The Semantics of ISO-Space

James Pustejovsky
Brandeis University
jamesp@brandeis.edu

Kiyong Lee
Korea University
ikiyong@gmail.com

Harry Bunt
Tilburg University
Harry.bunt@uvt.nl

Abstract

An understanding of spatial information in natural language is necessary for many computational linguistics and artificial intelligence applications. In this paper, we outline the basic semantic structure for ISO-Space, an annotation scheme for the markup of spatial relations, both static and dynamic, as expressed in text and other media. We outline the basic formal semantic requirements of a model for spatial information, as expressed in the metamodel for ISO-Space, and demonstrate some illustrative compositions using type-theoretic derivations. We then show how the concrete syntax of the annotation structure for ISO-Space is consistent with the semantics provided for the metamodel.

1 Introduction

The specification for ISO (2019)[1] distinguishes four major types of spatially relevant elements for markup in natural language:

(1) a. SPATIAL ENTITIES: natural or artificial locations in the world that include places, paths, and trajectories (event paths), as well as objects participating in spatial relations.
b. SPATIAL SIGNALS AND SPATIAL MEASURES: linguistic markers that establish relations between places and spatial entities.
c. SPATIAL RELATIONSHIPS: The specific qualitative configurational, orientational, and metric relations between objects.
d. EVENTS AND MOTIONS: Eventualities involving movement from one location to another.

The corresponding metamodel for these elements is represented in Figure 1 below (Lee et al., 2018).

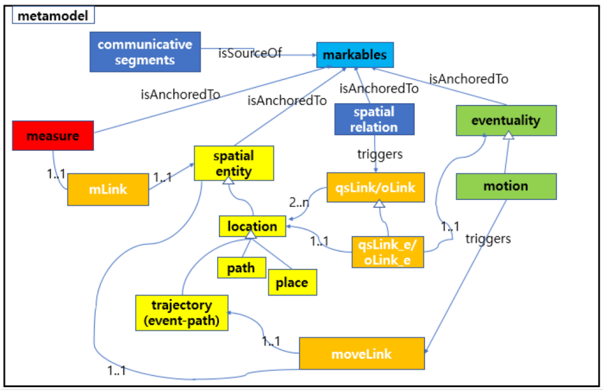

Figure 1: Metamodel of *ISO-Space*

There are three basic *unit element* types in this metamodel: (a) spatial entities; (b) eventualities; and (c) measures. In addition, there are four *relational element* types: (a) QSLINK, qualitative spatial links; (b)

[1]This is an ISO committee draft for the revision of ISO (2014) which restores the original proposal by Pustejovsky et al. (2012) and Pustejovsky and Yocum (2013) that event-paths be treated as a fundamental (complex) entity type triggered by motion events.

OLINK, identifying orientation; (c) MOVELINK, specifying the figure and ground of a movement event;[2] and (d) MLINK, which identifies the metric of a region or distance between regions. These relation types are associated with the SPATIAL_SIGNAL tag.

Qualitative spatial relations (typically within 2D space) can be captured with the relations shown in Table (1) below, from RCC8 (Randell et al., 1992). RCC8 is not, however, able to capture directional or orientational relations and constraints (Freksa, 1992; Frank, 1996; Mossakowski and Moratz, 2012; Zimmermann and Freksa, 1996).

Relation	**Description**
DC	Disconnected
EC	External Connection
PO	Partial Overlap
EQ	Equal
TPP	Tangential Proper Part
TPP_i	Inverse of TTP
NTTP	Non-Tangential Proper Part
NTTP_i	Inverse of NTTP

Table 1: RCC8 Relations.

The goal of this paper is to outline an initial semantics for ISO (2019), a revised version of ISO (2014) focusing on the underlying type structure for the metamodel elements, and how the mapping from annotation structure to interpretation is accomplished.

