The ISA-17 Quantification Challenge: Background and introduction

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Abstract

This short paper provides background information for the shared quantification annotation task at the ISA-17 workshop, a.k.a. the Quantification Challenge. The role of the abstract and concrete syntax of the QuantML markup language are explained, and the semantic interpretation of QuantML annotations in relation to the ISO principles of semantic annotation. Additionally, the choice of the test suite of the Quantification Challenge is motivated.

1 Introduction

The ISA-17 Quantification Challenge was motivated by the decision of the International Organisation for Standardisation ISO to develop an international standard for the annotation of quantification in natural language, extending the series of standards for semantic annotation called the ISO Semantic Annotation Framework (SemAF, ISO 24617)). Other parts of this series include standards for the annotation of

(1) time and events (ISO 24617-1, 'ISO-TimeML');

(2) dialogue acts (ISO 24617-2, 'DiAML');

(3) semantic roles (ISO 24617-4);

(4) spatial information (ISO 24617-7, 'ISO-Space');

(5) discourse relations (ISO 24617-8, 'DR-Core');

(6) coreference (ISO 24617-9, 'Reference Annotation Framework').

Also belonging to this series is the meta-standard ISO 24617-6, 'Principles of semantic annotation', which defines a common methodological framework for developing other parts of SemAF.

As the first steps in the development of an annotation standard for quantification, preliminary studies have been conducted and reported at LREC 2018 (Bunt, Lee and Pustejovsky, 2018), at IWCS 2019 (Bunt, 2019), and in a technical report of Tilburg University (Bunt, 2021) in which the markup language QuantML is defined. On the basis of these studies, the document ISO WD 24617-12 was drafted. The ISA-17 Quantification Challenge is intended to identify the strengths, limitations, and deficiencies of the QuantML proposal by inviting experts in quantification and/or in semantic annotation to explore the application of QuantML in the annotation of a range of test sentences that display some of the phenomena that the future standard would hope to cover.

This paper is organised as follows. Section 2 briefly summarizes the ISO Principles of semantic annotation, especially where it concerns the architecture of a semantic annotation scheme, including the design of an abstract syntax and the specification of a concrete syntax plus the significance of a compositional semantics of the (abstract syntactic structures of the) annotations, and applies this to the QuantML annotation scheme. Section 3 introduces and motivates the choices in the test suite used in the Quantification Challenge.

2 QuantML

2.1 Annotation scheme architecture

The usual definition of a markup language consists of the specification of a number of XML elements, attributes, and values, that can be used to form descriptions of the linguistic properties of certain stretches of text or speech, called 'markables'. The definitions of TimeML (Pustejovsky et al., 2007) and SpatialML (Mani et al, 2010) illustrate this.

According to the ISO Principles of semantic annotation ISO 24617-6; see also Bunt (2015) and

Pustejovsky et al. (2017)) a semantic annotation scheme has a three-part architecture consisting of (1) an abstract syntax that specifies the possible *annotation structures* at a conceptual level as set-theoretical constructs, such as pairs and triples of concepts; (2) a concrete syntax, that specifies a representation format for annotation structures (for example using XML); (3) a semantics that specifies the meaning of the annotation structures defined by the abstract syntax.

The distinction of an abstract and a concrete syntax is motivated by the fundamental distinction between 'annotations' and 'representations', made in the Linguistic Annotation Framework (ISO standard 24612, see also Ide and Romary (2004). An 'annotation' captures certain linguistic information, independent on a particular representation format, while a 'representation' specifies a format for representing annotations. In the three-part architecture, 'annotations' are the conceptual structures defined by the abstract syntax (and called 'annotation structures'); 'representations' correspond to the particular format in which these structures are expressed (which we will usually call 'annotations', following the most common usage of this term). ISO standards for semantic annotation are intended to apply not at the level of representation formats, but that of the information they represent: the level of conceptual annotation structures.

