Lexical and Compositional Semantics

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Important Note

Some of this material is from:

Speech and Language Processing: An Introduction to Natural Language Processing, Computational Linguistics, and Speech Recognition

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These slides are for Computational Linguistics courses

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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

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Lexical Semantics

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

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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)

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Relations in Lexical Semantics

- 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)

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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

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Polysemy

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

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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

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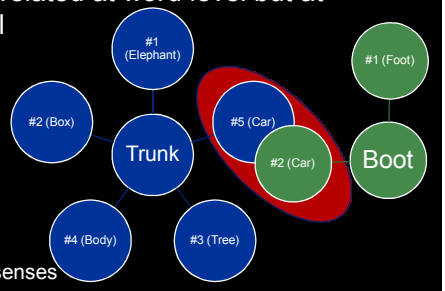
How is meaning related? Synonyms

- Words not related at word level but at sense level
  - Trunk
  - Boot



- Synoyms
  - synsets
    - Sets of senses
    - {trunk#5, boot#2, …}

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How is meaning related? 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

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How is meaning related? 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

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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?

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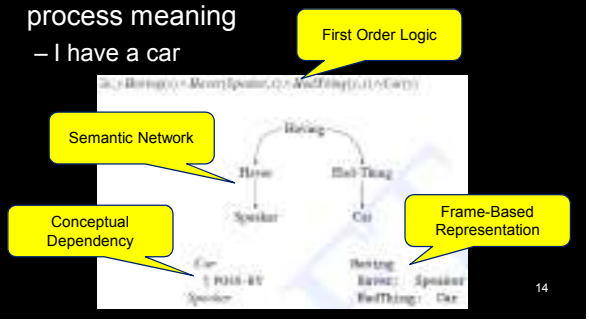
Compositional Semantics

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



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What is Needed in a Representation

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

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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

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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

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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

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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)

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Expressiveness

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

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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

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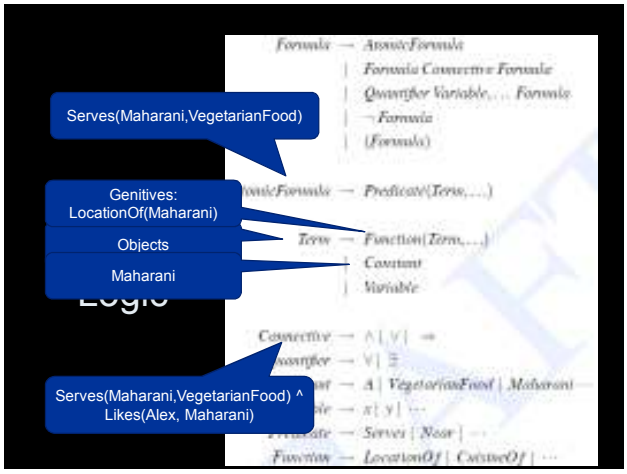

FOL: Variables and Quantifiers

- Substitution semantics of quantifiers
  - A restaurant that serves Mexican food near ICSI
  - $\exists x\ Restaurant(x) \wedge Serves(x, MexicanFood) \wedge Near(LocationOf(x), LocationOf(ICSI))$
  - *All vegetarian restaurants serve vegetarian food*
  - $\forall x\ VegetarianRestaurant(x) \rightarrow Serves(x, VegetarianFood)$

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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
  - $\lambda x.P(x)\ (A) = P(A)$

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FOL: Lambda Notation

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

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FOL: Inference Rules

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

$$\frac{VegetarianRestaurant(Leaf) \qquad VegetarianRestaurant(x) \rightarrow Serves(x, VegetarianFood)}{Serves(Leaf, VegetarianFood)}$$

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Semantic Analysis

- Avari serves meat
- $\exists e\ ISA(e,Serving) \wedge Server(e, Avari) \wedge Served(e, meat)$

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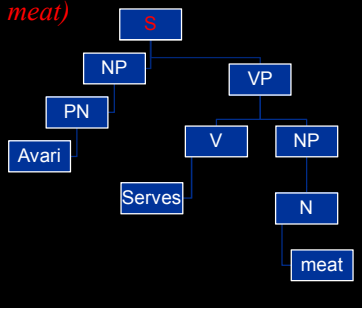
Semantic Analysis

- $\exists e\ ISA(e,Serving) \wedge Server(e, Avari) \wedge Served(e, meat)$



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Semantic Analysis

- Avari serves meat
- Lexicon
  - PN → Avari *{Avari}*
  - N → meat *{Meat}*
  - V → serves

  $\{\lambda x.\lambda y.\ \exists e\ ISA(e, Serving) \wedge Server(e, y) \wedge Served(e, x)\}$
    - Argument structure
    - roles

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Semantic Analysis

- Avari serves meat
- Rules
  - NP → N {N.sem}
  - NP → PN {PN.sem}
  - VP → V NP {V.sem (NP.sem)}
  - S → NP VP {VP.sem (NP.sem)}

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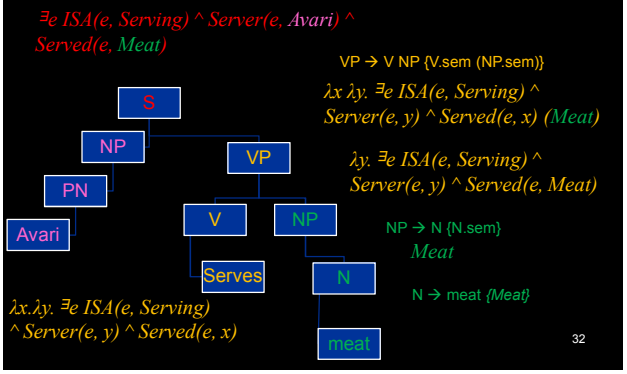
Semantic Analysis



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Thank You

Questions

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