

Natural Language Processing: Part II Overview of Natural Language Processing (L90): ACS

Lecture 7: Lexical Semantics

Simone Teufel (Materials mostly by Ann Copestake)

Computer Laboratory
University of Cambridge

October 2018

Outline of today's lecture

Semantic relations

Polysemy

Word sense disambiguation

Grounding

Lexical semantics

- ▶ Limited domain: mapping to some knowledge base term(s). Knowledge base constrains possible meanings.
- ▶ Issues for broad coverage systems:
 - ▶ Boundary between lexical meaning and world knowledge.
 - ▶ Representing lexical meaning.
 - ▶ Acquiring representations.
 - ▶ Polysemy and multiword expressions.

Gary Larson's approach to lexical meaning



“Now! *That* should clear up
a few things around here!”

Approaches to lexical meaning

- ▶ Formal semantics: **extension** — what words denote (e.g., cat' : the set of all cats).
- ▶ Semantic primitives: e.g., *kill* means CAUSE (NOT (ALIVE)).
- ▶ Meaning postulates:

$$\forall e, x, y[\text{kill}'(e, x, y) \rightarrow \exists e'[\text{cause}'(e, x, e') \wedge \text{die}'(e', y)]]$$

- ▶ Ontological relationships: informal or formal (description logics): this lecture (informal approaches).
- ▶ Distributional approaches (lecture 8 and 9).

Approaches to lexical meaning

- ▶ Formal semantics: **extension** — what words denote (e.g., cat' : the set of all cats).
- ▶ Semantic primitives: e.g., *kill* means CAUSE (NOT (ALIVE)).
- ▶ Meaning postulates:

$$\forall e, x, y[\text{kill}'(e, x, y) \rightarrow \exists e'[\text{cause}'(e, x, e') \wedge \text{die}'(e', y)]]$$

- ▶ Ontological relationships: informal or formal (description logics): this lecture (informal approaches).
- ▶ Distributional approaches (lecture 8 and 9).

Approaches to lexical meaning

- ▶ Formal semantics: **extension** — what words denote (e.g., cat' : the set of all cats).
- ▶ Semantic primitives: e.g., *kill* means CAUSE (NOT (ALIVE)).
- ▶ Meaning postulates:

$$\forall e, x, y[\text{kill}'(e, x, y) \rightarrow \exists e'[\text{cause}'(e, x, e') \wedge \text{die}'(e', y)]]$$

- ▶ Ontological relationships: informal or formal (description logics): this lecture (informal approaches).
- ▶ Distributional approaches (lecture 8 and 9).

Approaches to lexical meaning

- ▶ Formal semantics: **extension** — what words denote (e.g., cat' : the set of all cats).
- ▶ Semantic primitives: e.g., *kill* means CAUSE (NOT (ALIVE)).
- ▶ Meaning postulates:

$$\forall e, x, y[\text{kill}'(e, x, y) \rightarrow \exists e'[\text{cause}'(e, x, e') \wedge \text{die}'(e', y)]]$$

- ▶ Ontological relationships: informal or formal (description logics): this lecture (informal approaches).
- ▶ Distributional approaches (lecture 8 and 9).

Is this object a table?



Other examples to think about

- ▶ tomato
- ▶ thought
- ▶ democracy
- ▶ push
- ▶ sticky

Hyponymy: IS-A

- ▶ (a sense of) *dog* is a **hyponym** of (a sense of) *animal*
- ▶ *animal* is a **hypernym** of *dog*
- ▶ hyponymy relationships form a **taxonomy**
- ▶ works best for concrete nouns

Some issues concerning hyponymy

- ▶ not useful for all words: *thought*, *democracy*, *push*, *sticky*?
- ▶ individuation differences: is *table* a hyponym of *furniture*?
- ▶ multiple inheritance: e.g., is *coin* a hyponym of both *metal* and *money*?
- ▶ what does the top of the hierarchy look like?

Other semantic relations

Classical relations:

Meronymy: PART-OF e.g., *arm* is a **meronym** of *body*, *steering wheel* is a meronym of *car* (piece vs part)

Synonymy e.g., *aubergine/eggplant*.