The third component of a semantic annotation scheme, the specification of a semantics of annotation structures, is a requirement specific of *semantic* annotations, the *requirement of semantic adequacy* (Bunt and Romary (2002)): if the annotations would not have a well-defined semantics, it would not be clear what semantic information they add to the natural language expressions they annotate. Defining the semantics at the level of the *abstract* syntax puts the focus of an annotation standard at the conceptual level, rather than at the level of representation formats.

Formally, the definition of an annotation scheme is a triple consisting of specifications of an abstract syntax (AS), a concrete syntax (CS), and a semantics ($ASem$):

(1) $A = \langle ASyn_a, ASyn_c, ASem \rangle$

The abstract syntax consists of the specification of a set of basic concepts, called the 'conceptual inventory' (CI), and a set of constructions (AC) for forming conceptual structures out of basic concepts.

(2) $ASyn_a = \langle CI, AC \rangle$

Together, the sets CI and AC define the class of well-formed annotation structures.

The concrete syntax specification $ASyn_C$ contains a vocabulary V_c, the specification CC of a class of syntactic structures, such as XML elements, and an encoding function F_e. The components V_c and CC together define a class of well-formed representations, and F_e assigns such a representation to every well-formed annotation structure.

(3) $ASyn_c = \langle V_c, CC, F_e \rangle$

The semantics $ASem$ can be specified in various ways, for example as a model-theoretic semantics $\langle M, I_M \rangle$ with a model M and an interpretation function I_M that assigns concepts from M as meanings to annotation structures.

The three parts of the annotation schema are related through the encoding function F_e and the interpretation function I_M. In particular, a requirement for the relation between abstract and concrete syntax is that the concrete syntax is *complete* and *unambiguous* (Bunt (2010)) for the abstract syntax, i.e. every annotation structure has a representation in the concrete syntax, and every representation is the encoding of exactly one annotation structure. In other words, F_e is a total function and so is its inverse F_e^{-1}. The semantic component should also be complete: every annotation structure has a semantic interpretation.

Two types of structure are distinguished in an abstract syntax: *entity structures* and *link structures*. An entity structure contains semantic information about a segment of primary data and is formally a pair $\langle m, s \rangle$ consisting of a markable (m), which refers to a segment of primary data, and certain semantic information (s). A link structure contains information about the way two or more segments of primary data are semantically related. In QuantML three types of entity structure are defined (participant structures, event structures, and modifier structures) and two types of link structure (participation links and scope links). Participation links relate participants to events; scope links indicate scope relations between participants. See further Section 2.3.

The three-part structure of a semantic annotation scheme does not need to frighten the users of such a scheme: annotators (human or automatic) only have to deal with concrete representations. They can rely, however, on the abstract syntax and its semantics that comes with the definition of the scheme, in particular when in doubt how to use the concrete syntax for annotating certain linguistic phenomena: rather than just relying on annotation guidelines, which are bound to be incomplete, they check the semantics for the precise implications of the choices offered by the concrete syntax.

2.2 QuantML concrete syntax

A concrete QuantML syntax is specified here in the form of an XML representation of annotation structures. For each type of entity structure, defined by the abstract syntax, a corresponding XML element is defined; each of these elements has an attribute @xml:id whose value is a unique identification of (the information in) the element, and an attribute @target, whose value anchors the annotation in the primary data, having a markable as value (or a sequence of markables). In addition, these elements have the following attributes:

1. the XML element <entity>, for representing participant structures, has the attributes @domain, @involvement, @definiteness and optionally @size (default value: ≥ 1;
2. the XML element <event>, for representing event structures, has the attribute @pred for specifying an event type;
3. the XML element <qDomain>, for representing a quantification domain: has the attributes @source (with multiple values in the case of a conjunctive specification) and @restrictions;
4. the XML element <sourceDomain>, for representing quantification source domain specifications without modifiers: has the attributes @pred and @individuation;
5. the XML element <adjMod>, for representing adjectival modifiers, with the attributes @pred and @distr, and optionally the attribute @restrictions;
6. the XML element <nnMod>, for representing nouns as modifiers, with the attributes @pred and @distr, and optionally @restrictions;
7. the XML element <ppMod>, for representing PP modifiers, with the attributes @pRel, @pEntity, @distr and @linking;
8. the XML element <relClause>, for representing relative clauses, with the attributes @semRole, @clause, @distr and @linking;
9. the XML element <possRestr>, for representing possessive restrictions, with the attributes @possessor, @distr, and @linking.