2 Basic Types and Compositions

The semantics of ISO-Space2019 is formulated on the basis of its abstract syntax, but its interpretation rules apply to the semantic forms which are derived from annotation structures as represented by a concrete syntax. Hence, there are two levels of interpretation that need to be identified when defining a formal semantics of an annotation structure, as applied to linguistic expressions in natural language: language to abstract model; and concrete model to abstract model. In this section, we focus on the first mapping and articulate the underlying semantics of the entities represented in the metamodel in type-theoretic terms and demonstrate the composition of examples within each element type. In the next section, we illustrate the second mapping, from the annotation structure (implemented as a concrete syntactic expression) into the abstract model.

We assume a model with the following basic types, corresponding generally to the elements in Figure 1 above (Kracht, 2002).

(2) a. e, the type of objects
b. i, the type of time points
c. p, the type of spatial points
d. ϵ, the type of events
e. m, the type of measures
f. t, the type of truth values.

Further, following Kracht (2002), we introduce the *group* operator, $^\bullet$, which applies to a type to form a group type, e.g., the group of points, $p^\bullet$. We assume additional types can be constructed with conventional binary type constructors, $\rightarrow$ and $\times$. From these, we can define the standard set of functional types, e.g., $e{\rightarrow}t$, $\epsilon{\rightarrow}t$, $p{\rightarrow}t$, and so on. Further, we assume a semi-lattice of types, where $\sqsubseteq$ is a quasi-ordering on the set of types, such that, for types a, b, c: $a \sqsubseteq b$ and $b \sqsubseteq c$ implies $a \sqsubseteq c$; and $a \sqsubseteq a$. This introduces the *subtyping* relation between types: if $a \sqsubseteq b$, then a is a subtype of b.

[2] The MOVELINK in ISO (2019) is reformulated as outlined in Lee (2016), Pustejovsky and Lee (2017), and Lee et al. (2018).

2.1 Place and Spatial_Entity

The PLACE tag is used for annotating geolocations, such as *Germany* and *Boston*, as well as geographic entities such as lakes and mountains. Further, administrative entities that are registered as geolocations are also tagged as PLACE, e.g., towns and counties. Hence, in the example in (3), the qualitative spatial relation between the two entities is a relation between PLACEs. Both *Gothenburg* and *Sweden* are marked as PLACEs, which we will type as *regions*. A region, r, will be defined at a set of points, $p \to t$. This differs from Kracht (2002), where regions are defined as a subtype of $p^{\bullet}$, where $^{\bullet}$ is a group operator over basic types, but either analysis could be adopted for our present purposes. Further, a qualitative spatial mereotopological relation within RCC8 will be typed as a relation between regions: i.e., $QSLINK : r \to (r \to t)$.

(3) a. [**Gothenburg**$_{pl1}$] is [**in**$_{s1}$] [**Sweden**$_{pl2}$].
 b. $[\![\text{Gothenburg}]\!] = G$, $\langle G{:}p \to t \rangle$
 c. $[\![\text{Sweden}]\!] = S$, $\langle S{:}p \to t \rangle$
 d. $[\![\text{in}]\!] = \lambda y \lambda x[in(x, y)]$, $\langle \text{in}{:}r \to (r \to t) \rangle$
 e. $\text{in}(G, S)$

For many spatial relations in language, however, the entities involved are not inherently typed as locations or PLACEs. For example, humans and everyday objects carry a primary type of e, which we subtype or identify here as SPATIAL_ENTITY. When they participate in spatial relations, we assume there is a type coercion function, $\mathcal{L}$, which operates over an entity (or a collection of entities) and returns the spatial region associated with that entity (or entities), i.e., its location in space. Following Klein (1991) will call this the *eigenplace* for the entity (cf. also Wunderlich (1991) and Wunderlich, 1993). The type for this localization operator, $\mathcal{L}$ is: $e \to (p \to t)$. The example in (4) demonstrates how this operator shifts an entity to the type required by the spatial relation, namely r.

