Three Perspectives on Meaning

1. **Lexical Semantics**
   - The meanings of individual words

2. **Formal Semantics** (or Compositional Semantics or Sentential Semantics)
   - How those meanings combine to make meanings for individual sentences or utterances *(see skipped chapters)*

3. **Discourse or Pragmatics**
   - How those meanings combine with each other and with other facts about various kinds of context to make meanings for a text or discourse
   - **Dialog or Conversation** is often lumped together with Discourse
Sidebar: Compositional Semantic Analysis

- Applies principle of compositionality
  - Links semantic attachments to syntactic rules
    - Incrementally ties semantics to parse processing
    - Lambda calculus meaning representations
    - Most complexity pushed into lexical items

Today

- Introduction to Lexical Semantics
  - Homonymy, Polysemy, Synonymy, and more
  - Semantic Roles
  - Online Resources
Lexical Semantics

• Focus on word meanings:
  – Relations of meaning among words
    • Similarities & differences of meaning in sim context
  – Internal meaning structure of words
    • Basic internal units combine for meaning

Word Definitions

 What’s a word?
   Definitions so far: Types, tokens, stems, roots, inflected forms, etc...
   Lexeme: An entry in a lexicon consisting of a pairing of a form with a single meaning representation
   Lexicon: A collection of lexemes
Possible Word Relations

- Homonymy
- Polysemy
- Synonymy
- Antonymy
- Hypernomy
- Hyponomy
- Meronomy

Homonymy

- Lexemes share a form
  - Phonological, orthographic or both
  - But have unrelated, distinct meanings
- Clear examples
  - Bat (wooden stick-like thing) vs. bat (flying scary mammal thing)
  - Bank (financial institution) versus bank (riverside)
- Can be homophones, homographs:
  - Homophones:
    - Write/right, piece/peace, to/too/two
  - Homographs:
    - Desert/desert
    - Bass/bass
Issues for NLP Applications

- Text-to-Speech
  - Same orthographic form but different phonological form
    - bass vs. bass
- Information retrieval
  - Different meanings same orthographic form
    - QUERY: bat care
- Machine Translation
- Speech recognition

Polysemy

- The **bank** is constructed from red brick
  - I withdrew the money from the **bank**
    - Are these the same sense? Different?
- Or consider the following WSJ example
  - While some banks furnish sperm only to married women, others are less restrictive
    - Which sense of bank is this?
      - Is it distinct from the river bank sense?
      - The savings bank sense?
Polysemy

- A single lexeme with multiple related meanings (bank the building, bank the financial institution)
- Most non-rare words have multiple meanings
  - Number of meanings related to word frequency
  - Verbs tend more to polysemy
  - Distinguishing polysemy from homonymy isn’t always easy (or necessary)

Metaphor vs. Metonymy

- **Metaphor**: two different meaning domains are related
  - Citibank claimed it was misrepresented.
  - Corporation as person
- **Metonymy**: use of one aspect of a concept to refer to other aspects of entity or to entity itself
  - The Citibank is on the corner of Main and State.
  - Building stands for organization
How Do We Identify Words with Multiple Senses?

- ATIS examples
  - Which flights *serve* breakfast?
  - Does America West *serve* Philadelphia?
- The “zeugma” test: conjoin two potentially similar/dissimilar senses
  - ?Does United *serve* breakfast and San Jose?
  - Does United *serve* breakfast and lunch?

Synonymy

- Word that have the same meaning in some or all contexts.
  - filbert / hazelnut
  - couch / sofa
  - big / large
  - automobile / car
  - vomit / throw up
  - Water / H₂O
- Two lexemes are synonyms if they can be successfully substituted for each other in all situations
  - If so they have the same *propositional meaning*
Few Examples of Perfect Synonymy

- Even if many aspects of meaning are identical
  - Still may not preserve the acceptability based on notions of politeness, slang, register, genre, etc.
- E.g., water and H$_2$O, coffee and java

Terminology

- **Lemmas** and wordforms
  - A *lexeme* is an abstract pairing of meaning and form
  - A *lemma* or citation form is the grammatical form that is used to represent a lexeme.
    - Carpet is the lemma for carpets
  - Specific surface forms carpets, sung are called wordforms
- The lemma bank has two senses:
  - Instead, a bank can hold the investments in a custodial account in the client’s name.
  - But as agriculture burgeons on the east bank, the river will shrink even more.
- A sense is a discrete representation of one aspect of the meaning of a word
Synonymy Relates Senses not Words

- Consider *big* and *large*
- Are they synonyms?
  - How *big* is that plane?
  - Would I be flying on a *large* or a small plane?
- How about:
  - Miss Nelson, for instance, became a kind of *big* sister to Benjamin.
  - Miss Nelson, for instance, became a kind of *large* sister to Benjamin.
- Why?
  - *big* has a sense that means being older, or grown up
  - *large* lacks this sense

