Introduction to Natural Language Processing

Chapter 14

Today's Outline

Announcements - CS Day (posters)

HW review

Exam discussion

Semantics

Semantics

Up until to now, we have not focussed at all on what things *mean*.

The approach to meaning that we'll follow here is based on the systematic creation of meaning representations – representations that bridge the gap from linguistic forms to knowledge of the world.

We assume that the meaning of linguistic utterances can be captured in formal structures.

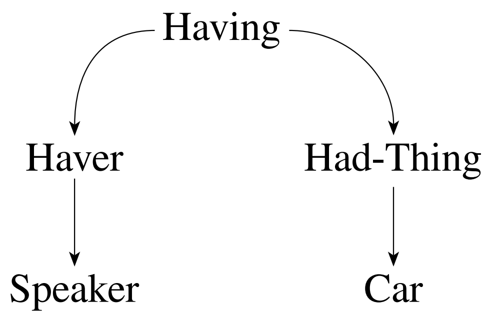
Meaning Representations

What can serve as a meaning representation ... Well anything that serves the core practical purposes of a program that is doing semantic processing ...

- answer questions
- determining truth
- making inference
- ...

Sample Meaning Representations

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



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

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

I have a car.

- First-Order Predicate Calculus
- Semantic Networks
- Conceptual Dependency
- Frame-based Representations

Meaning Representations (cont.)

Consider the following examples:

- Is Denver north of Pueblo?
- Is Pueblo south of Denver?
- Denver is north of Pueblo.
- If I'm driving south on I25 from Cheyenne will I get to Denver or Pueblo first?
- If Denver is north of Colorado Springs and Colorado Springs is north of Pueblo, is Denver north of Pueblo?

Verifiability

Why are meaning representations needed?

Examples

- Does Spice Island serve vegetarian food?
- Serves(SpiceIsland,VegetarianFood)

Verifiability: The system's ability to compare representation to facts in KB.

Basic Assumptions

Focus on literal meaning

- conventional meanings of words
- ignore context

Ambiguity

I want to eat someplace that's close to Pitt.

Mary ran last year and George did too.

I baked the cake on the table.

Old men and women go to the park.

Every student did an assignment.

Vagueness

Vagueness: Uncertainty; exact specifics of the entity not known

I want to eat Italian food.

I have a car and Alex has two.

Canonical Form

Inputs that mean the same thing have the same representation.

"Standardized" representation of meaning for (potentially) multiple utterances.

- Does Spice Island have vegetarian dishes?
- Do they have vegetarian food at Spice Island?
- Are vegetarian dishes served at Spice Island?
- Does Spice Island serve vegetarian fare?

Alternatives

- four different semantic representations
- store all possible meaning representations in KB

Canonical Form: Pros and Cons

Advantages

- simplifies reasoning taks
- compactness of representations: don't need to write inference rules for all the different "paraphrases" of the same meaning

Disadvantages

- complicates task of semantic analysis

More on Canonical Form

Fortunately, there are some systematic meaning relationships among word senses and among grammatical constructions that can be exloited to make semantic analysis tractable.

Example

- *Spice Island serves vegetarian food.*
- *Vegetarian dishes are served by Spice Island.*

Food and *dishes* have at least one shared word sense, so same meaning representation can be assigned to phrases containing them.

Knowledge of the relationship between active and passive sentence constructions allows us to assign the same semantic roles to *Spice Island* (server) and *vegetarian food/dishes* (thing being served) in either grammatical construction.

Inference

Inference: Draw valid conclusions based on the meaning representation of inputs and its store of background knowledge.

Can vegetarians eat at Spice Island?

Facts about the world, not facts about any linguistic regularity.

Meaning Representations: FOPC

We'll make use of First Order Predicate Calculus (FOPC) as our meaning representation.

It is not ideal and doesn't do everything we want. But it is pretty close.

