INTRODUCTION TO NATURAL LANGUAGE PROCESSING

CHAPTER 16
Outline

Review

Lexical Semantics

- Meaning of Words
- Lexical Relations
- WordNet
- Thematic Roles
- Selectional Restrictions
- Conceptual Dependency
Review: Meaning Representations

The approach to meaning that we’ll present is based on the systematic creation of meaning representations—representations that bridge that gap from linguistic forms to knowledge of the world.
Review: Semantic Analysis

Semantic analysis is the process of taking in some linguistic form and producing a meaning representation for it.

Most methods rely in some way on a prior or concurrent syntactic analysis (parse).

We’ll outline a compositional rule-to-rule approach.
Review: Compositional Semantics

At the core of most methods is the principle compositionality which states that the meaning of the whole is based on the meaning of parts.

The parts are the words and syntactic constituents specified by the grammar.
Review: Semantic Attachments

Given semantic attachments to context free grammar rules there are two approaches possible:

1. Alter a syntactic parser so that when completed constituents are created, the semantic function attached to the rule is applied and a meaning representation is created and stored with that state.

2. Let the parser run to completion and walk the resulting tree running the semantic attachments from the bottom-up.
The Lexicon

A lexicon contains lexemes.

The meaning of a lexeme (lexical semantics) is specified by its relation to the world and by its relation with other lexemes.

Lexical semantics is concerned with both relations among word meanings, and internal structure. Thus lexemes are NOT unanalyzable atomic symbols, as we have assumed so far.
Lexical Semantics

Meanings of words

Lexemes, lexicon, sense(s)

• a lexeme is an entry in the lexicon consisting of a pairing between form and sense(s)
• form: a particular orthographic and phonological form
• sense: a symbolic meaning representation (a set of related senses)
• lexicon: a finite list of lexemes

Examples

• Red, n: the color of blood or a ruby
• Blood, n: the red liquid that circulates in the heart, arteries and veins of animals
• Right, adj: located nearer the right hand esp. being on the right when facing the same direction as the observer

Do dictionaries give us definitions?
Lexical Relations I: Homonomy

What is homonymy?

- A *bank* holds investments in a custodial account.
- Agriculture is burgeoning on the east *bank*.

What about *bat*?

Variants

- homophones - “read” and “red”
- homographs - “bass” and “bass”

Applications

- spelling correction
- speech recognition
- text to speech
Lexical Relations II: Polysemy

What is polysemy?

- They rarely serve red meat.
- He served as U.S. ambassador.
- He might have served his time in prison.

Homonymy: distinct and unrelated meanings, possibly with different etymology (multiple lexemes)

Polysemy: single lexeme with multiple RELATED meanings

Example: an “idea bank”
Word Sense Disambiguation

For any given lexeme, how can its sense be reliably distinguished?

Are these the same sense of *serve*?

- Which of those flights *serve* breakfast?
- Does USAIR *serve* Pittsburgh?

Zeugma:

- ? Does USAIR *serve* breakfast and Pittsburgh?

What about

- Diane *went* to NYC.
- Diane *went* to William and Mary.
Lex. Rel. III: Metaphor, Metonymy

What is metaphor?

• That doesn’t *scare* Digital.

What is metonymy?

• GM *killed* the Fiero.

Extension of existing sense to a new meaning.
Lexical Relations IV: Synonymy

What is synonymy? Substitutability.

• How *big* is that plane?
• How *large* is that plane?

Compare:

• A *big* fat apple
• A *large* fat apple
• A *big* sister
• A *large* sister

What about *home* / *house*?

Influences on substitutability:

• subtle shades of meaning differences
• polysemy
• register
• collocational constraints
Lexical Relations V: Hyponomy

What is hyponomy?

General: hyponym

Specific: hypernym

- Example: “car” is a hyponym of “vehicle” and “vehicle” is a hypernym of “car.”
- Test: “That is a car” implies “That is a vehicle”

What is ontology?

What is taxonomy?

What is object hierarchy?
Semantic Networks

Used to represent relationships between words

Example: WordNet - created by George Miller’s team at Princeton

• http://www.cogsci.princeton.edu/~wn
WordNet (1.6)

WordNet is the most widely used hierarchically organized lexical database for English – Fellbaum (1998).