Antonymy e.g., *big/little*

Also:

Near-synonymy/similarity e.g., *exciting/thrilling*
e.g., *slim/slender/thin/skinny*

WordNet

- ▶ <http://wordnetweb.princeton.edu/perl/webwn>
- ▶ large scale, open source resource for English
- ▶ hand-constructed
- ▶ wordnets being built for other languages
- ▶ organized into **synsets**: synonym sets (near-synonyms)

Overview of adj red:

- **S: (adj) red**, [reddish](#), [ruddy](#), [blood-red](#), [carmine](#), [cerise](#), [cherry](#), [cherry-red](#), [crimson](#), [ruby](#), [ruby-red](#), [scarlet](#) (of a color at the end of the color spectrum (next to orange); resembling the color of blood or cherries or tomatoes or rubies)
- **S: (adj) crimson**, **red**, [violent](#) (characterized by violence or bloodshed) "*writes of crimson deeds and barbaric days*"– *Andrea Parke*; "*fann'd by Conquest's crimson wing*"– *Thomas Gray*; "*convulsed with red rage*"– *Hudson Strode*
- **S: (adj) crimson**, **red**, [reddened](#), [red-faced](#), [flushed](#) (especially of the face) reddened or suffused with or as if with blood from emotion or exertion) "*crimson with fury*"; "*turned red from exertion*"; "*with puffy reddened eyes*"; "*red-faced and violent*"; "*flushed (or crimson) with embarrassment*"

Hyponymy in WordNet

Sense 6

big cat, cat

=> leopard, Panthera pardus

=> leopardess

=> panther

=> snow leopard, ounce, Panthera uncia

=> jaguar, panther, Panthera onca,

Felis onca

=> lion, king of beasts, Panthera leo

=> lioness

=> lionet

=> tiger, Panthera tigris

=> Bengal tiger

=> tigress

Using hyponymy

- ▶ Semantic classification: e.g., for named entity recognition.
e.g., **JJ Thomson Avenue** is a place.
- ▶ RTE style inference: **find/discover**
- ▶ Query expansion in search

Collocation

- ▶ two or more words that occur together more often than expected by chance (informal description — there are others)
- ▶ some collocations are **multiword expressions** (MWE):
striped bass
- ▶ non-MWEs: **heavy snow**

Polysemy

- ▶ **homonymy**: unrelated word senses. *bank* (raised land) vs *bank* (financial institution)
- ▶ **polysemy**: related but distinct senses. *bank* (financial institution) vs *bank* (in a casino)
- ▶ *bank* (N) (raised land) vs *bank* (V) (to create some raised land): **regular polysemy**. Compare *pile*, *heap* etc
- ▶ In WN, homonyms and polysemous word forms are therefore associated with multiple (different) synsets.

No clearcut distinctions.

Dictionaries are not consistent.

WN example – “interest”

Noun

- ▶ **S (n) interest, [involvement](#)** (a sense of concern with and curiosity about someone or something) *“an interest in music”*
- ▶ **S (n) [sake](#), interest** (a reason for wanting something done) *“for your sake”; “died for the sake of his country”; “in the interest of safety”; “in the common interest”*
- ▶ **S (n) interest, [interestingness](#)** (the power of attracting or holding one’s attention (because it is unusual or exciting etc.)) *“they said nothing of great interest”; “primary colors can add interest to a room”*
- ▶ **S (n) interest** (a fixed charge for borrowing money; usually a percentage of the amount borrowed) *“how much interest do you pay on your mortgage?”*
- ▶ **S (n) interest, [stake](#)** ((law) a right or legal share of something; a financial involvement with something) *“they have interests all over the world”; “a stake in the company’s future”*
- ▶ **S (n) interest, [interest group](#)** (usually plural) a social group whose members control some field of activity and who have common aims) *“the iron interests stepped up production”*
- ▶ **S (n) [pastime](#), interest, [pursuit](#)** (a diversion that occupies one’s time and thoughts (usually pleasantly)) *“sailing is her favorite pastime”; “his main pastime is gambling”; “he counts reading among his interests”; “they criticized the boy for his limited pursuits”*

Verb:

- ▶ **S (v) interest** (excite the curiosity of; engage the interest of)
- ▶ **S (v) [concern](#), interest, [occupy](#), [worry](#)** (be on the mind of) *“I worry about the second Germanic consonant shift”*
- ▶ **S (v) [matter to](#), interest** (be of importance or consequence) *“This matters to me!”*

“interest/4” – a closer look

S: (n) interest (a fixed charge for borrowing money; usually a percentage of the amount borrowed) “how much interest do you pay on your mortgage?”

direct hyponym / **full hyponym**

- ▶ **S: (n) compound interest** (interest calculated on both the principal and the accrued interest)
- ▶ **S: (n) simple interest** (interest paid on the principal alone)

direct hyponym/ **inherited hypernym** / sister term:

