Representing Meaning

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Slides from:

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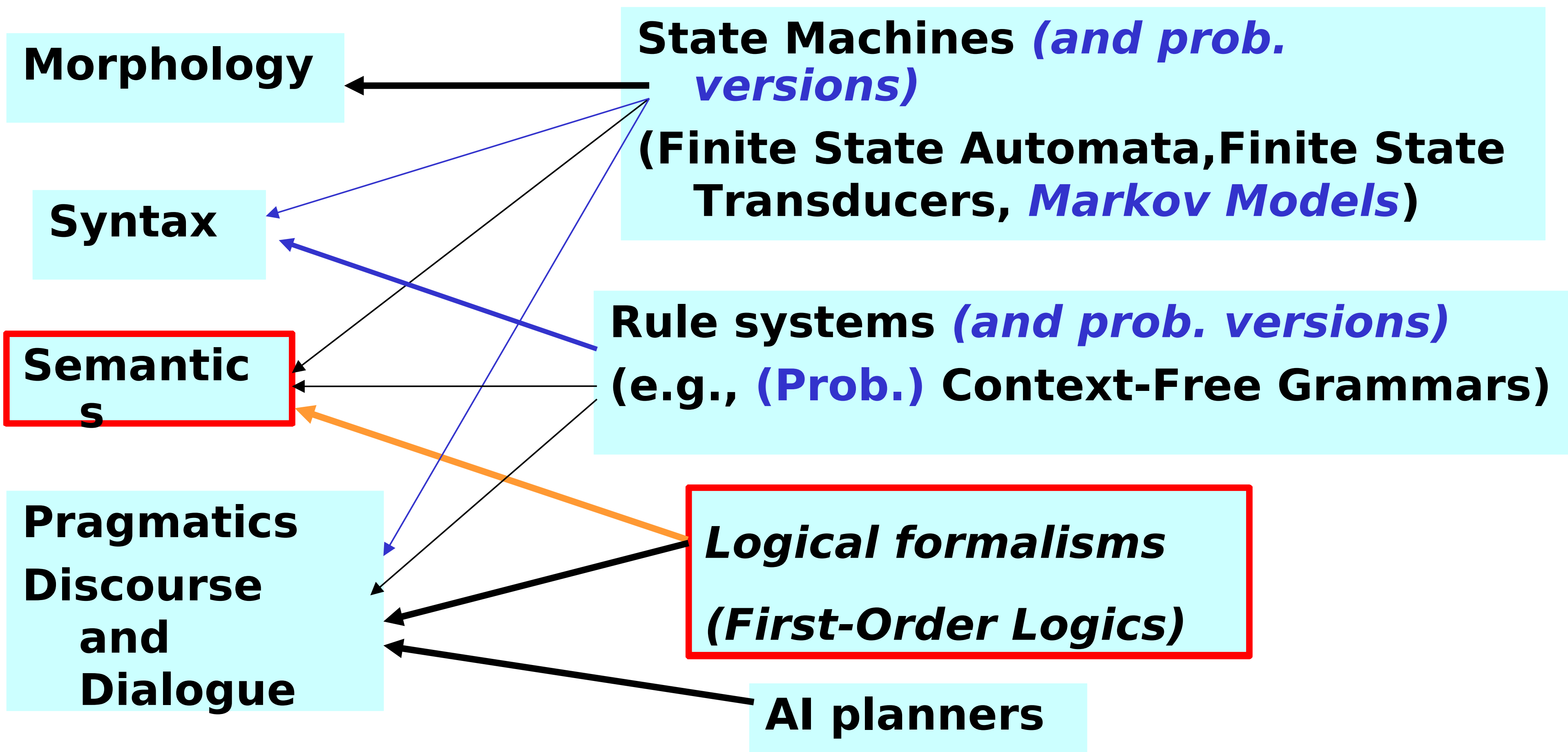
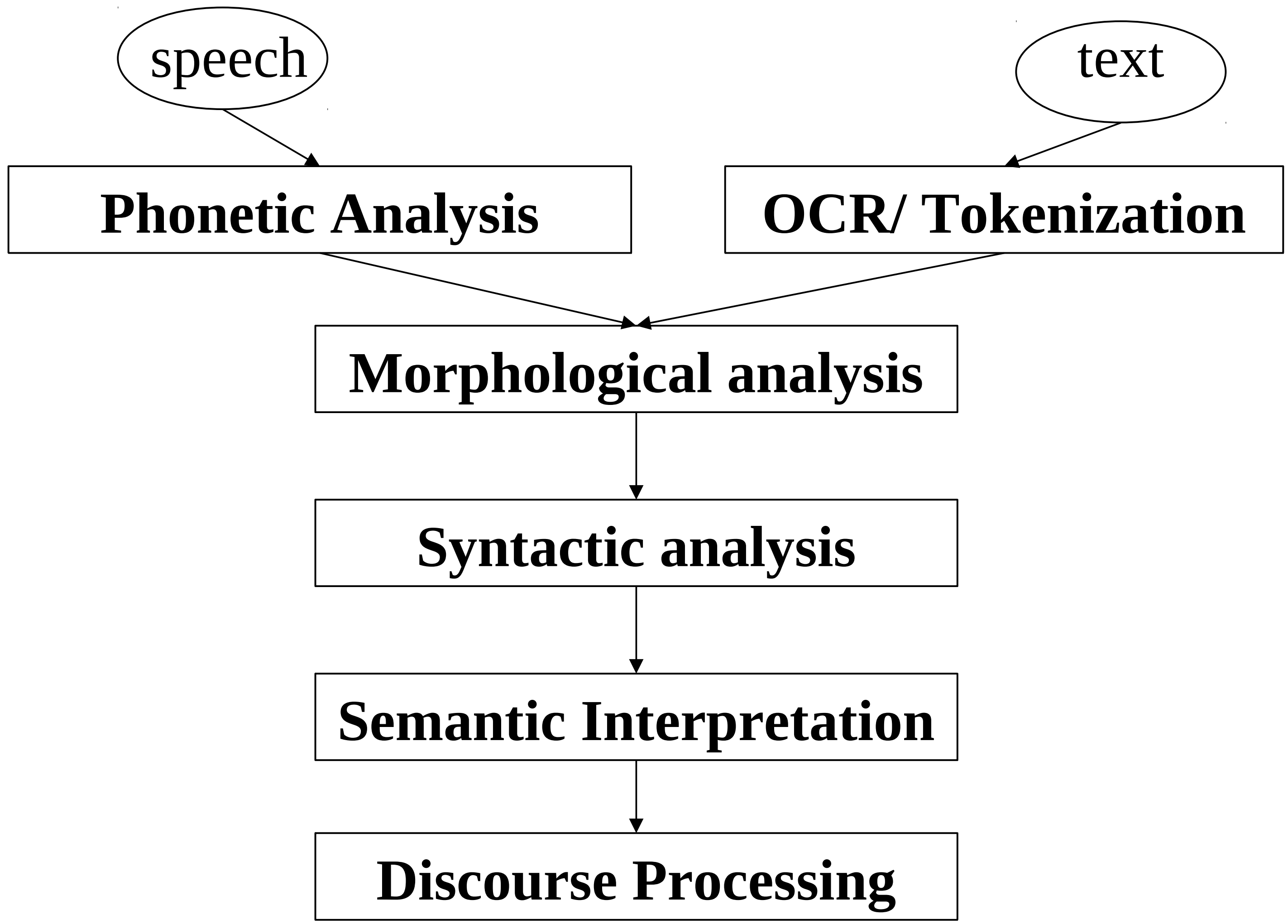
Agenda