For the two types of link structure defined by the abstract syntax, a corresponding XML element is defined:

- <participation> has the attributes @event, @participant, @semRole, @distr, and @evScope (default value: “narrow”), and optionally @exhaustiveness (default value: “non-exhaustive”), @rep (repetitiveness, default value: ≥ 1), and @polarity (default value: “positive”);
- <scoping> has the attributes @arg1, @arg2, @scopeRel.

2.3 QuantML abstract syntax

The QuantML abstract syntax defines the following entity structures $\langle m, s\rangle$ with markable m and semantic content s:

1. Participant structures: s is a triple or quadruple $\langle DS, q, d, N\rangle$, where DS is a domain specification, q is a specification of domain involvement, d is a definiteness, and N is a numerical size specification (optional).
2. Event structures: s is a predicate denoting an event domain.
3. Modifier structures: s contains a predicate for (NP head) noun modification by an adjectives, noun, prepositional phrase, relative clause, or possessive restriction, plus parameters for specifying properties of the modification.

The following link structures are defined:

1. Participation links: A 6-9 tuple as shown in (4), where the first two components are the linked event and participant structures, and the other components indicate properties of the way in which the participants are involved in the events, specifying a semantic role (R), a distribution (d), an event scope (σ) that specifies whether the event structure has wider or narrower scope than the participant structure, and optionally an exhaustiveness (ξ), a repetitiveness (ρ), and a polarity (p).

(4) $L_{P1} = \langle \epsilon_e, \epsilon_p, R, d, \sigma, p \rangle$

2. Scope relation links: triples ⟨participation link, participation link, scope relation⟩.

The conceptual inventory of the abstract syntax includes:[1]

1. predicates that characterise quantification domains, corresponding to the meanings of common nouns of the language of the primary data;
2. predicates that characterise event domains, corresponding to the meanings of verbs (and some other lexical items);
3. predicates corresponding to the meanings of adjectives or prepositions;
4. relations that denote semantic roles; for this purpose, the semantic roles defined in ISO 245617-4 (Semantic roles) are used;
5. binary and ternary relations for specifying proportional domain involvement, such as most, 'half, 'total', and "between";
6. non-numerical quantitative predicates for specifying domain involvement, like some and several;
7. parameters for specifying definiteness, polarity, distributivity, individuation, relative scoping, repetitiveness and exhaustivity.

Quantification annotation is associated with the units that in linguistics are called (small) clauses, i.e. a finite verb and its arguments. This is the level of syntactic structure where issues arise of the relative scoping of quantified participants in different roles, as well as relative scoping of event quantification and participant quantification. Annotation structures at this level are quadruples consisting of an event structure, a set of participant structures, a set of link structures that relate participants to events, and a set of link structures that specify scope relations; see (5), where ϵ_{ev} is an event structure; $\epsilon_{P1}...\epsilon_{Pn}$ are participant structures; $L_{P1}, ..., L_{Pn}$ are participation link structures, and $sc_1, ..., sc_k$ are scope link structures.

(5) $A = \langle \epsilon_{ev}, \{\epsilon_{P1}, ..., \epsilon_{Pn}\}, \{L_{P1}, ..., L_{Pn}\}, \{sc_1, ..., sc_k\} \rangle$

2.4 Semantics

The design of QuantML was inspired by the theory of generalized quantifiers (GQT, Barwise and Cooper 1981; Keenan and Westerstaahl), 1997, combined with neo-Davidsonian event semantics (Davidson, 1967; Parsons, 1990), viewing natural language quantifiers as properties of sets of participants involved in sets of events. Champollion (2015) has shown the viability of this type of combination.