Antonyms

- Senses that are *opposites* with respect to one feature of their meaning
- Otherwise, they are very similar
  - dark / light
  - short / long
  - hot / cold
  - up / down
  - in / out
- More formally: antonyms can
  - Define a binary opposition or an attribute at opposite ends of a scale (*long/short, fast/slow*)
  - Be *reversives*: *rise/fall, up/down*
Hyponyms

- A sense is a **hyponym** of another if the first sense is more specific, denoting a subclass of the other
  - *car* is a hyponym of *vehicle*
  - *dog* is a hyponym of *animal*
  - *mango* is a hyponym of *fruit*
- Conversely
  - *vehicle* is a hypernym/superordinate of *car*
  - *animal* is a hypernym of *dog*
  - *fruit* is a hypernym of *mango*

<table>
<thead>
<tr>
<th>superordinate</th>
<th>vehicle</th>
<th>fruit</th>
<th>furniture</th>
<th>mammal</th>
</tr>
</thead>
<tbody>
<tr>
<td>hyponym</td>
<td>car</td>
<td>mango</td>
<td>chair</td>
<td>dog</td>
</tr>
</tbody>
</table>

Hyponymy Defined

- Extensional
  - The class denoted by the **superordinate**
  - Extensionally includes class denoted by the **hyponym**
- Entailment
  - *A sense A is a hyponym of sense B if being an A entails being a B*
- Hyponymy is usually **transitive**
  - (A hypo B and B hypo C entails A hypo C)
WordNet

- A hierarchically organized lexical database
- On-line thesaurus + aspects of a dictionary
  - Versions for other languages are under development

<table>
<thead>
<tr>
<th>Category</th>
<th>Unique Forms</th>
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<tbody>
<tr>
<td>Noun</td>
<td>117,097</td>
</tr>
<tr>
<td>Verb</td>
<td>11,488</td>
</tr>
<tr>
<td>Adjective</td>
<td>22,141</td>
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<tr>
<td>Adverb</td>
<td>4,601</td>
</tr>
</tbody>
</table>

Where to Find WordNet

- [http://wordnetweb.princeton.edu/perl/webwn](http://wordnetweb.princeton.edu/perl/webwn)
WordNet Entries

The noun “bass” has 8 senses in WordNet.
1. bass¹ - (the lowest part of the musical range)
2. bass², bass part¹ - (the lowest part in polyphonic music)
3. bass³, basso¹ - (an adult male singer with the lowest voice)
4. sea bass¹, bass⁴ - (the lean flesh of a saltwater fish of the family Serranidae)
5. freshwater bass¹, bass⁵ - (any of various North American freshwater fish with lean flesh (especially of the genus Micropterus))
6. bass⁶, bass voice¹, basso² - (the lowest adult male singing voice)
7. bass² - (the member with the lowest range of a family of musical instruments)
8. bass⁸ - (nontechnical name for any of numerous edible marine and freshwater spiny-finned fishes)

The adjective “bass” has 1 sense in WordNet.
1. bass¹, deep⁶ - (having or denoting a low vocal or instrumental range)
   "a deep voice"; "a bass voice is lower than a baritone voice"; "a bass clarinet"

WordNet Noun Relations

<table>
<thead>
<tr>
<th>Relation</th>
<th>Also called</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypernym</td>
<td>Superordinate</td>
<td>From concepts to superordinates</td>
<td>breakfast¹ → meal¹</td>
</tr>
<tr>
<td>Hyponym</td>
<td>Subordinate</td>
<td>From concepts to subtypes</td>
<td>meal¹ → lunch¹</td>
</tr>
<tr>
<td>Member Meronym</td>
<td>Has-Member</td>
<td>From groups to their members</td>
<td>faculty² → professor¹</td>
</tr>
<tr>
<td>Has-Instance</td>
<td>Instance</td>
<td>From concepts to instances of the concept</td>
<td>composer¹ → Bach¹</td>
</tr>
<tr>
<td>Member Holonym</td>
<td>Member-Of</td>
<td>From instances to their concepts</td>
<td>Assisi¹ → author¹</td>
</tr>
<tr>
<td>Part Meronym</td>
<td>Has-Part</td>
<td>From members to their groups</td>
<td>copilot¹ → crew¹</td>
</tr>
<tr>
<td>Part Holonym</td>
<td>Part-Of</td>
<td>From wholes to parts</td>
<td>table² → leg³</td>
</tr>
<tr>
<td>Antonym</td>
<td></td>
<td>From parts to wholes</td>
<td>course⁷ → meal¹</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Opposites</td>
<td>leader¹ → follower¹</td>
</tr>
</tbody>
</table>
WordNet Verb Relations

