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Part 14: **Spatial semantics**

Gestion des ressources linguistiques — Cadre d'annotation sémantique (SemAF) —

Partie 14: Sémantique spatiale

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Contents

Page

Foreword

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This document was prepared by Technical Committee ISO/TC 37, *Language and terminology*, Subcommittee SC 4, *Language resource management*.

A list of all parts in the ISO 24617 series can be found on the ISO website.

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Introduction

This document establishes a semantic ground for supporting ISO 24617-7 (spatial information), which specifies an abstract syntax for the annotation of spatial information in language. It also specifies a way of translating the annotation structures generated by the abstract syntax of ISO 24617-7 into well-formed semantic forms. These semantic forms are represented in a type-theoretic first-order logic and made interpretable according to a model.

This document:

— validates the abstract specification of ISO 24617-7 for the annotation of spatial information in language on semantic grounds;

— specifies an interoperable format for interpreting spatial information, both static and dynamic.

Dynamic spatial information involves spatio-temporal information as well as information about motions in space and time. This document aims at satisfying such needs. An understanding of information in natural language is necessary for many computational linguistics and artificial intelligence (AI) applications. An explicit semantics is necessary for the specification provided by ISO 24617-7, as the representations created in accord with that language will not have a significant impact on AI and automatic inference without explicit interpretation.

Language resource management — Semantic annotation framework (SemAF) —

Part 14:
Spatial semantics

1 Scope

This document extends ISO 24617-7:2020, which specifies ways of annotating spatial information in natural language such as English, by establishing a formal semantics for its abstract syntax. The task of the proposed semantics is of two kinds:

a) translation of annotation structures to semantic forms;

b) model-theoretic interpretation of semantic forms.

Semantic forms are represented in a type-theoretic first-order logic. These semantic forms are then interpreted with respect to a model for part of the world to which an annotated language is referentially, or denotationally, anchored.

NOTE The basic framework and content of this document is based on Reference [1].

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 24617-7:2020, *Language resource management — Semantic annotation framework — Part 7: Spatial information*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
annotation structure
information structure created by marking up some linguistic expressions with relevant (semantic) information

Note 1 to entry: ISO 24617-7:2020, for instance, creates such annotation structures by marking up place names or motions and their spatial relations with relevant spatial information.

3.2
eigenplace
eigenspace
region or path occupied by an object

Note 1 to entry: A region may be considered as a particular finite path matching to an interval [x,x] such that its start and endpoint match or are identical. In that case, a region is considered as a point.

3.3
event-path
region of space occupied by a mover (moving object) throughout an event

3.4
first-order logic
formal language, artificially built for reasoning, with the values of its terms, particularly variables, ranging over individual objects only

Note 1 to entry: Second-order variables such as *P*, which ranges over properties of an individual, are temporarily introduced to allow the λ-operation in the process of deriving *semantic forms* (3.7), see 7.2, Note and Example 2, b) and c).

3.5
interpretation
function that maps a *semantic form* (3.7) to its denotation

Note 1 to entry: The interpretation function is represented by ⟦ ⟧ and, for each semantic form a, its denotation or the value of the interpretation, is represented by ⟦σ(a)⟧.

Note 2 to entry: In a model-theoretic semantics, the interpretation function ⟦ ⟧ is constrained by a model M and, for each semantic form a and a model M, such an interpretation is represented by $[\![\sigma(a)]\!]^M$.

3.6
model M
set-theoretical construct that represents part of the real or possible world denoted by *semantic forms* (3.7)

3.7
semantic form
logical form
representation of the semantic content of an *annotation structure* (3.1) of expressions in natural language

Note 1 to entry: The semantic form of an annotation structure a is represented by σ(a), where σ is a function that maps an annotation structure a to a semantic form that carries the semantic content of a.

Note 2 to entry: Semantic forms are often called “logical forms” because semantic forms are represented by a logical language such as *first-order logic* (3.4).

3.8
type
semantic type
kind or sort of an object denoted by a linguistic expression

4 Metamodel

This document shall be used together with ISO 24617-7:2020.