QuantML has an interpretation-by-translation semantics in the form of a compositional, recursive translation of annotation structures to Discourse Representation Structures (DRSs) as defined by (Kamp and Reyle, 1993). If the annotation structure is fully connected, i.e., if (1) all participant entity structures are linked to an event structure, and (2) for any two participant entity structures linked to the same event structure the relative scopes are specified, then the interpretation function delivers a standard DRS; if one or both of these conditions are not satisfied, then the interpretation delivers an underspecified DRS (UDRS, Reyle, 1984).

The QuantML semantics is compositional in the sense that the interpretation of an annotation structure is obtained by combining the interpretations of its component entity structures and participation link structures in a manner that is determined by the scope link structures. Combining GQT Casting the semantics in this form is particularly convenient for combining annotations of quantification with other types of semantic information, using annotation schemes of the ISO Semantic Annotation Framework (SemAF) and annotation scheme plug-ins (Bunt, 2019).

The semantic entities that correspond to participant entity structures may be of any kind: real-world objects, abstract entities, events, individual concepts, intentional and intensional entities, hypothetical and fictional entities. The design of QuantML aims to be neutral with respect to ontological and linguistic views on the existence of objects of various kinds and the need for them in semantic accounts of natural language.

Note that a participation link structure embeds the linked event structure and participant structure, to the effect that the annotation structures as defined by the abstract syntax are nested structures, as opposed to their flat XML-representations. The interpretation of a fully-connected annotation structure is therefore determined by the interpretation

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[1] This listing is slightly simplified. For the full specification see Bunt (2020).

of the participation link structures.

The semantics of a participation link structure is a combination of the semantics of its components by means of the interpretation function I_Q as specified in (6), where $\cup$ is the operation of merging two DRSs, as defined in DRT, and $\cup^*$ is the scoped merge operation, defined below in (11).

(6) a. $I_Q(\epsilon_E, \epsilon_P, R, \text{d}, \text{narrow}) = (I_Q(\epsilon_P) \cup^* I_Q(\epsilon_E)) \cup I_Q(\text{R, d, narrow})$

b. $I_Q(\epsilon_E, \epsilon_P, R, \text{d}, \text{wide}) = (I_Q(\epsilon_E) \cup^* I_Q(\epsilon_P)) \cup I_Q(\text{R, d, wide})$

c. $I_Q(\epsilon_E, \epsilon_P, R, \text{d}, \text{free}) = (I_Q(\epsilon_E) \cup I_Q(\epsilon_P)) \cup I_Q(\text{R, d, free})$

As an illustration, consider sentence (7), with its annotation and interpretation shown in Figure 1.

(7) All the students read three papers

A quantifier of the form *"All the D"* is interpreted as a DRS of the form (8), where capital letters are used for discourse referents that correspond to non-empty sets of individuals. This DRS says that there is a non-empty subset X of the quantification domain D containing all the contextually distinguished students, using the subscript '0' to indicate the contextually determined 'reference domain' or 'context set' (Westerståhl, 1985)). This subset X contains those elements of the reference domain that participate in a set of events. For the quantifier *"All the students"* this leads to the interpretation (8b). Similarly, the annotation of the quantifier *"three papers"* leads to the interpretation (8c).

(8) a. $[X|x \in X \leftrightarrow D_0(x)]$

b. $[X|x \in X \leftrightarrow \text{student}_0(x)]$

c. $[Y||Y| = 3, y \in Y \rightarrow \mathit{paper}(\text{y})\ ]$

For the semantic role R, the distribution d = 'individual', and the event scope σ = 'narrow', the interpretation of the third component in (6) is the DRS in (9), which says that there is a non-empty participant set of which every member has the role R in a non-empty set of events:

(9) $I_Q(\text{R,individual,narrow}) = [X|x \in X \leftrightarrow D_0(x), x \in X \rightarrow [E|e \in E \rightarrow R(e,x)]]$

Application of (6) and merging the DRS in (9) with the DRSs interpreting the participant structure and the event structure, results in (10) for the interpretation of the annotation of the sentence in (7).

