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 widesprad 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. ($P \vee Q$)
Fred eats rice or John eats rice ($P \vee R$)

- 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:	$eat(fred, rice)$	(i)
Everyone ate rice:	$\forall x.eat(x, rice)$	(ii)
Someone ate rice:	$\exists x.eat(x, rice)$	(iii)
Every dog had a bone:	$\forall x(dog(x) \rightarrow \exists y(bone(y) \wedge have(x, y)))$	(iv)
	$\exists y(bone(y) \wedge \forall x.(dog(x) \rightarrow have(x, y)$	(v)

  (ii) entails (i) and (iii); (i) entails (iii); (v) entails (iv)!

Adding tense and modifiers: Davidsonian Semantics

Introducing an event argument e to 'action' predicates is very useful:

Tense: Fred ate rice: $\exists e(eat(e, fred, rice) \wedge e \prec n)$

Modifiers: Fred ate rice with a fork at midnight:

$$\exists e(eat(e, fred, rice) \wedge e \prec n \wedge \\ \exists x(with(e, x) \wedge fork(x)) \wedge \\ at(e, midnight))$$

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

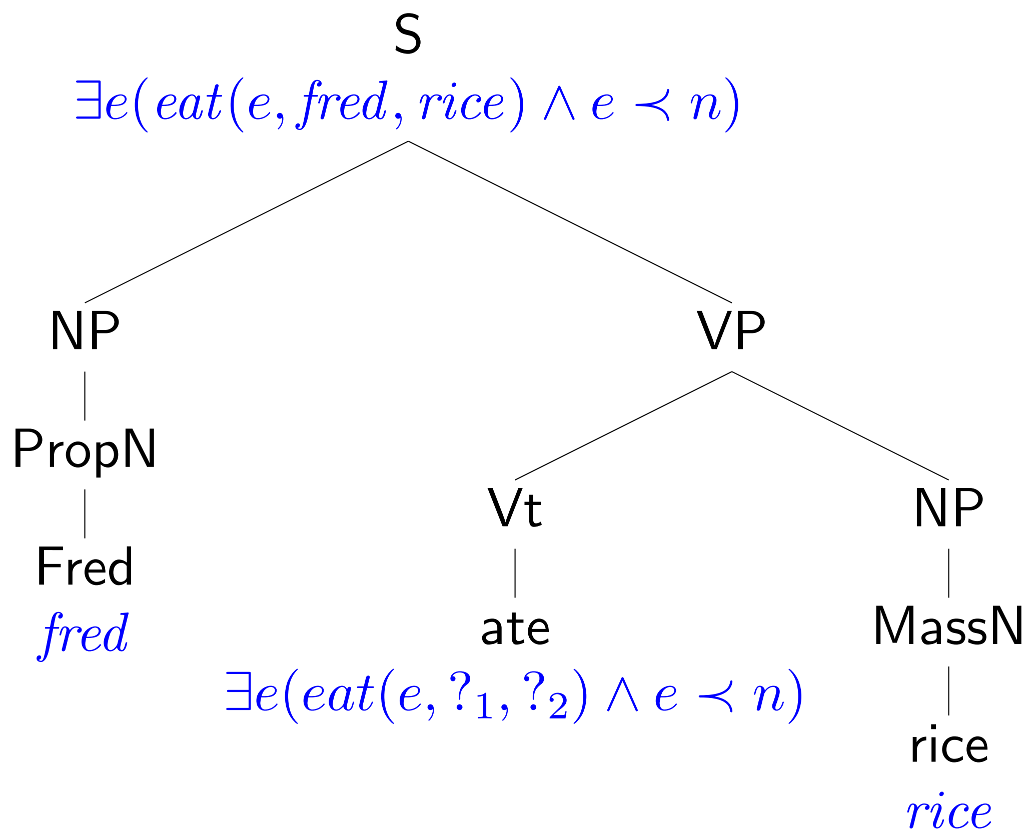
Compositionality

- **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



- 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?