(4) a. [**Robin**$_{sne1}$] is in [**Sweden**$_{pl1}$].
 b. $[\![\text{Robin}]\!] = R$, $\langle R{:}e \rangle$
 c. $[\![\text{Sweden}]\!] = S$, $\langle S{:}p \to t \rangle$
 d. $[\![\mathcal{L}(R)]\!] = \lambda x[loc(x, R)]$, $\langle x{:}p, \mathcal{L}{:}e \to (p \to t) \rangle$
 e. $[\![\text{in}]\!] = \lambda y \lambda x[in(x, y)]$, $\langle \text{in}{:}r \to (r \to t) \rangle$
 f. $\text{in}(\lambda x[loc(x, R)], S)$

The interpretation of SPATIAL_ENTITY in terms of its eigenplace will hold for how objects participate in PATHs as we will see below.

2.2 Paths

We define a path as a subtype of locations (formally regions) that have the additional constraint of being directional, and are often construed as one-dimensional. The notion of a path being introduced or created by an event has its origin in several previous authors, including Cresswell (1978), Jackendoff (1983), and Nam (1995). More recently and more in line with the present specification, we follow the analysis of Mani and Pustejovsky (2012), which is particularly well-suited to the specification in ISO-Space. Formally, paths have been analyzed as sequences of spaces (Nam, 1995) and sequences of vectors (Zwarts and Winter, 2000). Following Nam, let *int* be the type of the interval $[0, 1] \subset R$, and p be the type of a spatial point, as defined above. Then a *path*, π, will be that function $int \to p$, which indexes locations on the path to values from the interval [0,1]. Similarly, if *vec* is the type of vectors, then a *vector-based path*, π_v, can be defined as the function $int \to vec$. That is, it indexes the vectors associated with the path to values from the interval [0,1].

(5) a. [**Prague**$_{pl1}$] is on [**the Moldau River**$_{p1}$].
 b. [**Boston**$_{pl1}$] is at the end of [**the Mass. Turnpike**$_{p1}$].

In these examples, the qualitative spatial relation introduced by the predication identifies a place as situated within (or on) a path. Hence, the preposition *on* which governs the path-PP, [$_{PP}$ on [$_{NP}$the Moldau River]], carries a more specific type than a general QSLINK relation, namely: $\pi_v \rightarrow (r \rightarrow t)$. The type derivation for (5a) is illustrated below.

(6) a. [**Prague**$_{pl1}$] is on [**the Moldau River**$_{p1}$].
b. $[\![\text{Prague}]\!] = P$, $\langle P{:}p \rightarrow t \rangle$
c. $[\![\text{the Moldau River}]\!] = M$, $\langle M{:}\pi_v \rangle$
d. $[\![\text{on}]\!] = \lambda y \lambda x[on\_path(x,y)]$, $\langle \text{on\_path}{:}\pi_v \rightarrow (r \rightarrow t) \rangle$
e. $\text{on\_path}(P, M)$

As sentence (5b) illustrates, end-points of paths can be explicitly mentioned in text. The ISO-Space annotated examples below demonstrate reference to both end-points and mid-points.

(7) a. . . . the [**railroad**$_{p1}$] between [**Boston**$_{pl1}$] and [**New York**$_{pl2}$] . . .
PATH (id=p1, beginID=pl1, endID=pl2, form=NOM)

b. John took the [**road**$_{p1}$] through [**Boston**$_{pl1}$].
PATH (id=p1, midIDs=pl1, form=NOM)

Formally, the expressions introducing end- and mid-point locations are acting as functions from paths to path positions: $\pi_v \rightarrow int$; e.g., given a path $\langle 3,4,5,2,1,8 \rangle$, $end(\pi_v) = 8$.

