Formal semantics and corpus-based approaches to predicate-argument structure

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Structure

1. History of Semantic Roles
2. Contemporary Frameworks
3. Difficult Phenomena (from an empirical perspective)
4. Role Semantics vs. Formal Semantics
5. Cross-lingual aspects

Agenda

- Formal (sentence) semantics: a brief reminder of the basics
- Sources of world knowledge:
  - Ontologies
  - Corpus-based approaches
  - Frame-semantic analysis as a corpus-based approach based on something resembling an ontology
- Problems in combining the two

Formal (sentence) semantics: a brief reminder

- Sentence semantics:
  - Represent meaning of a sentence as a logic formula
  - The formula is then interpreted using model-theoretic semantics
- See e.g. LTF Gamut: Logic, Language, and Meaning

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Representing the meaning of a sentence as a logic formula

- Peter is a student: student'(peter')
- Peter is not a student: ¬student'(peter')
- Only Peter is a student: ∀x.(student'(x) ↔ x=Peter)
- Every child loves Asterix. ∀x.child'(x) →love'(x, Asterix)
- Everybody has a fault: ∀x.person'(x) →∃y.fault'(y) ∧ have'(x,y)
  ∃y.fault'(y) ∧ ∀x.person'(x) → have'(x,y)

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Representing the meaning of a sentence using logic: issues

- Compositionality: The meaning of an expression is completely determined by the meanings of its components
  - life: life'
  - hit: λxλy.hit'(y, x)
- Some important phenomena and questions:
  - Scope ambiguity, as shown in the "everybody has a fault" example
  - Plural
  - Negation

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Model-theoretic semantics

- Interpreting a logic language by mapping components to a domain
- An interpretation of a first-order logic consists of
  - a nonempty universe (domain) D
  - an interpretation function I:
    maps each n-place predicate symbol to a function from D^n to { true, false }
    I(sleep'): true for all entities that sleep, false for all other entities

Model-theoretic semantics cont'd

- Interpretation function I:
  maps each n-place predicate symbol to a function from D^n to { true, false }
  - I(sleep'): true for all entities that sleep, false for all other entities
- Equivalently: I maps a predicate symbol p to the set of entity tuples for which p holds
  - I(sleep') is the set of all entities that sleep
  - I(hit') is the set of entity pairs (e_1, e_2) such that e_1 hits e_2

Formal (sentence) semantics and inferences

- Representation of sentence meaning as a logic formula: Then a theorem prover can be used to infer new knowledge from text
  - All humans are mortal. $\forall x.human(x) \rightarrow mortal(x)$
  - Socrates is human. human(s)
  - So Socrates is mortal. mortal(s)
- For more sophisticated inferences, world knowledge is needed. Where can we get it?

Formal (sentence) semantics and lexical knowledge

- Sentence semantics:
  " The meaning of life is life' "
- The meaning of a word w:
  represented as w'.
  Different readings of w: w_1', w_2'…
- Interpretation is performed by interpretation function, which maps w' to the domain
- Additional lexical information can be included in the form of axioms
  - documentation: there exists an event that is a documenting event and of which this documentation is the result

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Sources of world knowledge: ontologies

- Ontologies typically contain:
  - Inheritance relations between concepts
  - Axioms

Sources of world knowledge: corpus-based approaches

- Lexical acquisition: learning lexical and world knowledge from corpora
  - Selectional preferences: Resnik 96
  - Hyponymy: Hearst 92
  - Causal connections, happens-before, …: VerbOcean, Chklovsky & Pantel 04
  - Part-whole relations: Girju et al 05

Frame-semantic analysis: corpus-based, with ontology

- Annotated corpus data with Frame-semantic analyses exists:
  - English FrameNet data
  - German SALSA data
- FrameNet has some properties of an ontology:
  - Frames have definitions (in natural language, though)
  - Frames are linked by Inheritance, Using, Subframe links

Frame-semantic analysis cont'd

- Lexical acquisition: learning additional knowledge about frames from corpora?
  - Selectional preferences for semantic roles
  - Inheritance relations between frames

Frame-semantic analysis as partial semantic analysis

- Formal (sentence) semantics: complete representation of sentence meaning
- Frame-semantic analysis:
  - Represents just frames and roles
  - Ignores negation, plural, scope
- Next up: example for complete frame-semantic analysis of a text

Frame-semantic analysis for contiguous text (from FrameNet webpage)

1. *Why* CA$_{\text{Capability}}$ *n't we* TEACH$_{\text{Education_teaching}}$ *our* CHILDREN$_{\text{Kinship}}$ *to* READ$_{\text{Reading}}$, WRITE$_{\text{Text_creation}}$ *and* reckon *? It 's not that we do n't* KNOW$_{\text{Awareness}}$ *how to , because we do . It 's that we do n't*

