Semantic Theory: Lexical Semantics I

Summer 2008

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Structure of this course

- Sentence semantics
- Discourse semantics
- Lexical semantics

Dolphins in First-order Logic

Dolphins are mammals, not fish.

∀d (dolphin'(d)→mammal'(d) ∧¬fish'(d))

Dolphins live-in pods.

∀d (dolphin'(d)→ ∃x (pod'(p) ∧live-in'(d,p))

Dolphins give birth to one baby at a time.

∀d (dolphin'(d)→
  ∀x ∀y ∀t (give-birth-to' (d,x,t) ∧give-birth-to' (d,y,t)
    → x=y)

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The dolphin text

Dolphins are mammals, not fish. They are warm blooded like man, and give birth to one baby called a calf at a time. At birth a bottlenose dolphin calf is about 90-130 cms long and will grow to approx. 4 metres, living up to 40 years. They are highly sociable animals, living in pods which are fairly fluid, with dolphins from other pods interacting with each other from time to time.

Function Words

Dolphins are mammals, not fish. They are warm blooded like man, and give birth to one baby called a calf at a time. At birth a bottlenose dolphin calf is about 90-130 cms long and will grow to approx. 4 metres, living up to 40 years. They are highly sociable animals, living in pods which are fairly fluid, with dolphins from other pods interacting with each other from time to time.

- Copula, connectives, quantifiers, negation, modal and tense operators, relative pronouns -> Sentence semantics
- Personal and possessive pronouns, definite article, local and tense adverbials -> Discourse semantics
- Other function words

Content words

Dolphins are mammals, not fish. They are warm blooded like man, and give birth to one baby called a calf at a time. At birth a bottlenose dolphin calf is about 90-130 cms long and will grow to approx. 4 metres, living up to 40 years. They are highly sociable animals, living in pods which are fairly fluid, with dolphins from other pods interacting with each other from time to time.

- Common nouns
- Full verbs
- Adjectives
- (Prepositions)

Lexical Semantics

- Seeing just the function words, you do not understand anything.
- Seeing the content words, you get a quite clear idea of what a document or utterance is about.
- But you need the function words to get beyond mere „aboutness“ knowledge: to learn about the what is stated or asserted.
- Nevertheless, content words bear the main load of semantic information.
- The meaning of content words is the object of lexical semantics.
- Lescial semantics is the most challenging subfield of semantics - theroetical as well as computational.

Challenges in lexical semantics

- Lexical ambiguity (and its resolution)
- Complexity and heterogeneity of single word senses (and its representation)
- The very size of the lexicon (and the development of wide-coverage lexical resources)

The word-meaning-relation

- The relation between
  - phonological/ orthographic words and
  - senses/ word meanings/ concepts

  is not one-to-one.
- One sense/ concept can be encoded in different phonological words: Synonymy
- One (phonological or orthographic) word can be associated with several senses: Lexical ambiguity

Lexical Ambiguity

- Ambiguity between unrelated senses: Homonymy (*bank* as *river bank* or *financial institution*)
- Ambiguity between semantically related concepts: Polysemy
- Homonyms are typically represented as different lexical entries (lexemes, lemmas), cases of polysemy as single entries with multiple sense descriptions.
  - No theoretically sound and operational criteria for the distinction between homonymy and polysemy

Polysemy

- Unsystematic cases of polysemy
  - *bank: financial institution - blood bank*
  - *case: carton - case: suitcase - case: pillowcase*
  - *to serve a meal - to serve as president*
- Systematic polysemy
  - *rabbit*, *dear, chicken*: animal – meat – fur
  - *fast car – fast road – fast driver*
- Systematic polysemy is sometimes seen not as part of the static lexical representation, but part of a dynamic process of “reinterpretation”, generating figurative readings.

Lexical Ambiguity

- Ambiguity, in particular polysemy, is a pervasive feature of the lexicon. The more frequent a word, the greater is typically the number of senses (up to about 50, according to standard dictionaries and WordNet).
- There is no clear criterion for the granularity of sense distinctions:
  - two distinct senses vs. two usage patterns of the same sense
  - *onion (eating onions – growing onions)*
- There is no clear-cut outer boundary for the set of possible senses of a lexical item
  - meaning extensions and figurative uses are always possible
- Words can occur in multiword expressions with a special interpretation
  - additional use of the word, or separate multiword entry in the lexicon?

Word-meaning is multi-layered

Diversity of word meaning

- The concepts corresponding to single readings of a word are typically multi-layered, consisting of heterogeneous kinds of information (crossing modality), among other things:
  - Propositional information – can be paraphrased in language, symbolically represented in a logical framework
  - Visual (or other sensory) prototypical information
  - Stereotypical information – valid in the „normal“, default case
- No clear-cut boundary between word meaning and world knowledge.
- No clear-cut boundary between common-sense meaning and domain-specific „ontological“ information.

