Similarity-Connections between Natural Language and Spatial Situations

Joana Hois, Oliver Kutz, and John Bateman

SFB/TR 8 Spatial Cognition
University of Bremen, Germany
{joana,okutz}@informatik.uni-bremen.de,bateman@uni-bremen.de

Abstract. Humans are able to describe specific spatial situations in various ways. The choice of particular descriptions is influenced by adequacy, general conventions, speaker preferences and alignments, dialogue strategies, and spatial circumstances. Such a description of a specific scene, however, can express different meanings in changing situations, i.e., is context-dependent.
We are therefore aiming at a general framework that provides formal representations of (i) the semantics of utterances, (ii) spatial situations, and (iii) their interrelationships determined by additional (contextual) information.
In order to interpret natural language descriptions with respect to a specific context, this framework specifies 'modules' for various aspects, and then defines similarity-based relations between them.

Natural language describes spatial environments in a flexible way: within one description, it changes fluently according to granularity, combinations of spatial relations, necessary information for specific purposes, discourse- and situation-dependent knowledge, functional aspects or attributes of spatial entities [Talmy, 2000; Herskovits, 1986; Coventry and Garrod, 2004; Tenbrink, 2007]. Formal, non-linguistic representations of space, in contrast, specify certain spatial aspects axiomatically. For instance, spatial qualitative calculi as one group of spatial logics differ in terms of the spatial entities and kinds of relationships they describe. Specifications within one calculus may correspond to aspects about regions, orientations, shapes, distances, movements, topology, or metric spaces [Cohn and Hazarika, 2001; Cohn and Renz, 2007]. In order to interpret natural language in the context of qualitative representations of space, we provide a method that formally connects these viewpoints on the basis of $\mathcal{E}$-connections [Kutz et al., 2004].

For describing linguistic semantics of utterances within a spatial system that understands and generates natural language, we apply a linguistically-motivated ontology, namely the Generalized Upper Model (GUM) [Bateman et al., 1995]. It offers, in particular, linguistic categorisations for spatial descriptions [Bateman et al., 2007] based on aspects given solely by the semantics. As Talmy [2000] points out, language schematises spatial information into underspecified qualitative concepts. These concepts then need to be adapted and interpreted with respect to specific spatial situations, i.e., linguistic descriptions give only indications of conceptualisations of space. These kinds of underspecifications render the connection between language and formal spatial (qualitative) theories with *uncertainty*.

In detail, such loose couplings are link-relations between linguistic and logical modules based on notions of *similarity*. These connections are highly context-dependent: they emerge dynamically in concrete situations, and they have to integrate additional factors about the environment, dependencies between interlocutors, speaker-specific choice and experiences [Tenbrink, 2007]. As connections between language and space are strongly influenced by such external factors, the relationship between instances in different domains can only be determined to a certain degree. To model these problems formally, we extend the combination technique of $\mathcal{E}$-connections by adding (heterogeneous) similarity measures. Local similarity compares objects within one domain, whilst comparing objects across domains leads to similarity measures that are motivated by and based on counterpart-theoretic semantics [Lewis, 1968]. This new formalism is called $\mathcal{S}$-connections. It provides a formal representation of connections of natural language descriptions with spatial conceptualisations that are influenced by given contexts, i.e., environmental aspects and perspectives. This framework also illustrates how natural language semantics can be determined in particular by their connection to spatial logics and axiomatisations [Hois and Kutz, 2008].

In a spatial situation, concrete similarities are calculated with respect to contextual aspects, i.e., they hold within a given situation but can vary and change over time (caused by changing external factors). This information is applied in calculating similarities between linguistic items and their spatial counterparts. The **heterogeneous similarity operators** between the linguistic ontology $\mathcal{L}_1$ and a logical module $\mathcal{L}_2$, intuitively, have the following semantics: $\langle\downdownarrows\rangle^1(A_1, A_2)$ gives a term of $\mathcal{L}_1$, consisting of all those points that are closer to something in A_1 than to any of A_2's counterparts (similarity is evaluated *locally*). Conversely, $\langle\upuparrows\rangle^1(A_1, A_2)$ gives a term of $\mathcal{L}_1$, consisting of all those points all of whose counterparts are closer to some of A_1's counterparts than to any point in A_2 (similarity is evaluated *externally* for the counterparts).