(8) a. [**Boston**$_{pl1}$] is at the end of [**the Mass. Turnpike**$_{p1}$].
b. $[\![\text{Boston}]\!] = B$, $\langle B{:}p \rightarrow t \rangle$
c. $[\![\text{the Mass. Turnpike}]\!] = MT$, $\langle MT{:}\pi_v \rangle$
d. $[\![\text{end}]\!] = \lambda x[end\_of(x)]$, $\langle x{:}\pi_v, \text{end\_of}{:}\pi_v \rightarrow int \rangle$
e. $[\![\text{on}]\!] = \lambda y \lambda x[on\_path(x,y)]$, $\langle \text{on\_path}{:}\pi_v \rightarrow (r \rightarrow t) \rangle$
f. $\text{on\_path}(B, MT) \wedge end\_of(MT) = B$

As mentioned above, the eigenplace of a SPATIAL_ENTITY can be situated on a path by coercion: namely, $\mathcal{L}$ coerces *John* to his eigenplace, and then the spatial relation predication situates this region onto the path, π_v.

(9) a. [**John**$_{sne1}$] is on [**the road**$_{p1}$].
b. $[\![\mathcal{L}(J)]\!] = \lambda x[loc(x, J)]$, $\langle x{:}p, \mathcal{L}{:}e \rightarrow (p \rightarrow t) \rangle$

3 Events and Paths Generated from Events

The term *event* as it is used in ISO-Space is borrowed directly from ISO-TimeML (ISO, 2012) , and is used as a cover term for situations that *happen*, *occur*, *hold*, or *take place*. Following Davidson (1967) and Parsons (1990), we can represent the event as an individual predicated of an event class (the verb), where the arguments are then related by semantic role relations. It has further been proposed that there is internal structure to events which structurally differentiates the Aktionsarten of Vendler's classes. This has come to be known as *event structure*.[3] On this theory, the subevent structure of the event is explicitly represented in the lexical semantics and subsequent compositional interpretations, giving rise to three basic event structures, STATE, PROCESS, and TRANSITION. The EVENT tag captures ISO-TimeML events that are related to another ISO-Space element by way of a link tag (e.g., a spatial anchoring such as "*sleeping* in the courtyard"). The MOTION tag, on the other hand, identifies those events involving movement of an object through space. All MOTION tags participate in a MOVELINK relation.

There are two basic strategies that languages typically exploit to convey the movement of an object through space (Talmy, 1985): path verb constructions; and manner verb constructions.

[3] Cf. Pustejovsky (1991) and Moens and Steedman (1988).

(10) a. Path Motion: *John arrived at home.*
b. Manner Motion: *John walked.*

In terms of their event structure, path-verbs are transitions while manner verbs are processes. In addition, path verbs are those predicates that *presuppose* a specific path for the moving object (the figure), along with a possible distinguished point or region on this path (the ground), which the figure is moving toward or away from. Manner verbs can be seen as *creating* a path as the motion event unfolds. This is illustrated formally below.

(11) a. Path-presupposing verb (with temporal anchor):
$\lambda y \lambda x \lambda i \lambda e \exists e_1, e_2, p[@_i \text{arrive}(e) \wedge \text{arrive\_act}(e_1, x, p) \wedge DC(e_1, x, y) \wedge \text{arrive\_result}(e_2, x, p)$
$\wedge EC(e_2, x, y) \wedge \text{end}(y, p) \wedge e = e_1 \circ e_2 \wedge e_1 \leq e_2 \wedge e_1 \leq e \wedge e_2 \leq e]$

b. Path-introducing verb (with temporal anchor): :
$\lambda x \lambda p \lambda i \lambda e[@_i \text{walk}(e) \wedge \text{walk\_act}(e, x, p)]$

Path predicates make the change of location explicit in the subevent representation (cf. Pustejovsky (1995). This states that the figure, x, moves along a path, p, represented by the event e. This entails a transition from not being at the ground, e_1, to finally being at the ground, e_2. It further gives the necessary temporal constraints along with the constraint that the ground must be the termination of the path.

The type of the path variable, p, introduced above is no different than that used in the examples in (4)-(9), namely π_v or *int→vec*. The difference, however, is that there is no lexical offset (markable) in the sentences in (10), which can be associated with this path.

