Natural Language Processing

Lecture 18a: Meaning Representation Languages

Semantics Road Map

1. Lexical semantics
2. Vector semantics
3. **Meaning representation languages** and **semantic roles**
4. Compositional semantics, semantic parsing
5. Discourse and pragmatics

INTENSION AND EXTENSION

Two Approaches to Semantics

- Intentional
  - Assumes that the word or utterance is intrinsically meaningful
  - Decompositional approaches to lexical semantics are intentional
- Extentional
  - Defines words and utterances by the the things in the world of which they are true
  - This lecture will concern extentional models of semantics

Extension

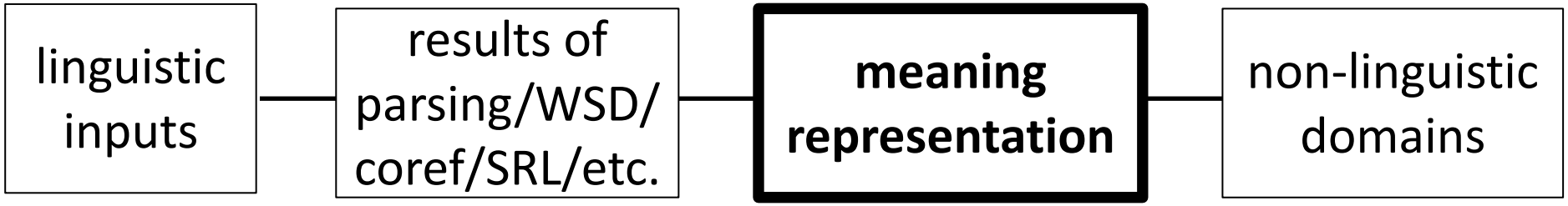
The meaning of *red* is the set of entities in the universe of which the predicate RED is true. Similarly, the meaning of *hit* is the set of <x,y> pairs of which HIT(x, y) is true.

In this lecture…

- We will look at ways of representing the extension of verbs and sentences
- We will also look at semantic roles and how they relate to meaning representation languages (MRLs)

DESIRABLE PROPERTIES OF MEANING REPRESENTATIONS

Meaning Representation?



For what kinds of tasks?

- Answering essay questions on an exam
- Deciding what to order at a restaurant
- Learning an activity via instructions
- Making an investment decision
- Recognizing an insult

Desirable Qualities: Verifiability

We want to be able to determine the truth of our representations.

"Does Udipi serve vegetarian food"?

Is SERVE(Udipi, vegetarian food) in our knowledge base?

What is the relationship between the meaning of a sentence and the world as we know it?

Desirable Qualities: Unambiguous Representation

Let's eat somewhere near campus.

(e.g., we want to eat *at* a place near campus)

(e.g., we eat places)

Our MRL must capture precisely one of these meanings—not both.

Desirable Qualities: Canonical Form

- “Mad Mex has vegetarian dishes.”
- “They have vegetarian food at Mad Mex.”
- “Vegetarian dishes are served at Mad Mex.”
- “Mad Mex serves vegetarian fare.”

Inputs that mean the same thing should have the same meaning representation.

Desirable Qualities: Inference, Variables, and Expressiveness

- "Can vegetarians eat at Mad Mex?"

- "I'd like to find a restaurant where I can get vegetarian food."

  SERVE(x, vegetarian food)

- "Delta flies Boeing 737s from Boston to New York."

One Limitation: Literality

We will focus on the **basic** requirements for meaning representation.

The basic requirements do not include correctly interpreting statements like:

- "Ford was hemorrhaging money."
- "I could eat a horse."

What entities do we want to represent?

A meaning representation scheme should let us represent:

- **objects** (e.g., people, restaurants, cuisines)
- **properties of objects** (e.g., pickiness, noisiness, spiciness)
- **relations between objects** (e.g., SERVE(Oishii Bento, Japanese))

The Knowledge Base

It contains the things that we "know"

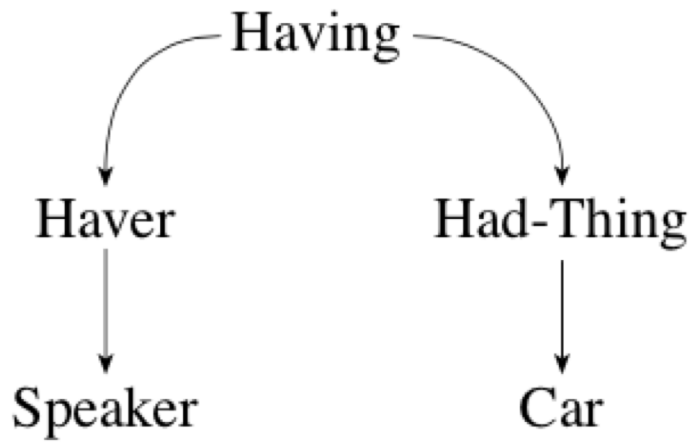
Our knowledge base

We can query it

THE CANDIDATES

“I have a car.”