- [$_{\text{Cause}}$Why] *CA*$^{\text{Target}}$ n't [$_{\text{Entity}}$we] [$_{\text{Event}}$teach our children to read , write and reckon] ?
- Why ca n't [$_{\text{Teacher}}$we] *TEACH*$^{\text{Target}}$ [$_{\text{Student}}$our children] [$_{\text{Skill}}$to read , write and reckon] ?
- Why ca n't we teach [$_{\text{Ego}}$our] [$_{\text{Alter}}$ *CHILDREN*$^{\text{Target}}$] to read , write and reckon ?
- Why ca n't we teach [$_{\text{Reader}}$our children] to *READ*$^{\text{Target}}$, write and reckon ? [$_{\text{Text}}$INI]
- Why ca n't we teach [$_{\text{Author}}$our children] to read , *WRITE*$^{\text{Target}}$ and

FrameNet example cont'd: All words in capitals are predicates

1. *The* ART$_{\text{Craft}}$ *of* change-ringing *is* PECULIAR$_{\text{Idiosyncrasy}}$ *to the* ENGLISH$_{\text{People_by_origin}}$ *, and ,* LIKE$_{\text{Similarity}}$ most English PECULIARITIES$_{\text{Idiosyncrasy}}$, UNINTELLIGIBLE$_{\text{Grasp}}$ *to the* REST$_{\text{Rest}}$ *of the* WORLD$_{\text{Political_locales}}$.

2. *Dorothy L. Sayers* , *`` The Nine Tailors ''*

3. *ASLACTON , England* -- OF$_{\text{Partitive}}$ *all* SCENES$_{\text{Sensation}}$ *that* EVOKE$_{\text{Evoking}}$ RURAL$_{\text{Locale_by_use}}$ *England , this is one* OF$_{\text{Partitive}}$ *the* LOVELIEST$_{\text{Aesthetics}}$ *: An* ANCIENT$_{\text{Age}}$ stone CHURCH$_{\text{Buildings}}$ STANDS$_{\text{Being_located}}$ AMID$_{\text{Locative_relation}}$ *the* FIELDS$_{\text{Locale_by_use}}$ *, the* SOUND$_{\text{Sensation}}$ *of* BELLS$_{\text{Noise_makers}}$ CASCADING$_{\text{Fluidic_motion}}$ *from its* TOWER$_{\text{Building_subparts}}$, CALLING$_{\text{Request}}$ *the* FAITHFUL$_{\text{People_by_religion}}$ *to* EVENSONG$_{\text{Rite}}$.

Why integrate sentence semantics with something like frame-semantic analysis?

- Carlson (1984): a semantics that critically relies on semantic roles for semantics construction
- Our argument is different:
  - Not that semantics construction would need semantic roles
  - But that formal semantics can profit from ontology-based and corpus-based approaches that add lexical and world knowledge

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Integrating sentence semantics with frame-semantic analysis

- Modular combination?
  - Sentence semantics yields meaning representation for a sentence
  - Frame-semantic analysis adds knowledge about predicate meaning and meaning or argument positions
- Problems with vagueness again:
  - A problem for theorem provers
  - A problem for model-theoretic semantics

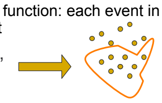
A problem for theorem provers

- Two types of non-certain knowledge from sense and role analysis:
  - defeasible information: "birds can fly"
  - more-or-less information
    - "falsehood" in conceptualization of "lie"
    - selectional preferences learned from corpora
- How can theorem provers deal with this?
  - Propositional logic: Bayesian networks
  - First-order logic: currently an active research area in the AI community

A problem for model-theoretic semantics

- Discussing the problem for theorem provers, we have assumed that we can integrate the information coming from the frame-semantic analysis into our sentence semantics.
  But can we?
- Interpretation function maps each n-place predicate symbol to a function from D^n to { true, false }
- What is the interpretation of lie'?
  - Interpretation function: each event in the domain is either a lie, or it isn't

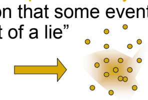
lie'



A problem for model-theoretic semantics

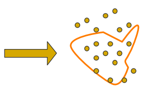
- It is not possible to model with an interpretation function a concept with fuzzy boundaries,
  i.e. the intuition that some event can be "kind of a lie", "a little bit of a lie"

lie'



- So: If we want to use an interpretation function, boundaries have to be made strict.

lie'



We stop here.

This is an introductory class, after all.

Summary

- Formal (sentence) semantics:
  - Representing the meaning of the whole sentence
  - Resulting formulas can be fed into a theorem prover for inferences
  - lexical meaning not at focus
- Ontologies and corpus-based approaches can furnish additional lexical and world knowledge
- Frame-semantic analysis as an ontology-based and corpus-based approach
  - Represents only part of the sentence meaning

Summary

- Combining formal sentence semantics with frame-semantic analyses or a similar approach:
  - Aim: augment lexical and world knowledge
- Problems with vagueness:
  - Non-certain knowledge difficult for theorem provers:
    - Defeasible knowledge
    - More-or-less knowleddge
  - Problem with model-theoretic semantics: Categories with “fuzzy boundaries” cannot be represented

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