- **S: (n) fixed charge, fixed cost, fixed costs** (a periodic charge that does not vary with business volume (as insurance or rent or mortgage payments etc.))
 - **S: (n) charge** (the price charged for some article or service) “the admission charge”
 - **S: (n) cost** (the total spent for goods or services including money and time and labor)
 - **S: (n) outgo, spending, expenditure, outlay** (money paid out; an amount spent)
 - **S: (n) transferred property, transferred possession** (a possession whose ownership changes or lapses)
 - **S: (n) possession** (anything owned or possessed)
 - **S: (n) relation** (an abstraction belonging to or characteristic of two entities or parts together)
 - **S: (n) abstraction, abstract entity** (a general concept formed by extracting common features from specific examples)
 - **S: (n) entity** (that which is perceived or known or inferred to have its own distinct existence (living or nonliving))

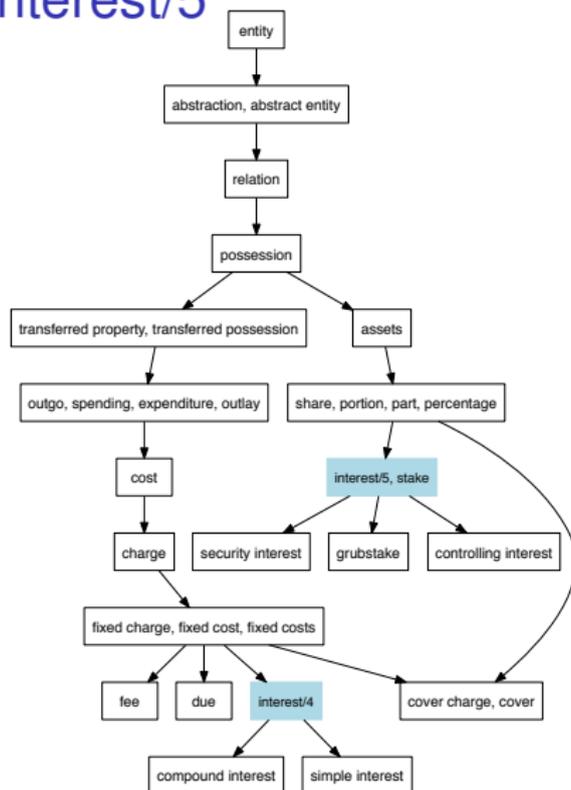
“interest/5” – a closer look

S: (n) interest, stake ((law) a right or legal share of something; a financial involvement with something) *“they have interests all over the world”; “a stake in the company’s future”*

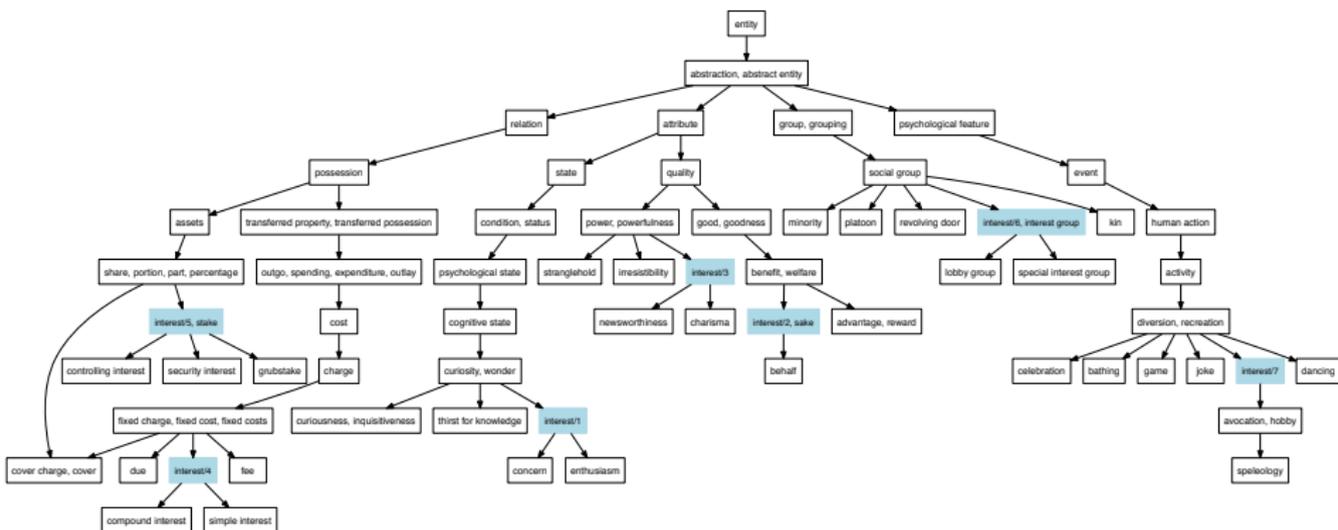
direct hyponym/ **inherited hypernym** / sister term:

