CSCI 5832
Natural Language Processing

Lecture 18
Jim Martin

Today: 3/22

- **Experiment**
- **Semantics**

Transition

- First we did words (morphology)
- Then simple sequences of words
- Then we looked at true syntax
- Now we're moving on to meaning. Where some would say we should have started to begin with.

Meaning

- Language is useful and amazing because it allows us to encode/decode…
  - Descriptions of the world
  - What we're thinking
  - What we think about what other people think
- Don't be fooled by how natural and easy it is… In particular, you never really…
  - Utter word strings that match the world
  - Say what you're thinking
  - Say what you think about what other people think

Meaning

- You're simply uttering linear sequences of words such that when other people read/hear and understand them they come to know what you think of the world.

Meaning

- So… I can stand up here and bounce waves of compressed air against your eardrums and have the effect of
  - Making you laugh, cry or go to sleep
  - Telling you how to make a soufflé
  - Describing the weather, or a double play, or a glass of wine to you.
- These are not easy tasks. They are amazing tasks. They just look easy.

Meaning Representations

- We're going to take the same basic approach to meaning that we took to syntax and morphology
- We're going to create representations of linguistic inputs that capture the meanings of those inputs.
- But unlike parse trees and the like these representations aren't primarily descriptions of the structure of the inputs…

Meaning Representations

- In most cases, they're simultaneously descriptions of the meanings of utterances and of some potential state of affairs in some world.

Meaning Representations

- What could this mean…
  - representations of linguistic inputs that capture the meanings of those inputs
- Lots of different things to lots of different philosophers.
- We're not going to go there. For us it means
  - Representations that permit or facilitate semantic processing

Semantic Processing

- Ok, so what does that mean?
- Representations that
  - Permit us to reason about their truth (relationship to some world)
  - Permit us to answer questions based on their content
  - Permit us to perform inference (answer questions and determine the truth of things we don't actually know)

Semantic Processing

- Touchstone application is often question answering
  - Can a machine answer questions involving the meaning of some text or discourse?
  - What kind of representations do we need to mechanize that process?

Semantic Processing

- We're going to discuss 2 ways to attack this problem (just as we did with parsing)
  - There's the theoretically motivated correct and complete approach…
    - Computational/Compositional Semantics
  - And there are practical approaches that have some hope of being useful and successful.
    - Information extraction

Semantic Analysis

- **Compositional Analysis**
  - **Create a FOL representation that accounts for all the entities, roles and relations present in a sentence.**
- **Information Extraction**
  - **Do a superficial analysis that pulls out only the entities, relations and roles that are of interest to the consuming application.**

Information Extraction (preview)

- **Investigators worked leads Monday in Riverside County where the car was reported stolen and reviewed security tape from Highway 241 where it was abandoned, said city of Anaheim spokesman John Nicoletti.**

- **Investigators worked leads [Monday] in [Riverside County] where the car was reported stolen and reviewed security tape from [Highway 241] where it was abandoned, said city of [Anaheim] spokesman [John Nicoletti].**

Break

- Can 1 person from each group send me by email
  - Your group members
  - Project title
  - 1 paragraph summary of the project
- Yet another colloquium today at 3:30 in 1B55. Should be good.

Representational Schemes

- We're going to make use of First Order Predicate Calculus (FOPC) as our representational framework
  - Not because we think it's perfect
  - All the alternatives turn out to be either too limiting or
  - They turn out to be notational variants

FOPC

- Allows for…
  - The analysis of truth conditions
    - Allows us to answer yes/no questions
  - Supports the use of variables
    - Allows us to answer questions through the use of variable binding
  - Supports inference
    - Allows us to answer questions that go beyond what we know explicitly

FOPC

- This choice isn't completely arbitrary or driven by the needs of practical applications
- FOPC reflects the semantics of natural languages because it was designed that way by human beings
- In particular…

Meaning Structure of Language

- The semantics of human languages…
  - Display a basic predicate-argument structure
  - Make use of variables
  - Make use of quantifiers
  - Use a partially compositional semantics

Predicate-Argument Structure

- Events, actions and relationships can be captured with representations that consist of predicates and arguments to those predicates.
- Languages display a division of labor where some words and constituents function as predicates and some as arguments.