Because we are interested in semantically interpreting the annotation structure associated with a linguistic utterance, we will need to distinguish between the concept of *path* encountered above, which is a component part of the domain of space (or a vector space), and this new motion-dependent concept of path: namely, an *event path* is that region of space occupied by a mover throughout an event. For this reason, Lee et al. (2018), following Pustejovsky et al. (2012), suggest that ISO-Space introduce a distinct tag, called an EVENT_PATH. We can type an event path as that path which is associated with an object over time. Assuming the moving object, x, can be represented spatially as its eigenplace, $\mathcal{L}(x)$, the trace of the path created by x is typed as follows: *event path*, π_ϵ, as the function $\epsilon \rightarrow \pi_v$. This is a function from events to the paths they create.

4 Semantic Interpretation of Annotation Structures

In this section we will demonstrate how the concrete syntax of ISO-Space, as deployed over a natural language example, receives an intermediate semantic interpretation, which can then be subsequently interpreted in a model. That is, the semantics of ISO-Space validates each of the annotation structures by mapping it into a semantic form and then interpreting it model-theoretically.

In an XML-based concrete syntax, the two elements `<eventPath>` and `<moveLink>` are implemented each with a list of attribute-value specifications. Each instance of a motion-event triggers an event-path and each event-path is uniquely associated with a motion-event. Such a motion-event is represented by the attribute `@trigger` with a specific value referring to that motion-event associated with an event-path. As a finite path, every event-path has two ends: one is identified as its start and the other, as its end because it is directed. Hence, the attributes `@start`, `@mids`, and `@end` are required attributes. Their values are *unspecified* if these locations are not explicitly mentioned.[4]

The semantics proposed here maps each of the entity structures into a semantic form and then combines all of the semantic forms compositionally into a final semantic representation based on the associated link structures. Each of the annotation structures is interpreted as a Discourse Representation Structure (DRS), as defined in Kamp and Reyle (1993), through the interpretation function σ, a mapping

[4] Spatial relators such as *from*, *to*, and *through* just define the start, end, and mids of an event-path, without carrying any semantic content. Once the delimiting bounds of an event-path are marked up, the function of spatial relators is discharged.

from the set of entity structures to first-order well-formed expressions, with unbound variables being interpreted as existential or set-denoting. An example annotation structure representation is shown in (12) along with the following σ interpretations.

(12) a. **Dataset**: John arrived in Gothenburg.
Word-segmented: John$_{w1}$ arrived$_{w2}$ in$_{w3}$ Gothenburg$_{w4}$.

b. **Core annotated**: John$_{x1}$ arrived$_{m1}$ in$_{sr1}$ Gothenburg$_{pl1}$ $\emptyset_{ep1}$.

c. **Annotation Structures**

```
<annotation xml:id="is1" lang="en" aScheme="ISO-Space"/>
{*Entity Structures*:}
<entity xml:id="x1" target="#w1" type="person"/>
<motion xml:id="m1" target="#w2" type="path" tense="past"/>
<sRelation xml:id="sr1" target="#w3" type="endPt-defining"/>
<place xml:id="pl1" target="#w4" form="nam" ctv="city"
   type="ppl" country="sw"/>
<eventPath xml:id="ep1" target="" end="#pl1"/>
{*Link Structure*:}
<moveLink xml:id="mvL1" relType="traverse" figure="#x1"
   ground="#ep1" trigger="#m1"/>
</annotation>
```

(13) a. **Semantic Representation of the Entity Structures**

$\sigma(x_1) = [named(x, John) \wedge person(x)]$
$\sigma(m_1) = [arrive(m) \wedge past(m)]$
$\sigma(pl_1) = [named(l_1, Gothenburg) \wedge city(l_1) \wedge in(l_1, sw)]$
$\sigma(ep_1) = [route(p) \wedge starts(p, <l_0, i_0>) \wedge ends(p, <l_1, i_1>)]$

b. **Semantic Representation of the Link Structure**

$\sigma(mvL_1) = [mover(x, e) \wedge \lambda PP(x)(\sigma(x_1))] \wedge$
$[\lambda PP(p)(\sigma(ep_1)) \wedge traverses(x, p)]$

Interpretations (a) and (b) in (13) show how each of the annotation structures is translated through the interpretation function, σ into a first-order expression. Being a complex structure with IDREFs for the values of its attributes, the link structure has extra λP expressions each of which allows a required variable adjustment.

