Introduction to Semantics

CMSC 723 / LING 723 / INST 725

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• First we did words (morphology & FST)

• Then simple sequences of words (language modeling & n-grams)

• Then we looked at syntax (POS tagging, dependency & constituency parsing)

• Now we’re moving on to meaning
Meaning

• Language is useful and amazing because it allows us to encode/decode...
  – Descriptions of the world
  – What we’re thinking about
  – What we think about what other people think

• Don’t be fooled by how natural and easy it is... In particular, you never really...
  – Utter word strings that match the world
  – Say what you’re thinking
  – Say what you think about what other people think
Meaning

different words/structure, same meaning

– She needed to make a quick decision in that situation.
– The scenario required her to make a split-second judgment.

– I saw the man.
– The man was seen by me.
Meaning

same words, different meaning

- I walked by the bank
  - ... to deposit my check.
  - ... to take a look at the river.

- Everyone on the island speaks two languages.
- Two languages are spoken by everyone on the island.
Syntactic parsing is not enough...
Meaning Representations

• create **representations** of linguistic inputs that capture the meanings of those inputs.

• In most cases, they’re **simultaneously** descriptions
  – of the meanings of utterances
  – and of some potential state of affairs in some world.
Meaning Representations

• NLP focuses on representations that permit or facilitate semantic processing
  – permit us to reason about their truth (i.e., their relationship to some world)
  – permit us to answer questions based on their content
  – permit us to perform inference (answer questions and determine the truth of things we don’t actually know)
Semantic Processing

• Example application: question answering

  – Can a machine answer questions involving the meaning of some text or discourse?

  – What kind of representations do we need to mechanize that process?
2 APPROACHES TO SEMANTIC PROCESSING
Semantic Analysis: 2 approaches

• Compositional Analysis
  – Complete analysis
  – Create a First Order Logic representation that accounts for all the entities, roles and relations present in a sentence

• Information Extraction
  – Superficial analysis
  – Pulls out only the entities, relations and roles that are of interest to the consuming application.
Investigators worked leads Monday in Riverside County where the car was reported stolen and reviewed security tape from Highway 241 where it was abandoned, said city of Anaheim spokesman John Nicoletti.
Investigators worked leads [Monday] in [Riverside County] where the car was reported stolen and reviewed security tape from [Highway 241] where it was abandoned, said city of [Anaheim] spokesman [John Nicoletti].
Investigators worked leads Monday in Riverside County where the car was reported stolen and reviewed security tape from Highway 241 where it was abandoned, said city of Anaheim spokesman John Nicoletti.
Information Extraction Relations

PERSON-SOCIAL
Family
Lasting
Business
Personal

PHYSICAL
Located
Near

GENERAL AFFILIATION
Citizen-Resident-Ethnicity-Religion
Org-Location-Origin

PART-WHOLE
Subsidiary
Geographical

ORG AFFILIATION
Founder
Owner
Membership
Investor
Student-Alum
Employment
Sports-Affiliation

ARTIFACT
User-Owner-Inventor-Manufacturer

17 relations from 2008 “Relation Extraction Task” from Automated Content Extraction (ACE)
Information Extraction Relations

- UMLS: Unified Medical Language System
  134 entity types, 54 relations

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<th>Injury</th>
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<tr>
<td>Pharmacologic Substance</td>
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<td>Pathologic Function</td>
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How would you build an information extraction system?
American Airlines, a unit of AMR, immediately matched the move, spokesman Tim Wagner said.
How would you predict relations between 2 entities?

PERSON

Founder?
Investor?
Member?
Employee?
President?

ORGANIZATION

American Airlines, a unit of AMR, immediately matched the move, spokesman Tim Wagner said.
First Order Logic as Representational Framework

Allows for...

– The analysis of truth conditions
  • Allows us to answer yes/no questions
– Supports the use of variables
  • Allows us to answer questions through the use of variable binding
– Supports inference
  • Allows us to answer questions that go beyond what we know explicitly
Meaning Structure of Language

The semantics of human languages...

– Display a basic predicate-argument structure
– Make use of variables
– Make use of quantifiers
– Use a partially compositional semantics
Predicate-Argument Structure

• Events, actions and relationships can be captured with representations that consist of predicates and arguments to those predicates.

• Predicates
  – Primarily Verbs, VPs, Sentences
  – Sometimes Nouns and NPs

• Arguments
  – Primarily Nouns, Nominals, NPs, PPs
  – But also everything else, depends on the context
Example: representing predicate-argument structure...

- *Mary gave a list to John.*
- Giving(Mary, John, List)
- More precisely
  - *Gave* conveys a three-argument predicate
  - The first argument is the subject
  - The second is the recipient, which is conveyed by the NP inside the PP
  - The third argument is the thing given, conveyed by the direct object
Example: representing predicate-argument structure

- Predicate-argument structures as templates
  
  - We can think of the verb/VP providing a template like the following

\[ \exists e, x, y, z \text{Giving}(e)^\wedge \text{Giver}(e, x)^\wedge \text{Given}(e, y)^\wedge \text{Givee}(e, z) \]

  - The semantics of the NPs and the PPs in the sentence plug into the slots provided in the template
A CFG specification of the syntax of First Order Logic Representations

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<td></td>
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<td>Quantifier Variable, ... Formula</td>
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<td></td>
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<td>¬ Formula</td>
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<th>→</th>
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<tr>
<td></td>
<td></td>
<td>Variable</td>
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| Connective | → | ∧ | ∨ | → |
| Quantifier | → | ∀ | ∃ |

| Constant | → | A | VegetarianFood | Maharani ... |
| Variable | → | x | y | ... |
| Predicate | → | Serves | Near | ... |
| Function | → | LocationOf | CuisineOf | ... |

See Textbook Section 17.3 for details
Semantic Analysis: 2 approaches

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Which approach can we use to...
discover information about specific entities?

\[ is\_a(\text{OBAMA}, \text{PRESIDENT}) \]
What approach can we use to summarize text?

Obama wins election. Big party in Chicago. Romney a bit down, asks for some tea.
Which approach can we use to query databases?
Which approach can we use to... instruct a robot?

at the chair, turn right
Recap... Intro to Semantics

– Meaning representations
  • motivated by semantic processing
  • for specific applications

– 2 approaches to semantic processing
  • complete FOL representation
  • vs. shallow information extraction