<table>
<thead>
<tr>
<th>Category</th>
<th>Unique Forms</th>
<th>Number of Senses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noun</td>
<td>94474</td>
<td>116317</td>
</tr>
<tr>
<td>Verb</td>
<td>10319</td>
<td>22066</td>
</tr>
<tr>
<td>Adjective</td>
<td>20170</td>
<td>29881</td>
</tr>
<tr>
<td>Adverb</td>
<td>4546</td>
<td>5677</td>
</tr>
</tbody>
</table>
## Format of WordNet Entries

WordNet sense entries consist of a set of synonyms, a dictionary-style definition (or gloss), and some examples of uses.

<table>
<thead>
<tr>
<th>Sense</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. bass</td>
<td>(the lowest part of the musical range)</td>
</tr>
<tr>
<td>2. bass, bass part</td>
<td>(the lowest part in polyphonic music)</td>
</tr>
<tr>
<td>3. bass, basso</td>
<td>(an adult male singer with the lowest voice)</td>
</tr>
<tr>
<td>4. sea bass, bass</td>
<td>(flesh of lean-fleshed saltwater fish of the family Serranidae)</td>
</tr>
<tr>
<td>5. freshwater bass, bass</td>
<td>(any of various North American lean-fleshed freshwater fishes especially of the genus Micropterus)</td>
</tr>
<tr>
<td>6. bass, bass voice, basso</td>
<td>(the lowest adult male singing voice)</td>
</tr>
<tr>
<td>7. bass</td>
<td>(the member with the lowest range of a family of musical instruments)</td>
</tr>
<tr>
<td>8. bass</td>
<td>(nontechnical name for any of numerous edible marine and freshwater spiny-finned fishes)</td>
</tr>
</tbody>
</table>
Sense Distribution for WordNet Verbs
## Lexical (N) Relations in WordNet

<table>
<thead>
<tr>
<th>Relation</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypernym</td>
<td>From concepts to superordinates</td>
<td>breakfast → meal</td>
</tr>
<tr>
<td>Hyponym</td>
<td>From concepts to subtypes</td>
<td>meal → lunch</td>
</tr>
<tr>
<td>Has-Member</td>
<td>From groups to their members</td>
<td>faculty → professor</td>
</tr>
<tr>
<td>Member-Of</td>
<td>From members to their groups</td>
<td>copilot → crew</td>
</tr>
<tr>
<td>Has-Part</td>
<td>From wholes to parts</td>
<td>table → leg</td>
</tr>
<tr>
<td>Part-Of</td>
<td>From parts to wholes</td>
<td>course → meal</td>
</tr>
<tr>
<td>Antonym</td>
<td>Opposites</td>
<td>leader → follower</td>
</tr>
</tbody>
</table>
## Verb Relations in WordNet

<table>
<thead>
<tr>
<th>Relation</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypernym</td>
<td>From events to superordinate events</td>
<td>fly $\rightarrow$ travel</td>
</tr>
<tr>
<td></td>
<td>From events to their subtypes</td>
<td>walk $\rightarrow$ stroll</td>
</tr>
<tr>
<td>Entails</td>
<td>From events to the events they entail</td>
<td>snore $\rightarrow$ sleep</td>
</tr>
<tr>
<td>Antonym</td>
<td>Opposites</td>
<td>increase $\leftrightarrow$ decrease</td>
</tr>
</tbody>
</table>
## Adj. and Adv. Relations in WordNet

<table>
<thead>
<tr>
<th>Relation</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antonym</td>
<td>Opposite</td>
<td>heavy ↔ light</td>
</tr>
<tr>
<td>Adverb</td>
<td>Opposite</td>
<td>quickly ↔ slowly</td>
</tr>
</tbody>
</table>
Synsets in WordNet

WordNet is organized around the notion of synset.

\{ chump, fish, fool, gull, mark, patsy, fall guy, sucker, shlemiel, shlemiel, soft touch, mug \}

Important: It is this exact synset that makes up one of the sense for each of the entries listed in the synset.

Theoretically, each synset can be viewed as a concept in a taxonomy – like the concepts described in Chapter 14.
Hyponomy in WordNet

Sense 3
bass, basso --
(an adult male singer with the lowest voice)
=> singer, vocalist
    => musician, instrumentalist, player
    => performer, performing artist
    => entertainer
    => person, individual, someone...
    => life form, organism, being...
    => entity, something
    => causal agent, cause, causal agency
    => entity, something

Sense 7
bass --
(the member with the lowest range of a family of musical instruments)
=> musical instrument
    => instrument
    => device
    => instrumentality, instrumentation
    => artifact, artefact
    => object, physical object
    => entity, something
Outline