- supports the determination of truth
- supports the answering of questions (via variables)
- supports inference

FOPC Syntax

$$
\begin{array}{rcl}
\textit{Formula} & \rightarrow & \textit{AtomicFormula} \\
& | & \textit{Formula Connective Formula} \\
& | & \textit{Quantifier Variable}, \ldots\ \textit{Formula} \\
& | & \neg\ \textit{Formula} \\
& | & (\textit{Formula}) \\
\\
\textit{AtomicFormula} & \rightarrow & \textit{Predicate}(\textit{Term}, \ldots) \\
\\
\textit{Term} & \rightarrow & \textit{Function}(\textit{Term}, \ldots) \\
& | & \textit{Constant} \\
& | & \textit{Variable} \\
\\
\textit{Connective} & \rightarrow & \wedge \mid \vee \mid \Rightarrow \\
\textit{Quantifier} & \rightarrow & \forall \mid \exists \\
\textit{Constant} & \rightarrow & A \mid \textit{VegetarianFood} \mid \textit{Maharani} \cdots \\
\textit{Variable} & \rightarrow & x \mid y \mid \cdots \\
\textit{Predicate} & \rightarrow & \textit{Serves} \mid \textit{Near} \mid \cdots \\
\textit{Function} & \rightarrow & \textit{LocationOf} \mid \textit{CuisineOf} \mid \cdots
\end{array}
$$

Truth Table

P	Q	$\neg P$	$P \wedge Q$	$P \vee Q$	$P \Rightarrow Q$
False	*False*	*True*	*False*	*False*	*True*
False	*True*	*True*	*False*	*True*	*True*
True	*False*	*False*	*False*	*True*	*False*
True	*True*	*False*	*True*	*True*	*True*

Meaning Structure of Language

This choice of FOPC isn't completely arbitrary or driven by the needs of applications ...

Human languages

- display a basic predicate-argument structure
- make use of variables (e.g., indefinites)
- make use of quantifiers (e.g., every, some)
- display a partially compositional semantics (sort of)

Predicate Argument Structure

It appears that languages make heavy use of a predicate-argument structure. In particular, there are words and constituents that prototypically act like predicates, and words and constituents that act like arguments.

Predicate-like elements

- verbs, VPs, prepositions, adjectives, some nouns

Argument-like elements

- nouns, nominals, NPs

Syntax

- NP give NP2 NP1
- NP give NP1 to NP2

Semantics

- give(x,y,z)

Example

John gave Mary a book.

$Giving(John, Mary, Book)$

More Examples

What about

- *John gave Mary a book for Susan.*
- $Giving(John, Mary, Book, Susan)$
- *John gave Mary a book for Susan on Wednesday.*
- $Giving(John, Mary, Book, Susan, Wednesday)$
- *John gave Mary a book for Susan on Wednesday in class.*
- $Giving(John, Mary, Book, Susan, Wednesday, InClass$

Problem: Except for the suggestive names of predicates and arguments, there is nothing that indicates the obvious logical relations among them.

Meaning Representation Problems

Assumes that the predicate representing the meaning of a verb has the same number of arguments as are present in the verb's syntactic categorization frame.

This makes it hard to

- determine the correct number of roles for any given event
- represent facts about the roles associated with an event
- insure that all and only the correct inferences can be derived from the representation of an event

Better

John gave Mary a book.

$\exists x, y Giving(x) \wedge Giver(John, x) \wedge Givee(Mary, x) \wedge Given(y, x) \wedge Isa(y, Book)$

This is the "right" way to do it.

- Can have variable number of arguments asociated with event: events have many roles and fillers can be glued on as appear in the input.
- Specifies categories (e.g. book) so that we can make assertions about categories themselves as well as their instances, e.g. *Isa(MobyDick,Novel)*, *AKO(Novel,Book)*.
- Reifies events so that they can be quantified and related to other events and obejcts via sets of defined relations.
- Can see logical connections between closely related examples without the need for meaning postulates.

Predicates

You can think of this as the Verb give contributing the predicate and the number and names of the arguments to the representation:

Ie. $Give$ means ...

$\exists w, x, y, z Giving(x) \wedge Giver(w, x) \wedge Givee(z, x) \wedge Given(y, x)$

The NPs in the sentence provided the values for the variables introduced by the named arguments to the Verb.

Earlier Examples

Is Denver north of Pueblo?

- $NorthOf(Denver, Pueblo)$

What is north of Denver?

- $\exists x NorthOf(x, Denver)$

If I'm driving ...

- $\forall x, y, z NorthOf(x, y) \wedge NorthOf(y, z) \Rightarrow NorthOf(x, z)$

For Next Time(s)

Exam

Chapter 15