Natural Language Processing

Lecture 19.2—3/17/2015
Martha Palmer

Q/A

Meaning Representations

- What does this mean…
  - representations of linguistic inputs that capture the meanings of those inputs
- 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 (i.e., their 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 already know to be true)

Semantic Processing

- The book discusses 2 ways to attack this problem (just as we did with parsing)
  - There's the principled, theoretically motivated approach…
    - Computational/Compositional Semantics
      - Chapters 17 and 18
  - And there are limited, practical approaches that have some hope of actually being useful
    - Information extraction
      - Chapter 22

We'll add a 3rd way

- Semantic parsing with probabilistic CCGs

Semantic Analysis

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

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.

Information Extraction Named Entities

- 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].

Information Extraction Events

- 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.

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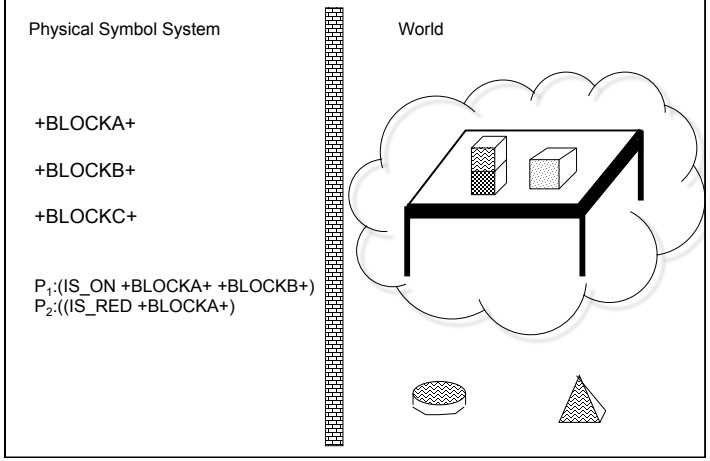
Representational Schemes

- We're going to make use of First Order Logic (FOL) as our representational framework
  - Not because we think it's ideal
  - Many of the alternatives turn out to be either too limiting or too complex or
  - They turn out to be notational variants

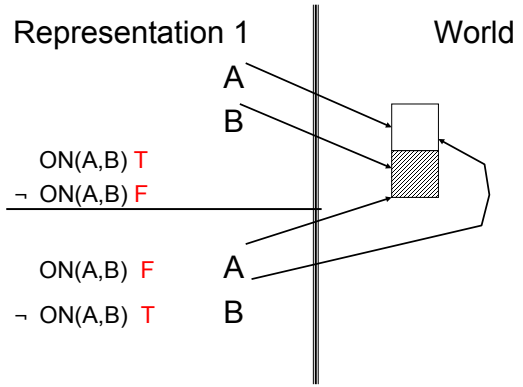
FOL

- 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

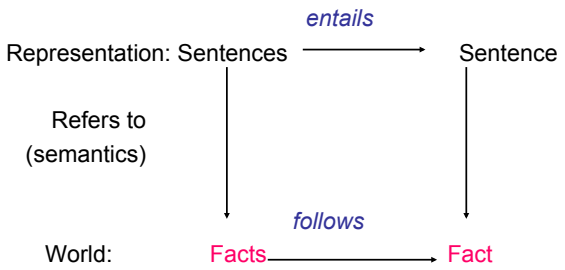
The Semantic Wall



Truth depends on Interpretation



Logical Interpretations



Logic

- Truth.
  - A sentence is true if the *state of affairs* it describes is actually the case in the world.
- Valid.
  - A sentence is **valid** if it's true no matter what the world is actually like or what the semantics is.
  - *tautologies* or *analytic truths*.

Two KR Languages

Representation Language	Inference Procedure
– Propositional Logic	– Unit Resolution
– First Order Logic	– General Resolution
	(Basis for Prolog)

Propositional Logic

- **Syntax.**
  - Sentences
    - T – True, F – False
    - P, Q, etc.
    - (Sentence), Sentence Connective Sentence, Sentence
  - Connectives
    - ¬ negation,
    - ∧ conjunction,
    - ∨ disjunction,
    - → implication, also (⇒,⊃)
    - ⇔ equivalence (biconditional implication)

Truth Tables

P: *The sun is shining*
Q: *The day is warm*
R: *The sun is shining and the day is warm.*

P	Q	P ∧ Q
F	F	
F	T	
T	F	
T	T	

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Propositional Logic

- **Semantics.** Specifies what facts in the world sentences refer to.
  P. Richard is a pacifist, **Q.** Richard is a Quaker.

