Lexical and Compositional Semantics

Important Note

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By Daniel Jurafsky, James H. Martin
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Semantics

- Need a mechanism to relate the phonological, morphological and syntactic structures to the knowledge of the world
- Allows to perform tasks
  - Writing an essay
  - Decide what to order in a restaurant
  - Learn to use a software

Lexical Semantics

- Study of meanings and relations of words
- Lexeme
  - Individual entry in a lexicon
  - Orthographic form
  - Phonological form
  - Sense

Relations in Lexical Semantics

- Homonymy
  - Least semantically interesting
  - Same orthographic and phonological form
  - Same part of speech
  - But unrelated meaning
    - Bank (of river)
    - Bank (with money)

- Homophones
  - Same phonological form but different orthographic form
    - Wood
    - Would

- Homographs
  - Same orthographic form but different phonological form
    - Bass (type of fish)
    - Bass (musical instrument)
Polysemy

- All categories so far have unrelated meaning
  - some resemblance in form
- Polysemy is resemblance in meaning
  - Evidence through etymology
  - Serve
    - Food
    - In a company
    - Time in prison

How many meanings?

- Identify different meanings
  - Trunk
    - Elephant
    - Tree
    - Car
    - Box
    - Body
- Label different meanings
  - Sense
    - Trunk#1, Trunk#2, …, Trunk#n
  - Explanation
  - Usage example in that sense

How is meaning related?

Polysemy

- How many distinct meanings?
- How are these related?
- How can they be distinguished?

How is meaning related?

Synonyms

- Words not related at word level but at sense level
  - Trunk
  - Boot
- Synonyms
  - Sets of senses
    - {trunk#5, boot#2, …}

Hypernyms/Homonyms

- Meanings are not at the same level, but refer to categories at specific or general level in relation to each other
  - Hypernym
    - more general (parent) of a specific category
      - Vehicle is hypernym of car
  - Hyponym
    - More specific (child) of a general category
      - Dog is hyponym of animal

Holonyms/Meronyms

- It is natural to see whole having parts or parts forming a whole
  - Holonym
    - Composite/entity with smaller parts/members
      - Tree is the holonym of trunk
  - Meronym
    - Part/member of a larger composite/entity
      - Bark is the meronym of trunk
WordNet

- Lexical Database
  - Arranged by Senses/Synsets
    - Each synset has a unique number
  - Relationships
- Core – English WordNet
- Global WordNet (GWN)
  - Urdu WordNet – www.CLE.org.pk
  - Other languages of Pakistan?

Compositional Semantics

- Need a mechanism to represent and process meaning
  - I have a car

What is Needed in a Representation

- Verifiability
- Unambiguous Representation
- Canonical Form
- Inference and Variables
- Expressiveness

Verifiability

- To be able to determine the truth of the representation
- If ask a question: Does Maharani serve vegetarian food?
  - Need a knowledge base which contains facts, e.g. Serves(Maharani, VegetarianFood)
  - Need a computational system to match the representation of meaning in question with the knowledge base

Unambiguous Representation

- Multiple meanings of a sentence should be clearly represent-able
  - For example: I wanna eat someplace that’s close to ICSI
- Need a mechanism to choose between multiple options
- Vagueness is not the same as ambiguous
  - Generic: I want to eat Italian food
  - Useful in various contexts

Canonical Form

- Different sentences with same meaning should be given the same form, called canonical form
  - E.g., these sentences mean the same
    - Does Maharani have vegetarian dishes?
    - Do they have vegetarian food at Maharani?
    - Are vegetarian dishes served at Maharani?
  - Difficult task as syntactic structure and lexical choices may be different
    - Need word senses and word sense disambiguation mechanism for lexical choices
Inference and Variables

- Inference: system’s ability to derive conclusions based on input and stored facts
- Variables: ability to represent unknown entities; handle indefinite references
  - I would like to find a restaurant where I can get vegetarian food
  - Serves(x, VegetarianFood)

Expressiveness

- Can express wide range of subject matter, knowledge of the world and language
  - Hard to achieve

Model: Connecting Representation with the World

- Elements: Domain
  - Mathew, Fanco, Katie, Caroline
  - Frasca, Med, Rio
  - Italian, Mexican, Eclectic
- Properties: Sets of Elements
  - Noisy
    - Frasca, Med and Rio are noisy
- Relations: Sets of tuples of elements
  - Likes
    - Matthew likes the Med
    - Katie likes the Med and Rio
  - Serves
    - Med serves eclectic
    - Rio serves Mexican

First Order Logic

- Knowledge representation mechanism
- Provides computational basis for verifiability, inference, expressiveness
- Able to address the modeling requirements

FOL: Variables and Quantifiers

- Substitution semantics of quantifiers
  - A restaurant that serves Mexican food near ICSI
  - $\exists x \text{ Restaurant}(x) \land \text{Serves}(x, \text{MexicanFood}) \land \text{Near}(\text{LocationOf}(x), \text{LocationOf}(\text{ICSI}))$
  - All vegetarian restaurants serve vegetarian food
  - $\forall x \text{ VegetarianRestaurant}(x) \rightarrow \text{Serves}(x, \text{VegetarianFood})$
**FOL: Lambda Notation**

- Provides the generic mechanism to define an expression to allow binding variables to specified terms
  - $\lambda x. P(x)$
  - This binding process is called lambda reduction
  - $\lambda x. P(x) (A) = P(A)$

- $\lambda x.\lambda y. \text{Near}(x,y)$
  - $\lambda x.\lambda y. \text{Near}(x,y) (A) = \lambda y. \text{Near}(A,y)$
  - $\lambda y. \text{Near}(A,y) (B) = \text{Near}(A,B)$

**FOL: Inference Rules**

- Modus Ponens
  - $\alpha \rightarrow \beta = \beta$

  VegetarianRestaurant(Leaf)
  VegetarianRestaurant($x$) $\rightarrow$
  Serves($x$, VegetarianFood)
  ---------------------------------------------
  Serves(Leaf, VegetarianFood)

**Semantic Analysis**

- Avari serves meat
  - $\exists e \text{ ISA}(e, \text{Serving}) \land \text{Server}(e, \text{Avari}) \land \text{Served}(e, \text{meat})$

- Lexicon
  - PN $\rightarrow$ Avari \{Avari\}
  - N $\rightarrow$ meat \{Meat\}
  - V $\rightarrow$ serves
  - $\{\lambda x.\lambda y. \exists e \text{ ISA}(e, \text{Serving}) \land \text{Server}(e, y) \land \text{Served}(e, x)\}$
    - Argument structure
    - roles
Semantic Analysis

- Avari serves meat

- Rules
  - NP $\rightarrow$ N {N.sem}
  - NP $\rightarrow$ PN {PN.sem}
  - VP $\rightarrow$ V NP {V.sem (NP.sem)}
  - S $\rightarrow$ NP VP {VP.sem (NP.sem)}