possible that the more conventional purely topological use of *on* is being superceeded by this idiomatic use. However, while this may be the case, it is also notable that the ratings assigned to *on* in the extreme positions are less than those given for *to* and *at*. One possible reason for this situation could be that the more conventional topological interpretation of *on* interfers with this idiomatic directional usage. Lastly, we note that *to*, while not traditionally treated as a topological preposition, does demonstrate topological features in that it is sensitive to landmark boundary in a similar fashion to *at*; namely, its acceptability increases notably once the target is no longer contained within the landmark.

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