- **S: (n) share, portion, part, percentage** (assets belonging to or due to or contributed by an individual person or group) *“he wanted his share in cash”*
- **S: (n) assets** (anything of material value or usefulness that is owned by a person or company)
 - **S: (n) possession** (anything owned or possessed)
 - **S: (n) relation** (an abstraction belonging to or characteristic of two entities or parts together)
 - **S: (n) abstraction, abstract entity** (a general concept formed by extracting common features from specific examples)
 - **S: (n) entity** (that which is perceived or known or inferred to have its own distinct existence (living or nonliving))

interest/4 and interest/5



Interest – all senses



Word sense disambiguation

Needed for many applications, problematic for large domains.
Assumes that we have a standard set of word senses (e.g., WordNet)

- ▶ frequency: e.g., *diet*: the food sense (or senses) is much more frequent than the parliament sense (Diet of Wurms)
- ▶ collocations: e.g. *striped bass* (the fish) vs *bass guitar*: syntactically related or in a window of words (latter sometimes called 'cooccurrence'). Generally 'one sense per collocation'.
- ▶ selectional restrictions/preferences (e.g., *Kim eats bass*, must refer to fish)

WSD techniques

- ▶ supervised learning: cf. POS tagging from lecture 3. But sense-tagged corpora are difficult to construct, algorithms need far more data than POS tagging
- ▶ unsupervised learning (see below)
- ▶ Machine readable dictionaries (MRDs): e.g., look at overlap with words in definitions and example sentences
- ▶ selectional preferences: don't work very well by themselves, useful in combination with other techniques

Standalone WSD

Once a very common research topic, now less studied:

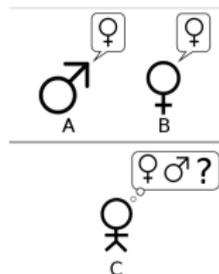
- ▶ Evaluation issues
- ▶ Lack of a good standard
- ▶ Not application-independent:
 - ▶ Speech synthesis: e.g., **bass** Homonyms are not always homophones, but mostly are.
 - ▶ SMT and similar applications: WSD part of the model. Translation differences don't necessarily correspond to source language ambiguity.

Grounding

- ▶ meaning isn't (just) about symbols: humans need to recognize and manipulate things in the world.
- ▶ 'grounding': relate symbols to the real world (often associated with Harnad, but other authors too).
- ▶ is grounding an essential part of meaning?
- ▶ preliminary/abstract discussion here — more concrete in later lectures.

Turing: 'Computing machinery and Intelligence'

- ▶ introduces the 'Turing Test' to replace the question 'Can machines think?'
- ▶ 'The Imitation Game': a man (A), a woman (B) and an interrogator (C).
- ▶ Questions put to both A and B: both pretend to be a woman. C must decide.
- ▶ Replace A with machine, B remains human, how often will C get the identification wrong (after 5 minutes)?



Intelligence as ungrounded imitation?

- ▶ Turing described an abstract test (avoiding the complications of robotics, vision etc).
- ▶ But communication is central.
- ▶ Deception is key to the test: computer 'pretends' to be human.
- ▶ Many have argued that the point is not deception per se, but application of intelligence in tricking a human. The woman acts as a neutral control.
- ▶ Searle 'Chinese Room': discussion of consciousness, criticism of Strong AI.

Lexical meaning: what doesn't work

- ▶ meaning of **tomato** is tomato' or TOMATO
- ▶ meaning postulates
- ▶ dictionary definition
tomato: mildly acid red or yellow pulpy fruit eaten as a vegetable
good dictionary definition allows reader with some familiarity with a concept to identify it

Lexical meaning: unanswered questions

- ▶ how far does distributional semantics (next lecture) get us?
- ▶ grounding often claimed for systems combining vision and language: is this enough?
- ▶ are virtual worlds a possible basis for grounding?
- ▶ or do we really need robots?