(14) **Semantic Representation of the Entire Annotation Structure**

$\sigma(is1) = [\sigma(mvL_1) \oplus [\sigma(x_1) \oplus \sigma(m_1) \oplus \sigma(pl_1) \oplus \sigma(t_1) \oplus \sigma(ep_1)]]$
$= [mover(x, e) \wedge named(x, John) \wedge person(x)] \wedge$
$[route(p) \wedge starts(p, <l_0, i_0>) \wedge ends(p, <l_1, i_1>) \wedge$
$[named(l_1, Gothenburg) \wedge city(l_1) \wedge in(l_1, sw)] \wedge$
$[traverses(x, p)]$

The semantic form of (14) is that of the entire annotation structure ($is1$), compositionally obtained from the list of the semantic forms of the entity and link structures, which are given in (13).

5 Conclusion

In this paper, we have outlined an initial semantics for the specification language ISO-Space. We have proposed a type-theoretic interpretation corresponding to the objects and relations in the abstract syntax metamodel. This is then mapped to the interpretation functions which associate the concrete syntactic elements to the semantic interpretations in the model.

John arrived in Gothenburg.				
Syntax			**Semantics**	
ID	**TARGET**	**ANNOTATION**	**semTYPE**	**semFORM**
x1	John	`type="person"`	$x : e$ (entity)	$named(x, John)$ $person(x)$
m1	arrived	`tense="past"`	$e : event$ (event)	$arrive(e)$ $past(e)$
s1	in			
pl1	Gothenburg	`ctv="city"`	$l : r$ (region)	$named(l_2, Gothenburg)$ $city(l_2)$
ep1	$\emptyset$	`start="unknown"` `end="pl1"`	$p : \pi_v$ (path)	$starts$(p,$< l_1, i_1 >$) $ends$(p,$< l_2, i_2 >$)
	.	.	t (truth-value)	ϕ

mvL1		`figure="x1"`
		`ground="ep1"`
		`relType="traverses"`
				$mover(x, e)$
				$route(p)$
				$traverses(x, p)$

Table 2: Semantics based on Abstract Syntax

References

Cresswell, M. (1978). Prepositions and points of view. *Linguistics and Philosophy 2*, 1–41.

Davidson, D. (1967). The logical form of action sentences. In N. Rescher (Ed.), *The Logic of Action and Decision*, pp. 81–95. University of Pittsburg Press.

Frank, A. U. (1996). Qualitative spatial reasoning: Cardinal directions as an example. *International Journal of Geographical Information Science 10*(3), 269–290.

Freksa, C. (1992). Using orientation representation for qualitative spatial reasoning. In A. Frank, I. Campari, and U. Formentini (Eds.), *Theories and Methods of Spatio- temporal Reasoning in Geographic Space: Proceedings of the International Conference GIS - From Space to Territory*, Pisa, Italy, pp. 162–178.

ISO (2012). *ISO 24617-1:2012(E) Language resource management - Semantic annotation framework - Part 1: Time and events (ISO-TimeML)*. International Organization for Standarization, Geneva. Note: ISO Project leader: Kiyong Lee; Editors: James Pustejovsky (chair), Branimir Boguraev, Harry Bunt, Nancy Ide, and Kiyong Lee, ISO/TC 37/SC 4/WG 2.

ISO (2014). *ISO 24617-7:2014(E) Language resource management - Semantic annotation framework - Part 7: Spatial information (ISO-Space)*. International Organization for Standardization, Geneva. Note: ISO Project leaders: James Pustejovsky and Kiyong Lee, ISO/TC 37/SC 4/WG 2.

ISO (2019). *ISO/CD 24617-7:2014(E) Language resource management - Semantic annotation framework - Part 7: Spatial information (ISO-Space)*. International Organization for Standardization, Geneva. Note: ISO Project leaders: James Pustejovsky and Kiyong Lee, ISO/TC 37/SC 4/WG 2.