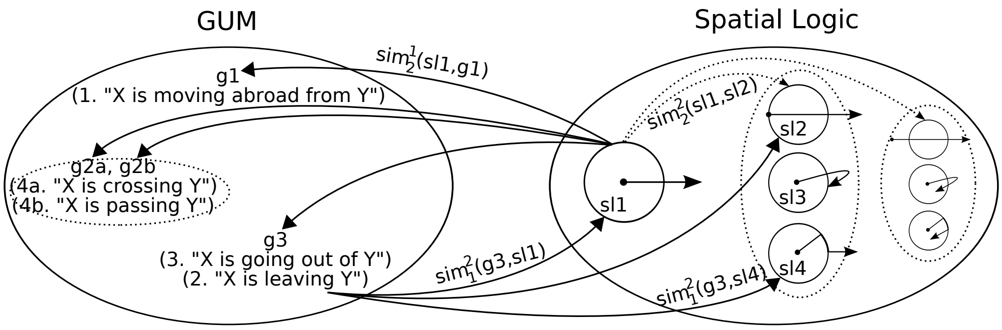

Fig. 1. Example of $\mathcal{S}$-connections between GUM and the 9^+-intersections for topological relations between a directed line segment and a region. Different similarity connections are outlined, such as $\mathsf{sim}_1^2(g3, sl1)$ (from GUM to SL), $\mathsf{sim}_2^1(sl1, g1)$ (from SL to GUM), and $\mathsf{sim}_2^2(sl1, sl2)$ (similarities within SL).

An example of an $\mathcal{S}$-connection for a specific situation is illustrated in Fig. 1. Here, $\mathcal{S}$-connections between GUM and the 9^+-intersections for topological relations between a directed line segment and a region [Kurata and Egenhofer, 2007] are defined. They differ in similarities of linguistic descriptions and topological relationships, as indicated by hierarchical dependencies in GUM and the neighbourhood relation in the calculus. Given the linguistic semantics of the utterance “X is leaving Y” in GUM, the most similar counterparts in the 9^+-intersections calculus are $\mathsf{sl1}$, $\mathsf{sl2}$ and $\mathsf{sl4}$, depending on situation-specific and external conditions. Concrete similarity measures of the $\mathcal{S}$-connection between $\mathsf{g3}$ and $\mathsf{sl1}$, $\mathsf{sl2}$, and $\mathsf{sl3}$, then have to be calculated on the basis of these conditions, i.e., determine which of them is the ‘most similar’ with respect to the specific context.

Bibliography

Bateman, J., Tenbrink, T. and Farrar, S. (2007). The Role of Conceptual and Linguistic Ontologies in Discourse. *Discourse Processes* 44, 175–213. Special Issue on Dialogue Modelling: Computational and Empirical Approaches.

Bateman, J. A., Henschel, R. and Rinaldi, F. (1995). Generalized Upper Model 2.0: documentation. Technical report, GMD/Institut für Integrierte Publikations- und Informationssysteme, Darmstadt, Germany.

Cohn, A. and Hazarika, S. (2001). Qualitative spatial representation and reasoning: an overview. *Fundamenta Informaticae* 43, 2–32.

Cohn, A. G. and Renz, J. (2007). Qualitative spatial representation and reasoning. In F. van Harmelen et al., ed., *Handbook of Knowledge Representation*. Oxford: Elsevier, pages 551–596.

Coventry, K. R. and Garrod, S. C. (2004). *Saying, seeing and acting. The psychological semantics of spatial prepositions*. Essays in Cognitive Psychology series. Hove, UK: Psychology Press.

Herskovits, A. (1986). *Language and Spatial Cognition: an interdisciplinary study of the prepositions in English*. Studies in Natural Language Processing. London: Cambridge University Press.

Hois, J. and Kutz, O. (2008). Counterparts in Language and Space — Similarity and S-Connection. Submitted.

Kurata, Y. and Egenhofer, M. (2007). The 9^+-intersection for topological relations between a directed line segment and a region. In B. Gottfried, ed., *1st Workshop on Behaviour Monitoring and Interpretation, KI 2007*.

Kutz, O., Lutz, C., Wolter, F. and Zakharyaschev, M. (2004). $\mathcal{E}$-Connections of Abstract Description Systems. *Artificial Intelligence* 156, 1–73.

Lewis, D. K. (1968). Counterpart Theory and Quantified Modal Logic. *J. of Philosophy* 65, 113–126.

Talmy, L. (2000). *Towards a cognitive semantics*. Cambridge, MA: A Bradford Book, M.I.T. Press.

Tenbrink, T. (2007). *Space, time, and the use of language: An investigation of relationships*. Berlin: Mouton de Gruyter.