- Introduction
- Computational Desiderata for Representations
- Meaning Structure of Language

Knowledge-Formalism Map

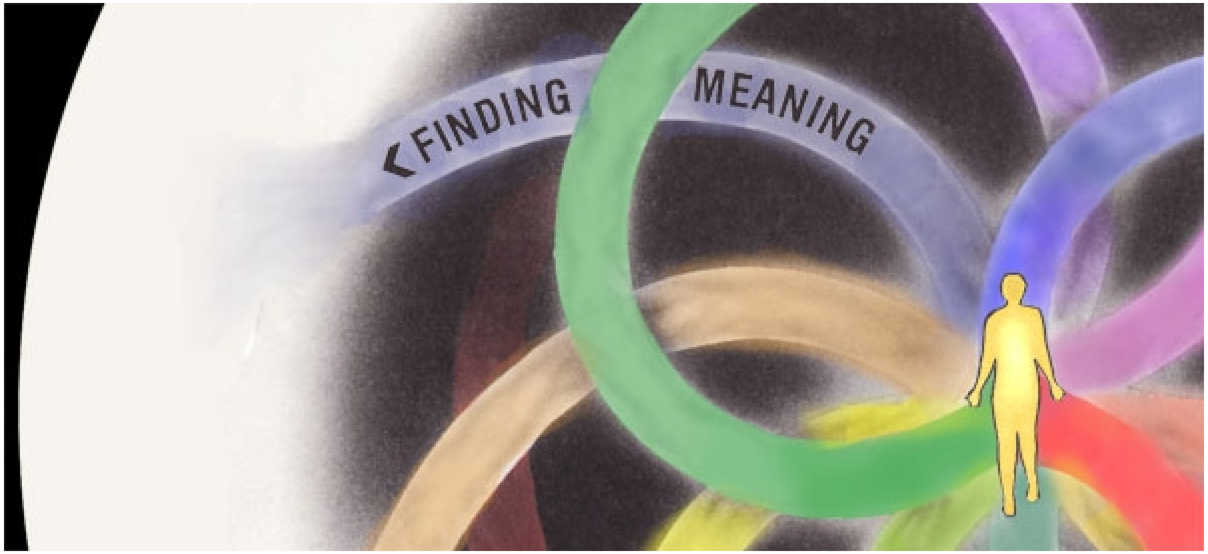


NLP Pipeline



Transition

- First we worked with words (morphology).
- Then we looked at syntax and grammar.
- Now we're moving on to meaning....



Meaning

- So far, we have focused on the structure of language – not on what things ***mean*.**
- We have seen that words have different meaning, depending on the context in which they are used.
- Everyday 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 that you've been misled
    - …

Meaning

- 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
  - What formalisms can be used

Meaning Representations

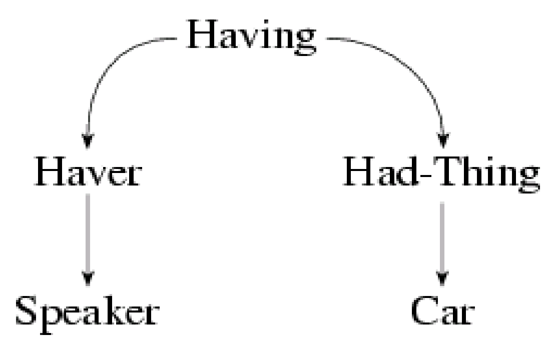
- Meaning representations
  - The meaning of linguistic utterances can be captured in formal structures
- Meaning representation languages
  - The frameworks that are used to specify the syntax and semantics of these representations
- Language tasks requiring some form of semantic processing
  - Answering an essay question on an exam
  - Deciding what to order at a restaurant by reading a menu
  - Learning to use a new piece of software by reading the manual
  - Following a recipe

Meaning Representations

- Semantic analysis
  - Take linguistic inputs and construct meaning representations that are made up of the *same kind stuff* that is used to represent this kind of everyday common sense knowledge of the world