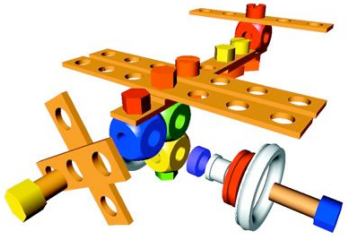
Size and complexity of the lexicon

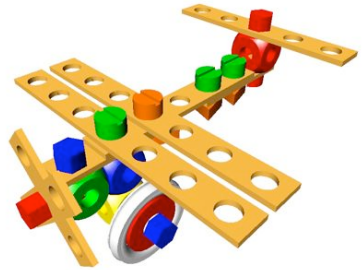
- The lexicon is very large (100 – 200K words in standard dictionaries or WordNet).
- No upper boundary to the size of the lexicon:
  - compounds, foreign words, special terminology (1.5 million new words in a 200 million word corpus of German)
  - subject to extreme application-dependent variation concerning extent and relevant dimensions
- The lexicon is heterogenous: multimodal and multi-dimensional

Central questions

- How do we organise/ represent lexical semantic information?
- How do we provide lexical semantic resources?
- Which kind of lexical-semantic information is required – given a (type of) application?
- Example 1: Robotics
- Example 2: Information Access

A robotics application





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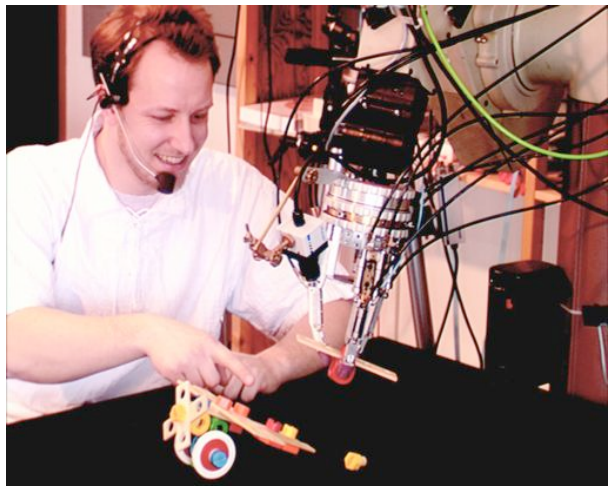

An information access application

Question Answering:

Question: *Which companies sell motor vehicles?*
Answer: *Volvo sells trucks*
Information needed: „Trucks are vehicles“

- We will restrict ourselves to propositional meaning information, in the following.

Representing Word Meaning

- Trivial Montague Grammar Translation:
  - bachelor --> bachelor‘
- Informal paraphrase:
  - „A bachelor is a male, adult, unmarried person“
- Semantic Decomposition using binary features:
  - bachelor --> [+male, +adult, - married]
- Semantic Decomposition using lambda-expressions:
  - bachelor --> λx(male(x) ∧ adult(x) ∧ ¬married(x)
- Meaning Postulates:
  - ∀x[bachelor(x) ↔ (male(x) ∧ adult(x) ∧ ¬married(x)]

Two Basic Alternatives

- Semantic decomposition:
  - kill --> λy λx(cause(x, become(¬alive(y))))
  - Representing word meaning (i.e., meaning of a specific word sense) through more basic „semantic atoms“ which form a complex structure
  - Specific meaning representations form a direct part of the meaning representation.
  - *John kills Bill* --> λy λx(cause(x, become(¬alive(y))))(b*)(j*)
    <--> cause(j*, become(¬alive(b*)))
- Meaning postulates:
  - ∀x ∀y[kill(x,y) --> cause(x, become(¬alive(y)))]
  - Representing word meaning by trivial translation: *kill* --> kill‘
  - Relating word meaning to other semantic material through constraints
  - *John kills Bill* --> λy λxkill(x, y)(b*)(j*)
    <--> kill(j*, b*)
  - Specific meaning information is made accessible through deduction / inference
  - kill(j*, b*), ∀x ∀y[kill(x,y) ↔ cause(x, become(¬alive(y)))]
    |= cause(j*, become(¬alive(b*)))

An argument for Decomposition

- *John opened the door again*
  - Reading1 presupposes: John had opened the door before
  - Reading2 presupposes: The door had been open before
- *open* --> λy λx(cause(x, become(open(y))))
- *John opened the door* -->
  cause(john, become(open(the-door)))
- Two readings by scope alternation of the aspectual sentence adverb „again“
  - again(cause(john, become(open(the-door))))
  - (cause(john, become(again(open(the-door))))
- „again“ can take scope within the part of the sentence representation contributed by the verb „open“

An argument for meaning postulates

- ∀y[truck(x) → vehicle(x)]
- Meaning postulates which gives a partial description of the meaning of a word relating it to another word meaning.
- Full semantic information is typically unavailable. Partial semantic information can not easily be encoded by a decompositional analysis. Meaning postulates allow to continuously add semantic information.

Basic Semantic Relations

- Hypernomy / hyponomy, the sub-/superconcept relation:
  - *car - truck, dog - animal, kill - murder*
- Meronymy, the part-of relation, and its inverse relation, holonymy, with three (well-motivated) sub-relations:

  Physical Part – Whole relation: *branch – tree*

  Member – Group relation: *tree – forest*

  Substance – Object relation: *wood – tree*
- Antonymy, a general super-concept for opposition/ contrast, comprising
  - Contrast (or antonymy in the narrower sense): *good – bad, expensive – cheap*
  - Complementarity: *man – woman, married – single*
  - Converse/ inverse relation: *buy – sell, ancestor - descendant*

  (according to Lyons 1979)