Computational Semantics

Ling 571
Deep Processing Techniques for NLP
February 7, 2011

Roadmap

- Computational Semantics
  - AI-completeness
  - More tractable parts
    - Lexical Semantics
    - Word Sense Disambiguation
    - Semantic Role Labeling
    - Resources
- Meaning Representation
  - Representational requirements
  - First-Order Logic
    - Syntax & Semantics

Tasks in Computational Semantics

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- Effectively AI-complete
  - Need representation, reasoning, world model, etc

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- Word sense disambiguation:
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- Semantic role labeling:
  - Identifying the thematic roles played by arguments in predicate

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- Decomposition:
  - Swim: GO FROM place1 TO place2 by SWIMMING

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Example: "Plant" Disambiguation

There are more kinds of plants and animals in the rainforests than anywhere else on Earth. Over half of the millions of known species of plants and animals live in the rainforest. Many are found nowhere else. There are even plants and animals in the rainforest that we have not yet discovered.

Biological Example

The Paulus company was founded in 1938. Since those days the product range has been the subject of constant expansions and is brought up continuously to correspond with the state of the art. We' re engineering, manufacturing and commissioning world-wide ready-to-run plants packed with our comprehensive know-how. Our Product Range includes pneumatic conveying systems for carbon, carbide, sand, lime and many others. We use reagent injection in molten metal for the…

Industrial Example

Label the First Use of "Plant"

Semantic Role Labeling

- John broke the window.
- John broke the window with a rock.
- The rock broke the window.
- The window was broken by John.

Semantic Role Labeling

- John$_{\text{AGENT}}$ broke the window$_{\text{THEME}}$.

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Semantic Resources

- Growing number of large-scale computational semantic knowledge bases
  - Dictionaries:
    - Longman Dictionary of Contemporary English (LDOCE)
  - WordNet(s)
  - PropBank
  - FrameNet
  - Semantically annotated corpora: SEMCOR, etc

WordNet

- Large-scale, manually constructed sense hierarchy
  - ISA hierarchy, other links
- Pod:
  - **1(n) {pod, cod, seedcase} (the vessel that contains the seeds of a**
  - **plant (not the seeds themselves)**
  - 2 **(n) {pod, seedpod} (a several-seeded dehiscent fruit as e.g. of a**
  - **leguminous plant)**
  - 3 **(n) {pod} (a group of aquatic mammals)**
  - 4 **(n) {pod, fuel pod} (a detachable container of fuel on an airplane)**
  - 5 **(v) {pod} (take something out of its shell or pod) pod peas or**
  - **beans**
  - 6 **(v) {pod} (produce pods, of plants)**

WordNet Taxonomy View

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

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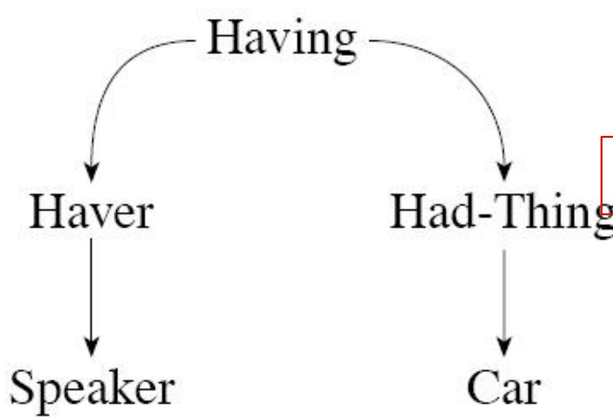
Representing Meaning

$$\exists e,y\ Having(e) \wedge Haver(e,Speaker) \wedge HadThing(e,y) \wedge Car(y)$$

First-order Logic



Semantic Network

Conceptual Dependency

$$\begin{array}{l} Car \\ \Uparrow \text{POSS-BY} \\ Speaker \end{array}$$

```
Having
 Haver:   Speaker
 HadThing:   Car
```

Frame-Based

Meaning Representations

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  - Representational vocabulary

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  - Representation of meaning of linguistic input
  - Representation of state of world

Representational Requirements

- Verifiability
- Unambiguous representations
- Canonical Form
- Inference and Variables
- Expressiveness
  - Should be able to express meaning of any NL sent

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    - Is KB assumed complete or incomplete?

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- Resolving the ambiguity?
  - Later

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- Single canonical form allows consistent verification

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  - Syntactic alternations:
    - E.g. active vs passive
    - Interrogative vs declarative forms, topicalization, etc

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  - True if variable can be replaced by some object s.t. resulting proposition can match some assertion in KB

Meaning Structure of Language

- Human languages
  - Display basic predicate-argument structure
  - Employ variables
  - Employ quantifiers
  - Exhibit a (partially) compositional semantics

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- Subcategorization frames indicate:
  - Number, Syntactic category, order of args

Semantic Roles

- Roles of entities in an event
  - E.g. $\text{John}_{\text{AGENT}}$ hit $\text{Bill}_{\text{PATIENT}}$
- Semantic restrictions constrain entity types
  - The dog slept.
  - ?The rocks slept.
- Verb subcategorization links surface syntactic elements with semantic roles

First-Order Logic

- Meaning representation:
  - Provides sound computational basis for verifiability, inference, expressiveness
- Supports determination of propositional truth
- Supports compositionality of meaning
- Supports inference
- Supports generalization through variables

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  - **Variables:**
    - *x, e*; as in *LocationOf(x)*

FOL Representation

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  - Relations among objects
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    - *Maharani is a restaurant. =>*
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  - $\forall$: universal quantifier: “for all”
    - All vegetarian restaurants server vegetarian food.

$\forall x Vegetarian\mathrm{Re}\, staurant(c) \Rightarrow Serves(x, VegetarianFood)$

Lambda Expressions

- Lambda notation: (Church, 1940)
  - Just like lambda in Python
  - Allows abstraction over FOL formulas
    - Supports compositionality
  - Applied to logical terms to form exp.
    - Binds formal params to term

  - Essentially unnamed function w/params
    - Application substitutes terms for formal params

Examples

$$\lambda x.P(x)$$

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

$$P(A)$$

$$\lambda x.\lambda y.Near(x,y)$$

$$\lambda x.\lambda y.Near(x,y)(Bacaro)$$

$$\lambda y.Near(Bacaro,y)$$

$$\lambda y.Near(Bacaro,y)(Centro)$$

$$Near(Bacaro,Centro)$$

Lambda Expressions

- Currying;
  - Converting multi-arguments preds to sequence of single argument preds
  - Why?

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  - Why?
    - Incrementally accumulates multiple arguments spread over different parts of parse tree