The metamodel presented in this clause outlines the basic semantic structure for the abstract syntax of ISO 24617-7 for easy reference, which specifies an annotation scheme for the markup of spatial relations, both static and dynamic, as expressed in text and other media. This specification distinguishes the following six major categories of spatially relevant elements for markup in natural language:

a) spatial entities: natural or artificial locations in the world that include places, paths and event-paths, as well as individual entities participating in spatial relations;

b) spatial relators (signals): linguistic markers that establish relations between places and spatial entities;

c) spatial measures: quantitative information associated with spatial entities;

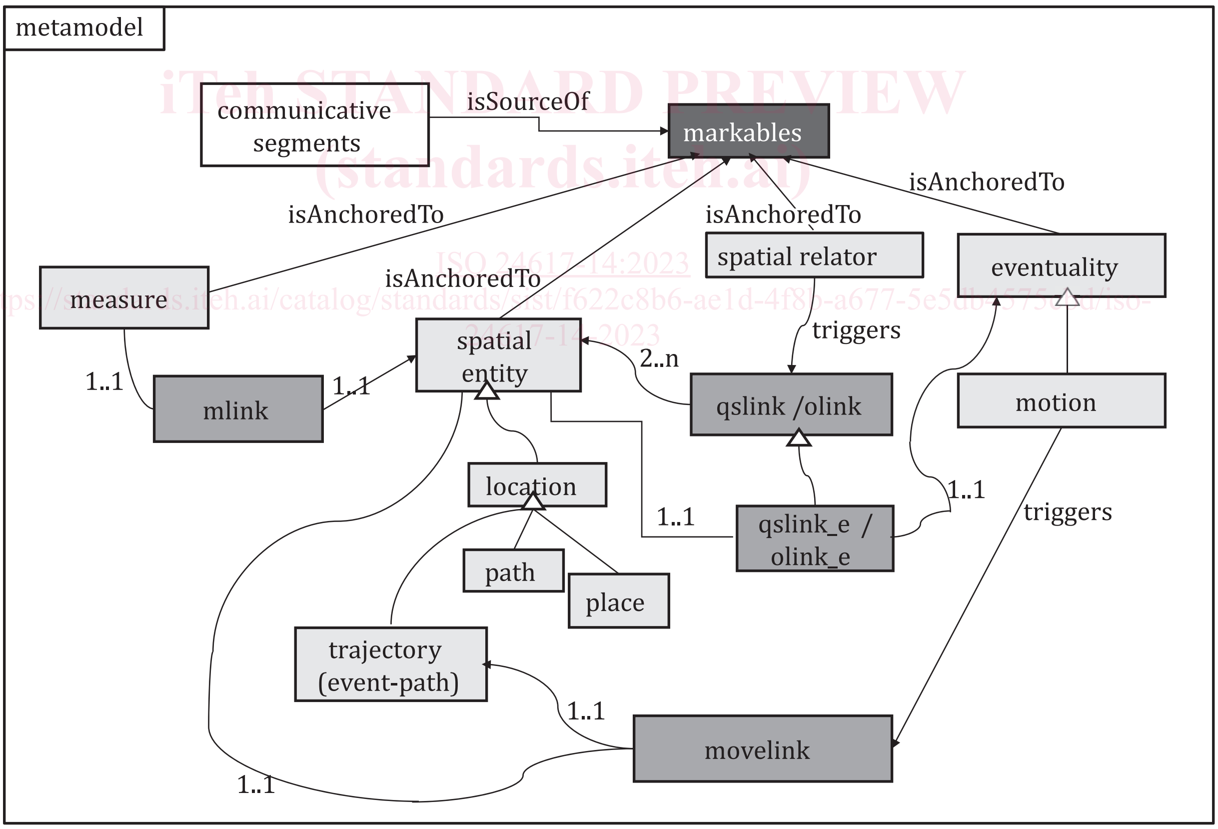
d) events and motions: eventualities either static or dynamic;

NOTE Unlike static eventualities such as referring to states, dynamic eventualities (motions) involve movement from one location to another triggering a trajectory (event-path).

e) static spatial relations: specific qualitative configurational, orientational and metric relations between objects;

f) dynamic spatial relations: movement of an object triggered by a motion from one location to another creating an event-path.

The corresponding metamodel for these categories is represented in Figure 1.



NOTE Source: Reference [2] with some modifications.

Figure 1 — Metamodel

Qualitative spatial link (qslink) and orientation link (olink) each relate one spatial object to another. In contrast, qslink_e and olink_e relate an eventuality of a special type such as “live” to a location such as “Boston” with a spatial signal “in”.

These categories are constrained by semantic types. Each of the categories listed in the abstract syntax of isoSpace is shown to match one of the semantic types defined in Clause 5.