Lexical Semantics Papers

Review Meaning of Words

- Lexicons, Lexemes, Forms, Senses
- Lexical Relations
- WordNet

Today

- WordNet demo
- Thematic Roles
- Selectional Restrictions
- Conceptual Dependency
- Framenet demo
Other Lexical Resources

The AI encyclopedia: CYC

Machine Readable Dictionaries: e.g., “stock” from the LDOCE

• 0100 a supply (of something) for use: a good stock of food
• 0200 goods for sale: Some of the stock is being taken without being paid for
• ...  
• 1200 a liquid made from the juices of meat, bones, etc., used in cooking

Roget’s Thesaurus
Limits of Hand-Encoded Resources

Manual resource construction is very costly

The coverage problem, e.g., words from the LOB corpus are not in the Oxford Dictionary

• proper noun: Chateau-Chalon
• foreign word: perestroika
• code: R101
• non-standard English: Havin’
• hyphen-omitted: bedclothes
• technical vocabulary: normoglycaemia
Internal Structure of Words

What are the meaning components underlying word sense?

Recall that a predicate-argument structure was the foundation of our meaning representation.

We assumed that certain classes of lexemes tend to contribute the predicate and the predicate argument structure, while others contribute the arguments.

The meaning representations associated with lexemes have internal structure and it is these structures, together with a grammar, that determine the relations among lexemes in a grammatical sentence.
Thematic Roles (theta-roles)

What is a thematic role?

\[ \exists w, x, y, z \text{Giving}(x) \land \text{Giver}(w, x) \land \text{Givee}(z, x) \land \text{Given}(y, x) \]

\[ \exists w, x, z \text{Breaking}(x) \land \text{Breaker}(w, x) \land \text{Broken}(z, x) \]
## Generic Thematic Roles

<table>
<thead>
<tr>
<th>Thematic Role</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGENT</td>
<td>The volitional causer of an event</td>
</tr>
<tr>
<td>EXPERIENCER</td>
<td>The experiencer of an event</td>
</tr>
<tr>
<td>FORCE</td>
<td>The non-volitional causer of the event</td>
</tr>
<tr>
<td>THEME</td>
<td>The participant most directly affected by an event</td>
</tr>
<tr>
<td>RESULT</td>
<td>The end product of an event</td>
</tr>
<tr>
<td>CONTENT</td>
<td>The proposition or content of a propositional event</td>
</tr>
<tr>
<td>INSTRUMENT</td>
<td>An instrument used in an event</td>
</tr>
<tr>
<td>BENEFICIARY</td>
<td>The beneficiary of an event</td>
</tr>
<tr>
<td>SOURCE</td>
<td>The origin of the object of a transfer event</td>
</tr>
<tr>
<td>GOAL</td>
<td>The destination of an object of a transfer event</td>
</tr>
</tbody>
</table>
### Examples of Thematic Roles

<table>
<thead>
<tr>
<th>Thematic Role</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGENT</td>
<td>The waiter spilled the soup.</td>
</tr>
<tr>
<td>EXPERIENCER</td>
<td>John has a headache.</td>
</tr>
<tr>
<td>FORCE</td>
<td>The wind blows debris from the mall into our yards.</td>
</tr>
<tr>
<td>THEME</td>
<td>Only after Benjamin Franklin broke the ice...</td>
</tr>
<tr>
<td>RESULT</td>
<td>The French government has built a regulation-size baseball diamond...</td>
</tr>
<tr>
<td>CONTENT</td>
<td>Mona asked “You met Mary Ann at a supermarket”?</td>
</tr>
<tr>
<td>INSTRUMENT</td>
<td>He turned to poaching catfish, stunning them with a shocking device...</td>
</tr>
<tr>
<td>BENEFICIARY</td>
<td>Whenever Ann Callahan makes hotel reservations for her boss...</td>
</tr>
<tr>
<td>SOURCE</td>
<td>I flew in from Boston.</td>
</tr>
<tr>
<td>GOAL</td>
<td>I drove to Portland.</td>
</tr>
</tbody>
</table>

So, for “John gave Mary a book”, instead of

$$\exists x, y \text{Giving}(x) \land \text{Giver}(John, x) \land \text{Givee}(Mary, x) \land \text{Given}(y, x) \land \text{ISA}(y, \text{Book})$$

we now have

$$\exists x, y \text{Giving}(x) \land \text{Agent}(John, x) \land \text{Goal}(Mary, x) \land \text{Theme}(y, x) \land \text{ISA}(y, \text{Book})$$
Early Theories of Thematic Roles

1967-1968: "The beginning of Lexical Semantics" (Fillmore; Gruber; Jackendoff (based on Gruber))

Two fundamentally different approaches to linguistics

- Gruber/Jackendoff: account for semantics and use grammar derived to say something about syntax
- Fillmore: account for syntax and use that to describe semantics
Thematic Level

Why posit a thematic level distinct from that of syntactic subcategorization?

