Meaning

We have seen that words have different meaning, depending on the context in which they are used.

Every day language tasks that require some semantic processing:

− Answering an essay question on an exam
− Deciding what to order at a restaurant by reading a menu
− Realizing you’ve been insulted
Meaning (continued)

- Now, look at meaning representations—representations that link linguistic forms to knowledge of the world
- We are going to cover:
  - What is the meaning of a word
  - How can we represent the meaning of a word in a sentential context
  - What formalisms can be used

Common Meaning Representations

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

```
Car
\uparrow POSS-BY
Speaker

Having
Haver: Speaker
HadThing: Car
```
Correspondence Between Representations

- They all share a common foundation: Meaning Representation consists of structures composed of sets of symbols
- Symbol structures are objects and relations among objects

What Can Serve as a Meaning Representation?

- Anything that serves the core practical purposes of a program that is doing semantic processing
- What is a Meaning Representation Language?
- What is Semantic Analysis?
**Requirements Meaning Representation: Verifiability**

- System can match input representation against representations in knowledge base. If it finds a match, it can return Yes; Otherwise No.
- Does Maharani serve vegetarian food?
  Serves(Maharani,vegetarian food)

**Requirements (continued): Unambiguous Representation**

- Single linguistic input can have different meaning representations
- Each representation unambiguously characterizes one meaning.
- Example: I wanna eat someplace that's close to UMD.
  - $E_1$: want(I,E₂)
  - $E_2$: eat(I,O₁,Loc₁)
Requirements (continued): Vagueness

- System should allow us to represent vagueness
- I want to eat Italian food

Representing Similar Concepts

- Distinct inputs could have the same meaning
  - Does Maharani have vegetarian dishes?
  - Do they have vegetarian food at Maharani?
  - Are vegetarian dishes served at Maharani?
  - Does Maharani serve vegetarian fare?
- Alternatives
  - Four different semantic representations
  - Store all possible meaning representations in KB
**Canonical Form**

- Solution: Inputs that mean same thing have same meaning representation
- Is this easy? No!
  - Vegetarian dishes, vegetarian food, vegetarian fare
  - Have, serve
- What to do?

**How to Produce a Canonical Form**

- Systematic Meaning Representations can be derived from thesaurus
  - food ___
  - dish ___|____one overlapping meaning sense
  - fare ___
- We can systematically relate syntactic constructions
  - [S [NP M] serves [NP vegetarian dishes]]
  - [S [NP vegetarian dishes] are served at [NP Maharani]]
**Inference**

- Consider a more complex request
  - Can vegetarians eat at Maharani?
  - Vs: Does Maharani serve vegetarian food?
- Why do these result in the same answer?
- Inference: Draw conclusions about truth of propositions not explicitly stored in KB
- \[ \text{serve(Maharani,VegetarianFood)} \Rightarrow \text{CanEat(Vegetarians,AtMaharani)} \]

**Non-Yes/No Questions**

- Example: I'd like to find a restaurant where I can get vegetarian food.
- \[ \text{serve}(x,\text{VegetarianFood}) \]
- Matching succeeds only if variable \( x \) can be replaced by known object in KB.
Meaning Structure of Language

- **Human Languages**
  - Display a basic predicate-argument structure
  - Make use of variables
  - Make use of quantifiers
  - Display a partially compositional semantics

Predicate-Argument Structure

- Represent concepts and relationships among them
- Some words act like arguments and some words act like predicates:
  - Nouns as concepts or arguments: red(ball)
  - Adj, Adv, Verbs as predicates: red(ball)
- Subcategorization (argument) frames specify number, position, and syntactic category of arguments
- Examples:
  - NP give NP2 NP1
  - NP give NP1 to NP2
  - give(x,y,z)
Semantics (Thematic) Roles

- Semantic Roles: Participants in an event
  - Agent: George hit Bill. Bill was hit by George
  - Patient: George hit Bill. Bill was hit by George
- Semantic (Selectional) Restrictions: Constrain the types of arguments verbs take
  - George assassinated the senator
  - *The spider assassinated the fly
- Verb subcategorization: Allows linking arguments in surface structure with their semantic roles
- Prepositions are like verbs
  - Under(ItalianRestaurant,$15)

First Order Predicate Calculus (FOPC)

- FOPC provides sound computational basis for verifiability, inference, expressiveness
  - Supports determination of truth
  - Supports compositionality of meaning
  - Supports question-answering (via variables)
  - Supports inference
FOPC Syntax