<table>
<thead>
<tr>
<th>Relation</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyponym</td>
<td>From events to superordinate events</td>
<td>fly^1 ⇒ travel^2</td>
</tr>
<tr>
<td>Troponym</td>
<td>From a verb (event) to a specific manner elaboration of that verb</td>
<td>walk^1 ⇒ stroll^1</td>
</tr>
<tr>
<td>Entails</td>
<td>From verbs (events) to the verbs (events) they entail</td>
<td>snore^1 ⇒ sleep^1</td>
</tr>
<tr>
<td>Antonym</td>
<td>Opposites</td>
<td>increase^1 ⇔ decrease^1</td>
</tr>
</tbody>
</table>

WordNet Hierarchies

Sense 3
bass, basso

⇒ singer, vocalist, vocalist, vocaliser
⇒ musician, instrumentalist, player
⇒ performer, performing artist
⇒ entertainer
⇒ person, individual, someone...
⇒ organism, being
⇒ living thing, animate thing,
⇒ whole, unit
⇒ object, physical object
⇒ physical entity
⇒ entity
⇒ causal agent, cause, causal agency
⇒ physical entity
⇒ entity

Sense 7
bass

⇒ (the member with the lowest range of a family of musical instruments)
⇒ musical instrument, instrument
⇒ device
⇒ instrumentality, instrumentation
⇒ artifact, artefact
⇒ whole, unit
⇒ object, physical object
⇒ physical entity
⇒ entity
How is ‘Sense’ Defined in WordNet?

- The set of near-synonyms for a WordNet sense is called a synset (synonym set); their version of a sense or a concept
- Example: chump as a noun to mean ‘a person who is gullible and easy to take advantage of’
  \{chump\textsuperscript{1}, fool\textsuperscript{2}, gull\textsuperscript{1}, mark\textsuperscript{9}, patsy\textsuperscript{1}, fall guy\textsuperscript{1}, sucker\textsuperscript{1}, soft touch\textsuperscript{1}, mug\textsuperscript{1}\}
- Each of these senses share this same gloss
- For WordNet, the meaning of this sense of chump is this list.
S: (n) **field** (a piece of land cleared of trees and usually enclosed)
S: (n) **battlefield, battleground, field of battle, field of honor, field** (a region where a battle is being (or has been) fought)
S: (n) **field** (somewhere (away from a studio or office or library or laboratory) where practical work is done or data is collected)
S: (n) **discipline, subject, subject area, subject field, field, field of study, study, bailiwick** (a branch of knowledge)
S: (n) **field, field of force, force field** (the space around a radiating body within which its electromagnetic oscillations can exert force on another similar body not in contact with it)
S: (n) **field, field of operation, line of business** (a particular kind of commercial enterprise)
S: (n) **sphere, domain, area, orbit, field, arena** (a particular environment or walk of life)
S: (n) **playing field, athletic field, playing area, field** (a piece of land prepared for playing a game)

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**From Chs 17/18: Predicate-Argument Structure**

- Verbs as predicates
- Subcategorization (or, argument) frames specify number, position, and syntactic category of arguments
  - NP likes NP
  - NP likes Inf-VP
  - NP likes NP Inf-VP

- This chapter: semantic constraints on arguments
  - Semantic roles
  - Selectional restrictions
Semantic (Thematic) Roles

- Subcat frames link arguments in surface structure with their semantic roles
  - Agent: George hit Bill. Bill was hit by George.
  - Patient: George hit Bill. Bill was hit by George.
- The claim of a theory of semantic roles is that these arguments of predicates can be usefully classified into a small set of semantically contentful classes
  - And that these classes are useful for explaining lots of things

Thematic Roles

- Describe semantic roles of verbal arguments
  - Capture commonality across verbs
    - E.g. subject of break, open is AGENT
      - AGENT: volitional cause
      - THEME: things affected by action
  - Enables generalization over surface order of arguments
    - John$_{AGENT}$ broke the window$_{THEME}$
    - The rock$_{INSTRUMENT}$ broke the window$_{THEME}$
    - The window$_{THEME}$ was broken by John$_{AGENT}$
Common semantic roles

- **Agent**: initiator or doer in the event
  - Sue killed the rat.
- **Patient**: affected entity in the event; undergoes the action
  - Sue killed the rat.
- **Theme**: object in the event undergoing a change of state or location, or of which location is predicated
  - The ice melted
- **Experiencer**: feels or perceive the event
  - Bill likes pizza.
- **Stimulus**: the thing that is felt or perceived