(10) $[X|x \in X \leftrightarrow \text{student}_o(x), x \in X \rightarrow$
$[Y||Y| = 3, y \in Y \rightarrow [E|\text{paper}(y),$
$e \in E \rightarrow [|\mathit{agent}(e,x), \mathit{theme}(e,y)]]]$

The scoped merge operation is designed to combine the information about quantified participation in two participation link structures, and is defined as follows:

(11) The scoped merge operation combines the information in its argument DRSs into a DRS that reflects the relative scoping of the quantifications involved, as well as the relative scopings of participants and events, while unifying the event discourse referents in the two arguments. (If this unification is not possible, then the operation fails.)

For annotation structures that do not fully specify the relative scopes of all the sets of participants involved in the same events, the semantic interpretation takes the form of a set of (sub-)DRSs that express the semantics of the participation link structures, plus the scope restrictions for their possible combination. Such an interpretation is known in DRT as an underspecified DRS (UDRS, Reyle, 1994).

A detailed specification of the semantics of QuantML annotation structures can be found in the technical report Bunt (2020), available on the ISA-17 website `https://sigsem.uvt.nl/isa17/TiCC_Report_Quantification-12-Print.pdf`.

3 The Quantification Challenge test suite

3.1 Quantification phenomena

The Quantification Challenge test suite has been constructed in such a way that its sentences illustrate the coverage of the QuantML proposal, with a number of challenging borderline cases that invite speculation and creativeness in finding adequate annotations. More specifically, the test suite covers the following phenomena:

- Definiteness and determinacy of NPs. Where an NP like *"the students"* is obviously definite, and semantically determinate, less obvious is how to characterize *"some of the students"* or *"one of my friends"*.

- Attributive and predicative adjectives.

- Deictic NPs such as *"I"* and *"you"*.

(7) All the students read three papers.

Markables:
m1 = all the students, m2 = students, m3 = read, m4 = three papers, m5 = papers.

QuantML annotation:
<entity xml:id=x1 target=#m1 domain=#x2 involvement=all definiteness=det/>
<sourceDomain xml:id=x2 target=#m2 pred=student/>
<event xml:id=e1 target=#m3 pred=read/>
<entity xml:id=x3 target=#m4 domain=#x4 involvement=3 definiteness=indet/>
<sourceDomain xml:id=x4 target=#m5 pred=paper/>
<participation event=#e1 participant=#x1 semRole=agent distr=individual evScope=narrow/>
<participation event=#e1 participant=#x3 semRole=theme distr=individual evScope=narrow/>
<scoping arg1=#x1 arg2=#x2 scopeRel=wider/>

Annotation structure:
$A = \langle \epsilon_{ev}, \{\epsilon_{P1}, \epsilon_{P2}\}, \{L_{P1}, L_{P2}\}, \{sc_1\}\rangle =$
$= \langle\langle \text{m3, read}\rangle, \{\langle m1, \langle m2, \langle \text{student,count}\rangle\rangle, \text{all, det}\rangle, \langle m4, \langle m5, \langle \text{paper,count}\rangle\rangle, 3, indet\rangle\},$
$\{\langle\langle m3, read\rangle, \langle m1, \langle m2, \langle student, count\rangle\rangle, all, indet\rangle\rangle, agent, individual, narrow\rangle,$
$\{\langle\langle m3, read\rangle, \langle m4, \langle m5, \langle paper, count\rangle\rangle, 3, indet\rangle\rangle, theme, individual, narrow\rangle\}$
$\langle\langle\langle \text{m3, read}\rangle, \{\langle m1, \langle m2, \langle \text{student,count}\rangle\rangle, \text{all, det}\rangle, \langle m4, \langle m5, \langle \text{paper,count}\rangle\rangle, 3, indet\rangle, \text{wider}\rangle\rangle$

c. Semantics:
$I_Q(A) = I_Q(L_{P1}) \cup^* I_Q(L_{P2}) \cup^* I_Q)(\epsilon_{ev}) =$
$[X|x \in X \leftrightarrow \text{student}_0(x), x \in X \rightarrow [Y|y \in Y \rightarrow [E|\ \text{paper}(y), e \in E \rightarrow [\ \text{agent}(e,x), \text{theme}(e,y)]]]]]$