- **Terms**
  - Constants: Maharani
  - Functions: LocationOf(Maharani)
  - Variables: x in LocationOf(x)
- **Predicates**: Relations that hold among objects
  - Serves(Maharani, VegetarianFood)
- **Logical Connectives**: Permit compositionality of meaning
  - I only have $5 and I don’t have a lot of time
  - Have(I,$5) \land \neg Have(I,LotofTime)

FOPC Semantics

- Sentences in FOPC can be assigned truth values True or False

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**Variables and Quantifiers**

- **Existential (∃):** There exists
  - A restaurant that serves Mexican food near UMD
    
  - \((∃x) \text{Restaurant}(x) \land \text{Serves}(x, \text{MexicanFood}) \land \text{Near(LocationOf}(x), \text{LocationOf}(UMD))\)

- **Universal (∀):** For all
  - All vegetarian restaurants serve vegetarian food
    
  - \((∀x) \text{VegetarianRestaurant}(x) \Rightarrow \text{Serves}(x, \text{VegetarianFood})\)

**FOPC Examples**

- **John gave Mary a book**
  - Previously: \(\text{Give}(\text{John}, \text{Mary}, \text{book})\)

- **Better:**
  
  - \((∃x) \text{Giving}(x) \land \text{Giver}(\text{John},x) \land \text{Givee}(\text{Mary},x) \land \text{Given}(\text{book},x)\)

- **Full Definition of Give:**
  
  - \((∃w,x,y,z) \text{Giving}(x) \land \text{Giver}(w,x) \land \text{Givee}(z,x) \land \text{Given}(y,,x)\)
Why Variableize?

- Multiple sentences containing “eat”
  - I ate.
  - I ate a turkey sandwich.
  - I ate a turkey sandwich at my desk.
  - I ate at my desk.
  - I ate lunch.
  - I ate a turkey sandwich for lunch
  - I ate a turkey sandwich for lunch at my desk.

- Seven different Representations:
  - Eating₁(Speaker)
  - Eating₂(Speaker,TurkeySandwich)
  - Eating₃(Speaker,TurkeySandwich,Desk)
  - Eating₄(Speaker,Desk)
  - Eating₅(Speaker,Lunch)
  - Eating₆(Speaker,TurkeySandwich,Lunch)
  - Eating₇(Speaker,TurkeySandwich,Lunch,Desk)

Solution with Variables

- Eating(v,w,x,y)

Examples revisited:
- (∃w,x,y) Eating(Speaker,w,x,y)
- (∃x,y) Eating(Speaker,TurkeySandwich,x,y)
- (∃x) Eating(Speaker,TurkeySandwich,x,Desk)
- (∃w,x) Eating(Speaker,w,x,Desk)
- (∃w,y) Eating(Speaker,w,Lunch,y)
- (∃y) Eating(Speaker,TurkeySandwich,Lunch,y)
- Eating(Speaker,TurkeySandwich,Lunch,Desk)
Representing Time

- Events are associated with points or intervals in time.
- We can impose an ordering on distinct events using notion of \textit{precedes}.
- Temporal logic notation:
  \( (\exists w,x,t) \text{Arrive}(w,x,t) \)
- Constraints on variable \( t \)
  \( I \text{ arrived in New York} \)
  \( (\exists t) \text{Arrive}(I,\text{NewYork},t) \land \text{precedes}(t,\text{Now}) \)

Interval Events

- Need \( t_{\text{start}} \) and \( t_{\text{end}} \)
- She was driving to New York until now
  
  \( (\exists t_{\text{start}},t_{\text{end}}) \text{Drive}(\text{She},\text{NewYork},t_{\text{start}},t_{\text{end}}) \land \text{precedes}(t_{\text{start}},\text{Now}) \land \text{Equals}(t_{\text{end}},\text{Now}) \)
Relation Between Tenses and Time

* Relation between simple verb tenses and points in time is not straightforward
* Present tense used like future:
  - *We fly from Baltimore to Boston at 10*
* Complex tenses:
  - *Flight 1902 arrived late*
  - *Flight 1902 had arrived late*

Reference Point

* Reichenbach (1947) introduced notion of Reference point (R), separated out from Speech time (S) and Event time (E)
* Example:
  - *When Mary's flight departed, I ate lunch*
  - *When Mary's flight departed, I had eaten lunch*
* Departure event specifies reference point.
We refer to the S,R,E notation as a Basic Tense Structure (BTS)