Foundations of Natural Language Processing
Lecture 18b
Formal Semantic Representations: Some First Steps

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Last Time

• What is meaning?

• What information should a representation of meaning capture (to make it useful for NLP)?

Now:

• First Order Logic as a (good) candidate for capturing semantic representations.

• First steps in deriving FoL logical forms of a sentence from its syntax
  – The Principle of Compositionality
Desiderata for (Literal) Semantic Representations

The semantic representation should:

- be **unambiguous**
  (> 1 semantic representation for *I made her duck* etc)

- support **automated inference**

- be **verifiable**: determine if the sentence is *true* with respect to a model of the world.

**Answer**: First order logic
An Aside: Logical vs. Commonsense inference

For now:

• John buttered toast at midnight on the lawn ⇒
  Someone buttered toast, Someone did something at midnight . . .

For later:

• The purchase of Houston-based LexCorp by BMI for $2B prompted widespread sell-offs by traders ⇒
  BMI acquired an American company
  (from RTE)

• John buttered toast at midnight on the lawn ⇒
  Some food preparation took place in the dark, with the cook standing on grass.
Why FoL and not Propositional Logic?

Fred eats lentils or he eats rice. \((P \lor Q)\)
Fred eats rice or John eats rice \((P \lor R)\)

- Doesn’t capture the internal structure of the proposition *Fred ate rice* (e.g. how its meaning is derived from that of “Fred”, “ate”, “rice”).

- We’re unable to express important relationships between, e.g.
  - Everyone eats rice \(\vdash\) Someone eats rice, Everyone eats something.
  - Fred eats rice \(\vdash\) Someone eats rice

- Fred ate rice: \(eat(fred, rice)\)
- Everyone ate rice: \(\forall x. eat(x, rice)\)
- Someone ate rice: \(\exists x. eat(x, rice)\)
- Every dog had a bone: \(\forall x (dog(x) \rightarrow \exists y (bone(y) \land have(x, y)))\)
  \(\vdash\) \(\exists y (bone(y) \land \forall x (dog(x) \rightarrow have(x, y))\)

(ii) entails (i) and (iii); (i) entails (iii); (v) entails (iv)!
Introducing an event argument $e$ to ‘action’ predicates is very useful:

**Tense:** Fred ate rice: $\exists e (\text{eat}(e, \text{fred}, \text{rice}) \land e \prec n)$

**Modifiers:** Fred ate rice with a fork at midnight:

$\exists e (\text{eat}(e, \text{fred}, \text{rice}) \land e \prec n \land$

$\exists x (\text{with}(e, x) \land \text{fork}(x)) \land$

$\text{at}(e, \text{midnight})$

Note how the second sentence entails the first via $\land$-elimination!
Compositionality

- **Compositionality**: The meaning of a complex expression is a function of the meaning of its parts and of the rules by which they are combined.

- So you can build a *logical form* of a sentence by specifying:
  
  **Lexical meanings**: Associate each word in the lexicon with a FoL expression.  
  **Composition rules**: Augmenting each syntax rule in a CFG with instructions for composing the FoL expressions on the RHS into a FoL expression for the LHS.
What we’re aiming for

\[ S \]
\[ \exists e (eat(e, fred, rice) \land e \prec n) \]

NP
  | PropN
  | Fred
  | fred

VP
  | Vt
  | ate

NP
  | MassN
  | rice
  | rice

• How do we get the bits to combine?

• What are the LFs of the intermediate nodes?
Summary

• NL supports logical inference and commonsense inference.

• FoL is a good candidate for validating logical inferences inherent in NL meanings.

• The Principle of Compositionality tells us how to combine LFs of phrases into LFs of longer phrases.

• Like grammar rules in syntax, it supports deriving LFs for an unbounded number of sentences from a finite number of rules.

Next time: Technically, how do we combine the LFs of NL phrases into LFs of NL phrases that are formed by combining those smaller phrases?