5 Semantic types

5.1 General

The semantics of isoSpace 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 shall be identified when defining a formal semantics of an annotation structure, as applied to linguistic expressions in natural language:

— language to abstract model;

— concrete model to abstract model.

This clause focuses on the first mapping. It articulates the underlying semantics of the entities represented in the metamodel in type-theoretic terms and demonstrates the composition of examples within each category. Clause 6 illustrates the second mapping, from the annotation structure (implemented as a concrete syntactic expression) into the abstract model.

5.2 Basic types

5.2.1 General

The model-theoretic semantics of ISO 24617-7:2020 is based on a theory of semantic types, which sorts out various objects denoted by linguistic expressions or their annotation structures. It is assumed that a model is characterized with the basic types in 5.2.2 and the functional types in 5.2.3, corresponding generally to the categories in Figure 1. Following Reference [3], the list of basic types is extended to eight basic types from the two basic types (*e*, the type of objects, and *t*, the type of truth values) in Montague Semantics (see Reference [4]) as given in 5.2.2.

5.2.2 Extended basic types

The basic types are as follows:

a) *t*, the type of truth values;

b) *e*, the type of objects (entities);

c) *i*, the type of time points;

d) *p*, the type of spatial points;

e) *v*, the type of events;

f) *m*, the type of measures;

g) *int*, the type of intervals;

h) *vec*, the type of vectors.

Further, following Reference [3], the group operator • (bullet) is introduced, which applies to a type to form a group type, e.g. the group of points, p•.

5.2.3 Functional types

Additional types can be constructed with conventional binary type constructors: → and ×. From these, the standard set of functional types is defined, e.g. $e \rightarrow t$, $v \rightarrow t$, $p \rightarrow t$. Further, a semi-lattice of types is defined, where ⊑ 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.

The following typical functional types are derived with the binary type constructor →:

a) $e \rightarrow t$, the type of properties of an individual;

b) $p \rightarrow t$, the type r of regions;

c) $v \rightarrow t$, the type ε of eventuality descriptors;

d) $int \rightarrow p$, the type π of (static) paths;

e) $int \rightarrow vec$, the type π_v of vector-based paths.

Following the neo-Davidsonian semantics, "John walks" can be represented as [$walk(e) \wedge agent(e,j)$] such that "John" is annotated as being the agent of the event "walk". Here, the variable e refers to an eventuality of type v, while the verb is an eventuality descriptor denoting a predicate of type $v \rightarrow t$ or ε. The individual constant j referring to John is of type e. As for the type of static paths and vector-based paths, see 5.4.

5.3 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 Example 1, the qualitative spatial relation between the two entities is a relation between places. Both "Gothenburg" and "Sweden" are marked as PLACE, which is typed as "region". A region, r, is defined as a set of points, $p \rightarrow t$. This differs from Reference [3], where regions are defined as a subtype of p•, while • is a group operator over basic types, but either analysis can be adopted for these purposes.

NOTE 1 To differentiate tag names from common nouns, tag names are represented in upper case, e.g. PLACE is a tag for places like Gothenburg or Sweden.

The spatial words such as "location", "place", and "region" are all used equivalently. In annotation, they are all tagged PLACE. Semantically, they do not denote spatial points of type p. For example, Gothenburg refers to a location, place or region of type $p \rightarrow t$.

Further, a qualitative spatial mereo-topological relation within RCC8 (the Region Connection Calculus 8 qualitative spatial relations, see Reference [5]) is typed as a relation between regions: i.e. qslink: $r \rightarrow (r \rightarrow t)$ for qualitative spatial link, formulated in ISO 24617-7:2020.

EXAMPLE 1

a) $[\text{Gothenburg}]_{pl1}$ is $[\text{in}]_{s1}$ $[\text{Sweden}]_{pl2}$.

b) ⟦Gothenburg⟧ = G, < G: $p \rightarrow t$>

c) ⟦Sweden⟧ = S, < S: $p \rightarrow t$ >

d) ⟦in⟧ = $\lambda y \lambda x[\text{in}(x,y)]$, < in: $r \rightarrow (r \rightarrow t)$>

e) 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 are subtyped or identified in these documents as spatialEntity. When they participate in spatial relations, a type coercion function, $\mathcal{L}$, is assumed to operate 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. The type for this localization operator, $\mathcal{L}$, is: $e \rightarrow (p \rightarrow t)$.