Jackendoff, R. (1983). *Semantics and Cognition*. MIT Press.

Kamp, H. and U. Reyle (1993). *From Discourse to Logic: Introduction to Modeltheoretic Semantics of Natural Language, Formal Logic and Discourse Representation Theory*. Kluwer Academic Publishers, Dordrecht.

Kracht, M. (2002). On the semantics of locatives. *Linguistics and philosophy 25*(2), 157–232.

Lee, K. (2016). An abstract syntax for ISO-Spac with its `<movelink>` reformulated. In H. Bunt (Ed.), *Proceedings of the Twelfth Joint ACL - ISO Workshop on Interoperable Semantic Annotation (ISA-12)*, pp. 28–37. Workshop at LREC2016, 28 May 2016, Portorož, Slovenia.

Lee, K., J. Pustejovsky, and H. Bunt (2018). Revising ISO-Space and the role of the movement link. In H. Bunt (Ed.), *Proceedings of the Fourteenth Joint ACL - ISO Workshop on Interoperable Semantic Annotation (ISA-14)*, pp. 35–44. Workshop at COLING2018, August 25, 2018, Santa Fe, New Mexico, USA.

Mani, I. and J. Pustejovsky (2012). *Interpreting Motion: Grounded Representations for Spatial Language*. Oxford University Press.

Moens, M. and M. Steedman (1988). Temporal ontology and temporal reference. *Computational Linguistics 14*(2), 15–28.

Mossakowski, T. and R. Moratz (2012). Qualitative reasoning about relative direction of oriented points. *Artificial Intelligence 180*, 34–45.

Nam, S. (1995). *The Semantics of Locative Prepositional Phrases in English*. Ph. D. thesis, University of California at Los Angeles.

Parsons, T. (1990). *Events in the Semantics of English. A Study in Subatomic Semantics*. Cambridge, MA: MIT Press.

Pustejovsky, J. (1991). The generative lexicon. *Computational Linguistics 17*(4).

Pustejovsky, J. and K. Lee (2017). Enriching the notion of path in ISO-Space. In H. Bunt (Ed.), *Proceedings of the Thirteenth Joint ACL - ISO Workshop on Interoperable Semantic Annotation (ISA-13)*, pp. 134–139. IWCS 2017 Workshop, Montpellier, France, September 19, 2017.

Pustejovsky, J., J. Moszkowics, and M. Verhagen (2012). The current status of ISO-Space. In H. Bunt (Ed.), *Proceedings of the Seventh Joint ACL–ISO Workshop on Interoperable Semantic Annotation (ISA-7), SRSL3 Workshop on Semantic Representation for Spoken Language, and I2MRT Workshop on Multimodal Resources and Tools*, pp. 23–30. LREC 2012 Workshop, Istanbul, Turkey.

Pustejovsky, J. and Z. Yocum (2013). Capturing motion in ISO-SpaceBank. In H. Bunt (Ed.), *Proceedings of the Ninth Joint ACL–ISO Workshop on Interoperable Semantic Annotation (ISA-9)*, pp. 25–34. IWCS 2013 Workshop, Potsdam, Germany.

Randell, D. A., Z. Cui, and A. G. Cohn (1992). A spatial logic based on regions and connection. *KR 92*, 165–176.

Talmy, L. (1985). Lexicalization patterns: semantic structure in lexical forms. In T. Shopen (Ed.), *Language typology and semantic description Volume 3: Grammatical categories and the lexicon*, pp. 36–149. Cambridge University Press.

Wunderlich, D. (1991). How do prepositional phrases fit into compositional syntax and semantics? *Linguistics 29*(4), 591–622.

Zimmermann, K. and C. Freksa (1996). Qualitative spatial reasoning using orientation, distance, and path knowledge. *Applied Intelligence 6*(1), 49–58.

Zwarts, J. and M. Winter (2000). Vector space semantics: A model-theoretic analysis of locative prepositions. *Journal of Logic, Language, and Information 9*, 169–211.