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

I have a car



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

```
Having
 Haver:   Speaker
 HadThing:  Car
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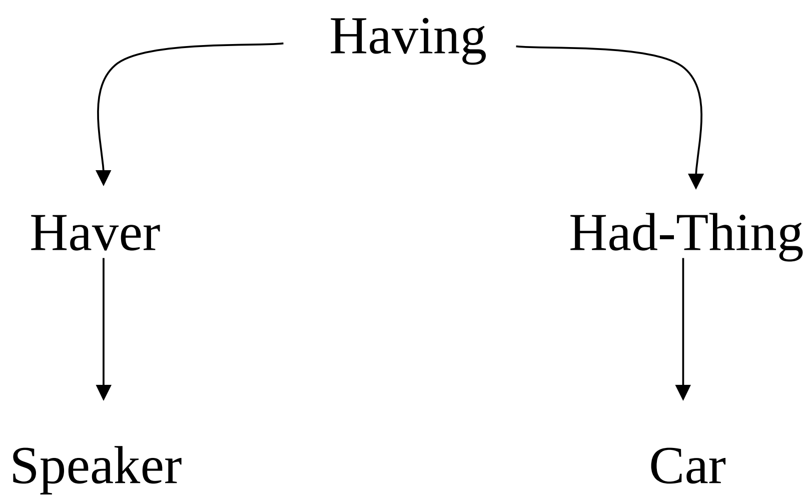
Common Meaning Representations

- First Order Predicate Calculus (FOPC):

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

- Semantic Net:



Common Meaning Representations

- Conceptual Dependency Diagram:

  Car

  ⇑ Poss-By

  Speaker

- Frame-based Representations:

Having Haver: Speaker HadThing: Car

Common Meaning Representations

- They all share a common foundation:
  - Meaning representation consists of structures composed of sets of symbols
  - These symbols structures correspond to objects, relations among objects, in some world being represented

What Can Serve as a Meaning Representation?

- Anything that serves the core practical purposes of a program that is doing semantic processing ...
  - Answer questions
    - *What is the tallest building in the world?*
  - Determining truth
    - *Is the blue block on the red block?*
  - Drawing inferences
    - *If the blue block is on the red block and the red block is on the tallest building in the world, then*
    - *the blue block is on the tallest building in the world*
- What are basic requirements of meaning representation?

Computational Desiderata for Representations

- Considering the issue of *why* meaning representations are needed and *what* they should do for us
  - Verifiability
  - Unambiguous representations
  - Canonical form
  - Inference and variables
  - Expressiveness

Computational Desiderata for Representations

- Verifiability
  - It must be possible to use the representation to determine the relationship between the meaning of a sentence and the world we know it.
  - The most straightforward way:
    - Compare, or match the representation of the meaning of an input against the representation in its **KB**, its store of information about its world.

(14.1) Does Maharani serve vegetarian food?

Serves (*Maharani*, *VegetarianFood*)

Computational Desiderata for Representations

- Unambiguous representations
  - Single linguistic input can legitimately have different meaning representations assigned to them.
  - (14.2) *I wanna eat someplace that's close to ICSI*.
    - Ordinary interpretation – eat *at* nearby location
    - Godzilla's interpretation
  - Regardless of any ambiguity in the raw input, it is critical that a meaning representation language support representations that have a single unambiguous interpretation.
  - **Vagueness**, a concept closely related to ambiguity

    (14.3) *I want to eat Italian food.* *(pasta? spaghetti? lasagna?)*

Computational Desiderata for Representations

- Canonical Form
  - Inputs that mean the same thing should have the same meaning representation
    - (14.4) *Does Maharani have vegetarian food*?
    - (14.5) *Do they have vegetarian food at Maharani*?
    - (14.6) *Are vegetarian dishes served at Maharani*?
    - (14.7) *Does Maharani serve vegetarian fare*?
  - Food, dish and fare – all have various word senses and some of the senses are synonymous with one another
  - The process of choosing the right sense in context is called word sense disambiguation (WSD)

Computational Desiderata for Representations

- If a system has the ability to choose that shared sense, then an identical meaning representation can be assigned to the phrases.

Computational Desiderata for Representations

- Inference and Variables
  - (14.10) *Can vegetarians eat at Maharani?*
  - There is a common sense connection between what vegetarians eat and what vegetarian restaurants serve
  - This is a fact about the world and not fact about any particular kind of linguistic regularity