Figure 1: Example annotation with abstract syntax and semantics

- Scope ambiguities, as in *"The editors didn't see a misprint"*.
- Conjoined NPs, like *"Bert and Alice"*.
- Relative clauses.
- Proper names.
- Temporal quantifiers, such as *"twice"*, *"two to three times"*, and *"every hour"*.
- Negations.
- Mass NPs.
- Anaphoric possessive pronouns (*"his"*, *"their"*).
- Complex possessives, as in *"The headmaster's childrens' toys"*.
- Collective quantifications, as in *"These machines combine 12 parts"*, interpreted as saying that each of the machines every time combines twelve parts.
- Exhasutive quantification.
- Quantification with unscpecific distribution, as in *"The boys carried the boxes upstairs"*.
- Complex NN-modifications, like *"new corona virus infections"*.

3.2 Markables

The sentences in the test suite all come with a suggestion for substrings to be used as markables in the annotation. This is to make the comparison of annotations made by different annotators easier, .

Concerning the choice of markables for a given (small) clause, first of all every NP is naturally a markable, describing a set of participants (or possibly a single participant), and the main verb (possibly with modifiers) is another markable, corresponding to the events in which the participants are involved. Other markables are those words that correspond to the predicates of the conceptual inventory in the abstract syntax and those in the concrete syntax, notably as values of the @pred attribute. This concerns all nouns, adjectives, prepositions, and numerical as well as non-numerical terms.

A direct consequence of this way of distinguishing markables, is that they may overlap; for example, the markable for an NP overlaps with the one for its head noun. In such a case, the numbering of markables is determined in the first place by its left boundary, and if they have the same left boundary, than by the linear position of the right boundary. So in the sentence *"Most of the students passed the exam"*, *Most"* is numbered as markable m1, and *"Most of the students"* as markable m2.

Markables may be discontinuous, for example, in *"The boys carried the boxes upstairs"*, the words *"carried upstairs"* is a discontinuous markable. Following the ordering convention of Discontinuous Phrase Structure Grammar (Bunt, 1996), the numbering of discontinuous markables is determined by their leftmost element, and if two such markables have the same leftmost element then by their next element, and so on.

3.3 Annotation guidelines

The documentation for annotating and interpreting the sentences of the test suite, in particular the technical report (Bunt, 2018), defines concepts and provides guidelines for dealing with these phenomena. These guidelines have not yet been very well developed, and a secondary purpose of the ISA-17 Quantification Challenge, besides the identification of its strengths and weaknesses for annotating quantification phenomena in a semantically adequate way, is to obtain a good picture of the ways in which these guidelines can be improved and extended. The introduction of decision trees to support annotators in choosing the right values of QuantML attributes may for example be an attractive direction.

References

J. Barwise and R. Cooper. 1981. Generalized Quantifiers and Natural Language. *Linguistics and Philosophy*, 4:159–219.

H. Bunt. 1996. Formal tools for the description and processing of discontinuous constituents. In Harry Bunt and Arthur van Horck, editors, *Discontinuous Constituency.*, pages 63–85. Mouton De Gruyter, Berlin.

H. Bunt. 2009. The DIT++ taxonomy for functional dialogue markup. In *Proceedings of AAMAS 2009 Workshop 'Towards a Standard Markup Language for Embodied Dialogue Acts'*, pages 13–24, Budapest.

H. Bunt. 2010. A methodology for designing semantic annotation languages exploring semantic-syntactic ISO-morphisms. In *Proceedings of the Second International Conference on Global Interoperability for Language Resources (ICGL 2010)*, pages 29–46, Hong Kong: City University.

H. Bunt. 2015. On the principles of semantic annotation. In *Proceedings 11th Joint ACL-ISO Workshop on Interoperable Semantic Annotation (ISA-11)*, pages 1–13, London.

H. Bunt. 2018. *Semantic Annotation of Quantification in Natural Language. TiCC Technical Report* 2018-15. Tilburg Center for Cognition and Communication, Tilburg University.