Truth Table gives an *interpretation*

P	Q	¬P	P ∧ Q	P ∨ Q	P → Q
F	F	T	F	F	T
F	T	T	F	T	T
T	F	F	F	T	F
T	T	F	T	T	T

Real life gets complicated

- usually, Quakers are pacifist
- usually, Republicans are not pacifist
- Richard is both a Quaker and a Republican
- Since Richard can be proved to be a pacifist in at least one case, he is believed to be a pacifist; however, since he can also be proved not to be a pacifist, he is also believed not to be a pacifist.

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Unit Clauses

- P → Q is equivalent to ¬P ∨ Q

P	Q	¬P	P ∧ Q	P ∨ Q	P→ Q	¬P∨ Q
F	F	T	F	F	T	
F	T	T	F	T	T	
T	F	F	F	T	F	
T	T	F	T	T	T	

Linguistic intuitions about logic?

- *If Patricia goes to the party then Emmet will go too.*
- *If wishes were money then we'd all be rich.*
- *If I were an ostrich, then I would be a bird.*
- *If I were an ostrich, then I would not be a bird.*

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Linguistic intuitions about "and"

- **P ∧ Q equivalent to Q ∧ P?**
  - *He woke up and saw on TV that he had won the lottery.*
  - *Combine the egg yolks with water in a bowl and whisk the mixture until foamy.*
  - *He made two false starts and was disqualified from the race.*
  - *Move and I'll shoot!*

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Necessary/analytic truth of propositions (sentences)

- Logically true by virtue of the meaning of the terms
  - *Either the Buffs will beat Florida State or the Buffs will not beat Florida State.* **P ∨ ¬ P**
  - *If the Buffs beat Florida State then Florida State loses to the Buffs.* **Reversal**
  - *All teams who win are teams.* **Quantifiers**
  - *The train will either arrive or it won't arrive.*

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Entailment 4.6

- P entails Q when the truth of P guarantees the truth of Q, and the falsity of Q guarantees the falsity of P.

- Composite Truth Table for entailment:

P	Q
T	→ T
F	→T or F
F	← F
Tor F	←T

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Entailment

- P entails Q when the truth of P guarantees the truth of Q, and the falsity of Q guarantees the falsity of P.

- Composite Truth Table for entailment:

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T	→ T
F	→T or F
F	← F
Tor F	←T

P	Q	P→ Q
F	F	T
F	T	T
T	F	F
T	T	T

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Entailment Examples

- The anarchist assassinated the emperor. P
- The emperor died. Q
- P → Q
- If P is true is Q true?
- If Q is False, is P false?
- If P is false, then what about Q?

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Sources for Entailments

- Hyponyms
  - *I bought a dress today*. P
  - *I bought clothes today*. Q
- Syntax
  - *Caesar won the war*. P
  - *The war was won by Caesar*. Q
- Paraphrases – mutually entail each other

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And now also….

- Necessarily true – tautologies
  - *Venus is Venus*
- Necessarily false – contradictions
  - *Here is not here*.
- Presuppositions
  - *The King of France is bald.*
    presupposes
  - There is a *King of France.*

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Entailment

- P entails Q when the truth of P guarantees the truth of Q, and the falsity of Q guarantees the falsity of P.
- Composite Truth Table for entailment:

P	Q
T	→ T
F	→T or F
F	← F
Tor F	←T

P	Q	P→ Q
F	F	T
F	T	T
T	F	F
T	T	T

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Unit Clauses

- P → Q is equivalent to ¬P ∨ Q

P	Q	¬P	P ∧ Q	P ∨ Q	P→ Q	¬P∨ Q
F	F	T	F	F	T	
F	T	T	F	T	T	
T	F	F	F	T	F	
T	T	F	T	T	T	

Inference Rules

- And Elimination

$$\frac{\alpha_1 \wedge \alpha_2, \wedge \ldots \wedge \alpha_n}{\alpha_1}$$

- And Introduction

$$\frac{\alpha_1, \ldots, \alpha_n}{\alpha_1 \wedge \alpha_2, \wedge \ldots \wedge \alpha_n}$$

Inference Rules (cont'd)

- Or Introduction

$$\frac{\alpha_i}{\alpha_1 \vee \alpha_2, \vee \ldots \vee \alpha_i \vee \ldots \vee \alpha_n}$$

- Double Negation Elimination

$$\frac{\neg\neg\alpha}{\alpha}$$

Inference Rules (cont'd)

- Modus Ponens (Implication Elimination)

$$\frac{\alpha \Rightarrow \beta, \alpha}{\beta}$$

De Morgan's laws

- $\neg(P \wedge Q) \leftrightarrow (\neg P) \vee (\neg Q)$
  - "not (A and B)" is the same as "(not A) or (not B)"
  - The negation of a conjunction is the disjunction of the negations
- $\neg(P \vee Q) \leftrightarrow (\neg P) \wedge (\neg Q)$
  - "not (A or B)" is the same as "(not A) and (not B)"
  - The negation of a disjunction is the conjunction of the negations.

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