  - **Inference**: refer generically to a system's ability to draw valid conclusions based on the meaning representation of inputs and its store of background knowledge
    - *I'd like to find a restaurant where I can get vegetarian food*
    - *Serves*(*x*, *VegetarianFood*)

Computational Desiderata for Representations

- Expressiveness
  - To be useful, a meaning representation scheme must be expressive enough to handle an extremely wide range of subject matter
  - Ideal situation: having a single meaning representation language that could adequately represent the meaning of any sensible natural language utterance

Meaning Structure of Language

- Various methods by which human language convey meaning:
  - Form-meaning associations,
  - Word-order regularities,
  - Tense systems,
  - Conjunction and quantifiers, and
  - A fundamental predicate-argument structure
- The last one has great practical influence on the nature of meaning representation languages.

Meaning Structure of Language

- All human language have a form of predicate-argument arrangement at the core of their semantic structure
- This predicate-argument structure asserts
  - The specific relationships hold among the various concepts underlying the constituent words and phrases that make up sentences
- This underlying structure permits the creation of a single composite meaning representation from the meanings of the various parts of an input
- One of the most important jobs of a grammar is to help organize this predicate-argument structure

Predicate-Argument Structure

- (14.12) I want Italian food.
  (14.13) I want to spend less than five dollars.
  (14.14) I want it to be close by here.

  ➡ *NP want NP*
  NP want Inf-VP
  NP want NP Inf-VP

- The syntactic frames specify the number, position, and syntactic category of the arguments that are expected to accompany a verb

  want in (14.12) specifies the following facts:

  # There are two arguments to this predicate.

  # Both arguments must be NPs.

  # The first argument is pre-verbal and plays the role of the subject.

  # The second argument is post-verbal and plays the role of the direct object.

- Two extensions of these frames into the semantic realm:
  - Semantic roles
  - Semantic restrictions on these roles

Predicate-Argument Structure

- Notion of semantic role
    - By looking at (14.12) through (14.14)
        - The pre-verbal argument plays the role of the entity doing the *wanting*, while
        - The post-verbal argument plays the role of concept that is *wanted*.
    - By noticing these regularities and labeling them accordingly, we can associate *the surface arguments of a verb* with a set of *discrete roles in its underlying semantics*
        - Verb subcategorization allows **linking** of arguments in the surface structure with the semantic roles
    - The study of roles associated with specific verbs and across classes of verbs is referred to as **thematic role** or **case role** analysis

Predicate-Argument Structure

- Notion of semantic restrictions
  - Only certain kinds, or *categories*, of concepts can play the role of *wanter*
  - *want* restricts the constituents appearing as first argument to, that can partake in a *wanting* role – **selection restriction**
- Predicate-argument structures other than verbs:
  - (14.15) an Italian restaurant under fifteen dollars

    Under(*ItalianRestaurant*, $15)
  - (14.16) Make a reservation for this evening for a table for two person at 8.

    Reservation(*Hearer*, *Today*, 8*PM*, *2*)

Predicate-Argument Structure

- Useful meaning representation language must support:
  - Variable arity predicate-argument structures.
  - The semantic labeling of arguments to predicates.
  - The statement of semantic constraints on the fillers of argument roles.

References

- Slides were adapted from:
  Speech and Language Processing, *Jurafsky and Martin*