Common semantic roles

- **Goal**:
  - Bill ran to Copley Square.
- **Recipient** (may or may not be distinguished from Goal):
  - Bill gave the book to Mary.
- **Benefactive** (may be grouped with Recipient):
  - Bill cooked dinner for Mary.
- **Source**:
  - Bill took a pencil from the pile.
- **Instrument**:
  - Bill ate the burrito with a plastic spork.
- **Location**:
  - Bill sits under the tree on Wednesdays
Linking of thematic roles to syntactic positions

- John opened the door
- AGENT       THEME
- The door was opened by John
- THEME                AGENT
- The door opened
- THEME
- John opened the door with the key
- AGENT       THEME        INSTRUMENT

Deeper Semantics

- From the WSJ…
  - He melted her reserve with a husky-voiced paean to her eyes.
  - If we label the constituents He and her reserve as the Melter and Melted, then those labels lose any meaning they might have had.
  - If we make them Agent and Theme then we can do more inference.
Thematic Role Issues

- Hard to produce
  - Standard set of roles
    - Fragmentation: Often need to make more specific
      - E.g., INSTRUMENTS can be subject or not
  - Standard definition of roles
    - Most AGENTs: animate, volitional, sentient, causal
    - But not all….

- Strategies:
  - Generalized semantic roles: PROTO-AGENT/PROTO-PATIENT
    - Defined heuristically (rather than necessary and sufficient): PropBank
  - Define roles specific to frames evoked by verbs/nouns: FrameNet

PropBank
http://verbs.colorado.edu/propbank/

- Corpus annotated with verbs/semantic roles (propositions and their arguments)
  - Penn and Chinese Treebank
  - Roles specific to verb sense
    - Numbered: Arg0, Arg1, Arg2,…
      - Arg0: PROTO-AGENT; Arg1: PROTO-PATIENT, etc
  - E.g. agree.01
    - Arg0: Agreeer
    - Arg1: Proposition
    - Arg2: Other entity agreeing
    - Ex1: [Arg0 The group] agreed [Arg1 it wouldn’t make an offer]
FrameNet
https://framenet.icsi.berkeley.edu/fndrupal/

- A lexical database of English that is both human- and machine-readable, based on annotating examples of how words are used in actual texts.
  - A dictionary of more than 10,000 word senses, most of them with annotated examples that show the meaning and usage
  - More than 170,000 manually annotated sentences provide a unique training dataset for semantic role labeling, used in information extraction, machine translation, etc.

FrameNet

- Semantic roles specific to Frame
  - Frame: script-like structure, roles (frame elements)
    - E.g. change_position_on_scale: increase, rise
      - Attribute, Initial_value, Final_value
  - Core, non-core roles
  - Relationships b/t frames, frame elements
    - Add causative: cause_change_position_on_scale
FrameNet

• FrameNet defines the frames and annotates sentences to show how the frame elements (FEs) fit syntactically around the word that evokes the frame

• Revenge frame:
  – [Avenger I] 'll GET EVEN [Offender with you] [Injury for this]!
  – [Punishment This attack was conducted] [Support in] RETALIATION [Injury for the U.S. bombing raid on Tripoli...]

• In the simplest case the word is a verb, but the second example is the noun retaliation

Selectional Restrictions

• Selectional Restrictions: constraints on the types of arguments verbs take

  *George assassinated the senator.
  \*The spider assassinated the fly.
  assassinate: intentional (political?) killing

• The astronaut married the star.
Selectional Restrictions

- Semantic type constraint on arguments
  - *I want to eat someplace close to Pitt*
  - *E.g. THEME of eating should be edible*
    - Associated with senses
- Vary in specificity:
  - *Imagine: AGENT: human/sentient; THEME: any*
- Representation:
  - Associate with WordNet synset (and hyponyms)

Time flies.
(thanks to Dr. Wiebe for Allegheny Cemetery photos)
S: (v) fly, wing (travel through the air; be airborne) "Man cannot fly"
S: (v) fly (move quickly or suddenly) "He flew about the place"
S: (v) fly, aviate, pilot (operate an airplane) "The pilot flew to Cuba"
S: (v) fly (transport by aeroplane) "We fly flowers from the Caribbean to North America"
S: (v) fly (cause to fly or float) "fly a kite"
S: (v) fly (be dispersed or disseminated) "Rumors and accusations are flying"
S: (v) fly (change quickly from one emotional state to another) "fly into a rage"
S: (v) fly, fell, vanish (pass away rapidly) "Time flies like an arrow"; "Time fleeing beneath him"

Summary

- Lexical Semantics
  - Homonymy, Polysemy, Synonymy, etc.
  - Thematic roles and selectional restrictions
- Computational resource for lexical semantics
  - WordNet, PropBank, FrameNet