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



Car

$\Uparrow$ POSS-BY

Speaker

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

FIRST-ORDER LOGIC

MRL #1: First-Order Logic

DressCode(ThePorch)

Cuisine(Udipi)

Functions

SERVES(UnionGrill, AmericanFood)

RESTAURANT(UnionGrill)

Predicates

- HAVE(Speaker, FiveDollars) ∧ ¬ HAVE(Speaker, LotOfTime)
- ∀x PERSON(x) ⇒ HAVE(x, FiveDollars)
- ∃x,y PERSON(x) ∧ RESTAURANT(y) ∧ ¬HASVISITED(x,y)

First Order Logic and Semantics

- Nouns correspond to one-place predicates:

  RESTAURANT(x) is true if x is a member of the set of restaurants

- Adjectives correspond to one-place predicates:

  VEGETARIAN(x) is true if x is a member of the set of things that are vegetarian

- Verbs correspond to one-place, two-place, or three-place predicates

  DINE(x) as in *Noah dined.*

  EAT(x, y) as in *Noah ate American food*.

  GIVE(x, y, z) as in *The bad sushi gave Noah a stomach ache*.

Modus Ponens and Forward Chaining

$$\frac{\begin{array}{l}\textsc{vegetarianrestaurant}(\text{Udipi}) \\ \forall x\, \textsc{vegetarianrestaurant}(x) \Rightarrow \textsc{serves}(x, \text{VegetarianFood})\end{array}}{\textsc{serves}(\text{Udipi}, \text{VegetarianFood})}$$

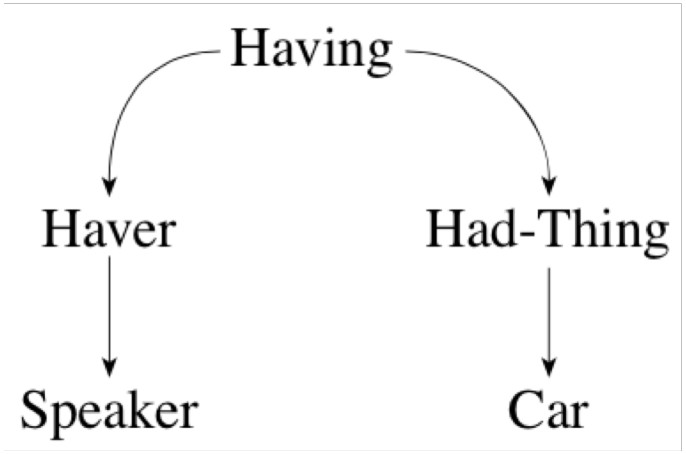
As individual facts are added to a knowledge base, modus ponens can be used to fire applicable implication rules.

First Order Logic: Advantages

- Flexible
- Well-understood
- Widely used

DESCRIPTION LOGICS

MRL #2: Description Logics




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

- Goal of description logics: understand and specify semantics for slot-filler representations
- More restrictive than FOL

TBox and ABox

- TBox: contains the knowledge about categories or concepts in the application domain

  All bistros are restaurants

  All restaurants are businesses

- ABox: facts about individuals in the domain

  Udipi is an Indian restaurant

Categories and Subsumption

IndianRestaurant(Udipi)

category domain element

Udipi is an Indian restaurant.

IndianRestaurant $\sqsubseteq$ Restaurant

subsumed subsumer

All Indian restaurants are restaurants.

Negation and Disjunction

IndianRestaurant ⊑ **not** ItalianRestaurant

Indian restaurants can't also be Italian restaurants.

Restaurant ⊑ (**or** ItalianRestaurant IndianRestaurant MexicanRestaurant)

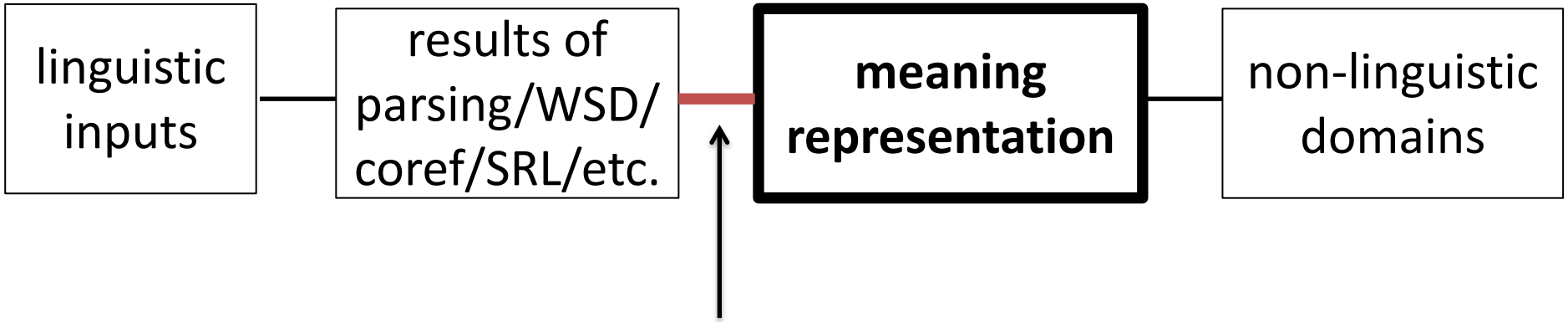
Restaurants are Italian restaurants, Indian restaurants, or Mexican restaurant.

Advantages

- Intuitive hierarchical representation
- Compatible with existing work on ontologies

LOOKING FORWARD

The Missing Link



Compositional semantics / semantic parsing