H. Bunt. 2019a. An annotation scheme for quantification. In *Proceedings 13th International Conference on Computational Semantics (IWCS 2019)*, pages 31–43, University of Gothenburg.

H. Bunt. 2019b. Plug-ins for content annotation of dialogue acts. In *Proceedings 15th Joint ISO-ACL Workshop on Interoperable Semantic Annotation (ISA-15)*, pages 34–45, Gothenburg, Sweden.

H. Bunt. 2021. *Semantic Annotation of Quantification in Natural Language, second edition. TiCC Technical Report* 2021-2. Tilburg Center for Cognition and Communication, Tilburg University.

H. Bunt, J. Pustejovsky, and K. Lee. 2018. Towards an ISO Standar for the Annotation of Quantification. In *Proceedings of the 11th International Conference on Language Resources and Evaluation (LREC 2018)*, Miyazaki, Japan.

H. Bunt and L. Romary. 2002. Towards Multimodal Content Representation. In *Proceedings of LREC 2002, Workshop on International Standards of Terminology and Language Resources Management*, pages 54–60, Las Palmas. Paris: ELRA.

L. Champollion. 2015. The interaction of compositional semantics and event semantics. *Linguistics and Philosophy*, 38 (1):31–66.

D. Davidson. 1967. The logical form of action sentences. In N. Rescher, editor, *The Logic of Decision and Action*. University of Pittsburgh Press.

N. Ide and L. Romary. 2004. International standard for a linguistic annotation framework. *Natural Language Engineering*, 10:221–225.

ISO. 2010. *ISO 24612: Language resource management: Linguistic annotation framework (LAF)*. International Organisation for Standardisation ISO, Geneva.

ISO. 2012. *ISO 24617-1: Language resource management – Semantic annotation framework – Part 1: Time and events ('ISO-TimeML')*. International Organisation for Standardisation ISO, Geneva.

ISO. 2014. *ISO 24617-2: Language resource management – Semantic annotation framework – Part 4: Semantic roles*. International Organisation for Standardisation ISO, Geneva.

ISO. 2016a. *ISO 24617-2: Language resource management – Semantic annotation framework – Part 6:Principles of semantic annotation*. International Organisation for Standardisation ISO, Geneva.

ISO. 2016b. *ISO WD 24617-2: Language resource management – Semantic annotation framework – Part 12: Quantification ('QuantML', Working Draft)*. International Organisation for Standardisation ISO, Geneva.

H. Kamp and U. Reyle. 1993. *From Discourse to Logic*. Kluwer Academic Publishers, Dordrecht.

E. Keenan and D. Westerståhl. 1997. Generalized Quantifiers in Linguistics and Logic. In *Generalized Quantifiers in Natural Language*, pages 837–993. Foris, Dordrecht.

I. Mani, C. Doran, D. Harris, J.Hitzeman, S.R. Quinby, J. Richer, B. Wellner, S. Mardis, and S. Clancy. 2010. SpatialML: Annotation Scheme, Resources, and Evaluation. *Language Resources and Evaluation*, 44(3):263–280.

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

S. Peters and D. Westerståhl. 2013. The Semantics of Possessives. *Language*, 89(4):713–759.

J. Pustejovsky, H. Bunt, and A. Zaenen. 2017. Designing annotation schemes: From theory to model. In Nancy Ide and James Pustejovsky, editors, *Handbook of Linguistic Annotation*, pages 21–72. Springer, Berlin.

J. Pustejovsky, R. Knippen, J. Litman, and R. Sauri. 2007. Temporal and event information in natural language text. In *Computing Meaning, Vol. 3*, pages 301–346. Springer, Dordrecht.

U. Reyle. 1993. Dealing with ambiguities by underspecification: Construction, representation, and deduction. *Journal of Semantics*, pages 123–179.

D. Westerståhl. 1985. Determiners and context sets. In Johan van Benthem and Alice ter Meulen, editors, *Generalized Quantifiers in Natural Language*, pages 45–71. Foris, Dordrecht.