Predicate-Argument Structure

- Predicates
  - Primarily Verbs, VPs, PPs, Sentences
  - Sometimes Nouns and NPs
- Arguments
  - Primarily Nouns, Nominals, NPs, PPs
  - But also everything else; as we'll see it depends on the context

Example

- *Mary gave a list to John.*
- Giving(Mary, John, List)
- More precisely
  - Gave conveys a three-argument predicate
  - The first arg is the subject
  - The second is the recipient, which is conveyed by the NP in the PP
  - The third argument is the thing given, conveyed by the direct object

Not exactly

- The statement
  - The first arg is the subject

  can't be right.
- Subjects can't be givers.
- We mean that the meaning underlying the subject phrase plays the role of the giver.

Better

- Turns out this representation isn't quite as useful as it could be.
  - Giving(Mary, John, List)
- Better would be

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

Predicates

- The notion of a predicate just got more complicated…
- In this example, think of the verb/VP providing a template like the following

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

- The semantics of the NPs and the PPs in the sentence plug into the slots provided in the template

Semantic Analysis

- Semantic analysis is the process of taking in some linguistic input and assigning a meaning representation to it.
  - There a lot of different ways to do this that make more or less (or no) use of syntax
  - We're going to start with the idea that syntax does matter
    - The compositional rule-to-rule approach

Compositional Analysis

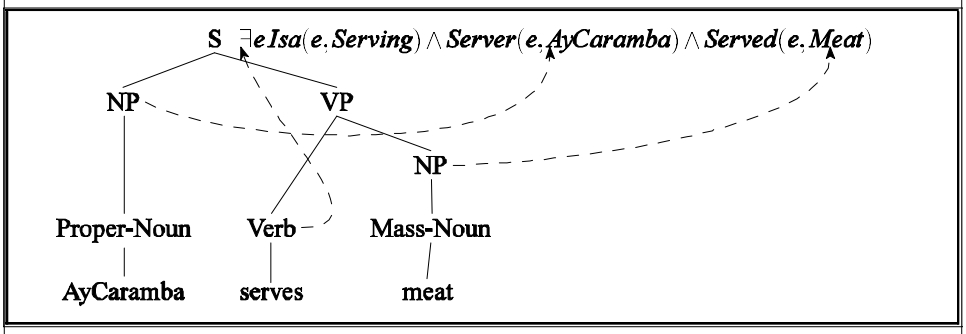
- **Principle of Compositionality**
  - **The meaning of a whole is derived from the meanings of the parts**
- **What parts?**
  - **The constituents of the syntactic parse of the input**
- **What could it mean for a part to have a meaning?**

Example

- **AyCaramba serves meat**

$$\exists e\ Serving(e) \wedge Server(e, AyCaramba) \wedge Served(e, Meat)$$

Compositional Analysis



Augmented Rules

- We'll accomplish this by attaching semantic formation rules to our syntactic CFG rules
- Abstractly

$$A \rightarrow \alpha_1 \ldots \alpha_n \quad \{f(\alpha_1.sem, \ldots \alpha_n.sem)\}$$

- This should be read as the semantics we attach to A can be computed from some function applied to the semantics of A's parts.