This takes some of the work away from the lexicon and places it on the grammar or the semantic analyzer:

1. capture similarity between different (but related) uses of same lexical item)
2. obviate need for subcategorization frames: mapping from syntax to lexical semantics

Evidence: “John flibbed Mary the google.”

• Who did it?
• What was flibbed?
• Who has the google?
Thematic Roles

Semantic roles, syntactic structures, and the prototypical places that roles appear.

AGENTS are prototypically subjects

In VPS where V NP VP, the first NP is often a GOAL, the second a THEME
Selectional Restrictions

What are selectional restrictions?

Recall the "Godzilla" example, *I want to eat someplace near campus.*

Let’s assume that *eat* has agent and theme roles, what can we say about their values?

Can, and should, we extend our FOPC meaning representations?
Selectional Restriction Implementation

A WordNet approach: hamburgers are edible

Sense 1
hamburger, beefburger --
(a fried cake of minced beef served on a bun)
=> sandwich
  => snack food
  => dish
  => nutriment, nourishment, sustenance...
  => food, nutrient
  => substance, matter
  => object, physical object
  => entity, something

What about …

• If you want to kill the Soviet Union, get it to try to eat Afghanistan.

• But it fell apart in 1931, perhaps because people realized you can’t eat gold for lunch if you’re hungry.

Can we use hyponymy to discover soft constraints and give a probability distribution (Resnik)?
Primitive Decomposition

Jim killed his philodendron

Jim did something to cause his philodendron to become not alive
### Schank’s Primitives

#### Conceptual Dependency

<table>
<thead>
<tr>
<th>Primitive</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATRANS</td>
<td>The abstract transfer of possession or control from one entity to another.</td>
</tr>
<tr>
<td>PTRANS</td>
<td>The physical transfer of an object from one location to another.</td>
</tr>
<tr>
<td>MTRANS</td>
<td>The transfer of mental concepts between entities or within an entity.</td>
</tr>
<tr>
<td>MBUILD</td>
<td>The creation of new information within an entity.</td>
</tr>
<tr>
<td>PROPEL</td>
<td>The application of physical force to move an object.</td>
</tr>
<tr>
<td>MOVE</td>
<td>The integral movement of a body part by an animal.</td>
</tr>
<tr>
<td>INGEST</td>
<td>The taking in of a substance by an animal.</td>
</tr>
<tr>
<td>EXPEL</td>
<td>The expulsion of something from an animal.</td>
</tr>
<tr>
<td>SPEAK</td>
<td>The action of producing a sound.</td>
</tr>
<tr>
<td>ATTEND</td>
<td>The action of focusing a sense organ.</td>
</tr>
</tbody>
</table>
Pred. Independence vs. Dependence

Predicate-Independent

• single set of roles is chosen independent of the type of predicates involved (no reference to type of predicates)
• Schank

Predicate-Dependent

• roles identified by particular positions arguments occupy with respect to primitive predicates
Decomposition vs. Non-Decomposition

Decomposition / Compositional Approach (Schank, Jackendoff) vs. Non-decomposition / Noncomposition Approach (Fillmore)

Within compositional approaches: exhaustive (Schank) vs. nonexhaustive (Jackendoff)
Underlying Motivation: "Strong AI"

Focus: understanding. Argues that the representation is reversible.

Rejects syntax during analysis. Allows it during generation.

Attempts to come up with well-defined system of rules and conceptualizations.

Inferences, expectation, syntax, conversational norms, real world.

Conceptual Structure (CD): Language-independent conceptual level.
Schank: Kill vs. Die
Schank: Problem 1

"John caused Mary to die" vs. "John killed Mary"
Identically substitutable?
Flaw of all compositional approaches of this nature.
Schank: Problem 2

The decompositions are very complex.

- Too specific
- Why are these conceptualizations so radically distinct from the syntactic realization?
- Talks CD from NL understanding point of view - what about generation?
The NLP Bottleneck

Acquisition of Computational Lexicons
For Next Time

Parts of Chapter 17