Example

- Easy parts…
  - NP -> PropNoun
  - NP -> MassNoun
  - PropNoun -> AyCaramba
  - MassMoun -> meat
- Attachments
  {PropNoun.sem}
  {MassNoun.sem}
  {AyCaramba}
  {MEAT}

Example

- S -> NP VP
- VP -> Verb NP
- Verb -> serves
- {VP.sem(NP.sem)}
- {Verb.sem(NP.sem)
- ???

$$\lambda x \lambda y \; \exists e \; Serving(e) \wedge Server(e, y) \wedge Served(e, x)$$

Lambda Forms

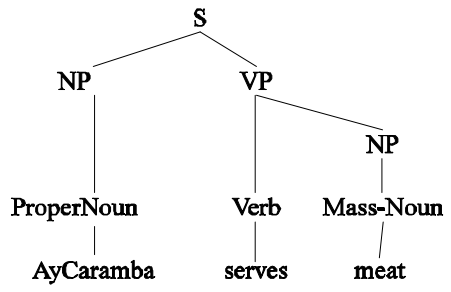
- A simple addition to FOPC
  - Take a FOPC sentence with variables in it that are to be bound.
  - Allow those variables to be bound by treating the lambda form as a function with formal arguments

$$\lambda x P(x)$$

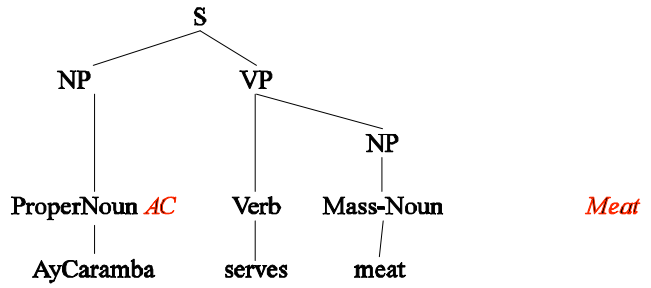
$$\lambda x P(x)(Sally)$$

$$P(Sally)$$

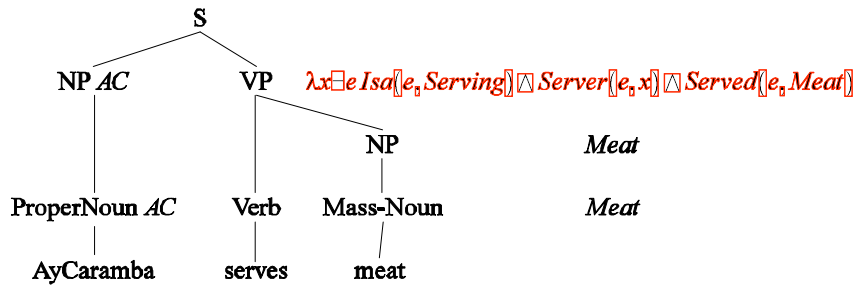
Example



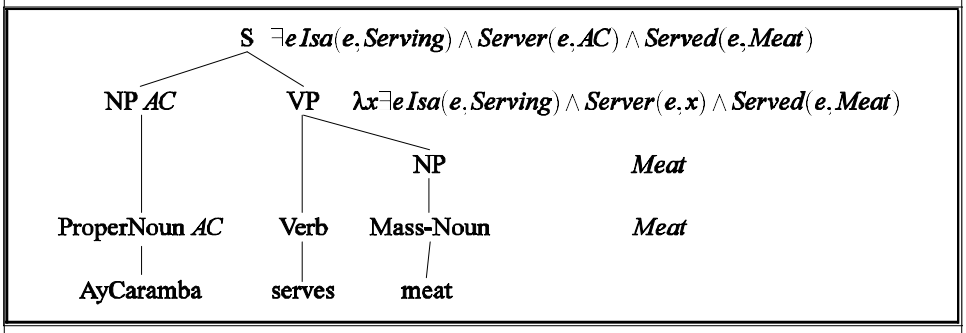
Example



Example



Example



Next Time

- Read Chapter 16 and 17 (to be posted real soon now).
- Schedule
  - Week after break is going to be devoted to Bio NLP (guest lectures by Kevin Cohen from UC Health Sciences).
  - After that we'll finish compostional semantics and move on to IE (a new chapter will be available).
  - Then we'll cover discourse, Q/A, and MT.