Semantics and Pragmatics of NLP Overview

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Welcome to SPNLP! First, Some Admin

- Course notes 1:
  - Patrick Blackburn and Johan Bos (2005) *Representation and Inference for Natural Language: A first course in computational semantics*, CSLI Publications.

  Available from all good bookshops, including Amazon. It costs £19 on Amazon. Buy it ASAP!
- Course notes 2:
  - Steven Bird, Ewan Klein and Edward Loper (2008?) *Natural Language Processing In Python*, available online from `http://nltk.sourceforge.net/index.php/Book`. See especially Chapter 12 (computational semantics) and Chapter 2 (intro to Python for NLP). Available as HTML and PDF.

Reading for this week

- Blackburn and Bos Volume I: Introduction, pp.xi–xvi.
- Blackburn and Bos Volume I: Chapter 1, pp.1–29.
- NLTK Book Chapter 12, up to and including Section 12.4.

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More Admin

- If you're taking this course for credit, you also need to register this with the ITO.
- No tutorials for this course, but:
  - contact EK by email for an appointment: `ewan@inf.ed.ac.uk`
  - AL has office hours on **Wednesdays, 11am to 12 noon**, in office number 8, 2FL 2 Buccleuch Place.

What is this course about?

Some terminology . . .

- semantics
- pragmatics
- natural language
- processing

NLP vs. CL

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Meaning in NLP

Appeals to meaning are pervasive (but not always explicit)

- Information Retrieval
- Information Extraction
- Summarization
- Question Answering
- Spoken Dialogue Systems

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Named-Entity Recognition

NER Example

<namex type="LOCATION">NAIROBI<namex/>, <namex type="LOCATION">Kenya<namex/> (<namex type="ORGANIZATION">AP<namex/>) _ <numex type="CARDINAL">Thousands<numex/> of laborers, students and opposition politicians on <timex type="DATE">Saturday<timex/> protested tax hikes imposed by their cash-strapped government, which they accused of failing to provide basic services. Beneath a scorching sun, they sang anti-government songs and chanted "<namex type="PERSON">Moi<namex/> must go," showing their derision for President <namex type="PERSON">Daniel arap Moi<namex/>, <namex type="LOCATION">Kenya<namex/>'s ruler for <timex type="DURATION">20 years<timex/>. By voice vote, the <numex type="CARDINAL">5,000<numex/> protesters approved a resolution calling for the government to scrap new taxes, convene a convention to write a new Constitution, stop harassing students and street vendors, and halt ethnic violence.

Textual Inference

RTE Example 1

Text Never before had ski racing, a sport dominated by monosyllabic mountain men, seen the likes of Alberto Tomba, the flamboyant Bolognese flatlander who at 21 captured two gold medals at the Calgary Olympics.

Hypothesis Alberto Tomba won a race.

Textual Inference

RTE Example 2

Text Claude Chabrol (born June 24, 1930) is a French movie director and has become well-known in the 40 years since his first film, Le Beau Serge, for his chilling tales of murder, including Le Boucher.

Hypothesis Le Boucher was made by a French movie director.

Textual Inference

RTE Example 3

Text	David Golinkin is the editor or author of eighteen books, and over 150 responsa, articles, sermons and books.
Hypothesis	Golinkin has written eighteen books.

- Syllogistic logic
- Formalizing mathematical reasoning (Frege)
- Calculus for describing valid inference

Logic & Semantics of Natural Language

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Propositional Logic

$$\frac{\phi \wedge \psi}{\phi} \qquad \frac{\phi \wedge \psi}{\psi}$$

$$\frac{\neg\neg\phi}{\phi}$$

Coordination Example

$$\frac{\text{Kim is walking and Kim is chewing gum}}{\text{Kim is walking}}$$

Double Negation Example

$$\frac{\text{Kim doesn't not chew gum}}{\text{Kim chews gum}}$$

$\phi \vdash \psi$ — 'there is a proof of ψ from ϕ'

Truth Conditions and Logical Consequence

- A minimal criterion for knowing the meaning of a sentence ϕ:
  knowing whether ϕ is true or false in a state of affairs.
- Whenever ϕ is true in some state of affairs s, ψ is also true in s.
- **Logical consequence:** $\phi \models \psi$
- For NL, will mostly use First Order Logic (FOL) — discussed later.

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Background Knowledge

Usually we make inferences relative to a set Γ of background assumptions:

- $\Gamma \cup \{\phi\} \models \psi$
- Part of this consists of conceptual knowledge — or an **ontology**
- AI Frame-based systems

Taxonomic Hierarchy

terrier isa *canine* isa *mammal* ...

- Can be formalized in (fragments of) First Order Logic.

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Reasoning with bounded resources

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- Decidability
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NLP vs. CL Again

- What can semantics do for NLP?
- What can computation do for theoretical models of NL semantics?

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Automating Language Comprehension

1. Automate the process of associating NL expressions with semantic representations or *logical forms*;
2. Automate the process of interpreting those logical forms and drawing inferences from them.

Challenges

1. Unlimited number of NL expressions!
   - Handled with **Compositionality:** The logical form of each phrase is a function of the logical forms of its syntactic parts.
2. Tension between expressibility, inferential power and complexity.
   - There is no perfect solution (Tarski)! In practice, people tailor logic to the application. We will focus on FOL.

Big Challenge: Ambiguity!

A semantic scope ambiguity...

Every man loves a woman

$\forall x(man(x) \rightarrow \exists y(woman(y) \wedge loves(x, y)))$

$\exists y(woman(x) \wedge \forall x(man(x) \rightarrow loves(x, y)))$

...and its interaction with anaphora

Every student worked on a project.
It was about computational semantics.
Every politician made a speech.
??It was about Iraq.

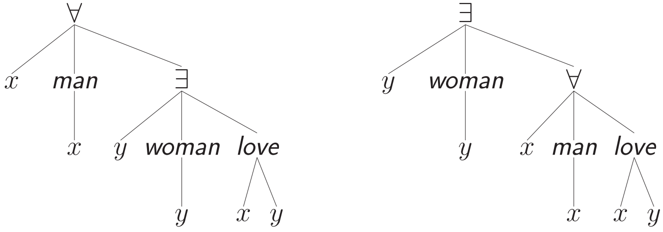
More Challenges: Combinatorics!

Constructing the LF directly from the NL's syntax means that the quantifier scope ambiguity must correspond to a syntactic ambiguity. So:

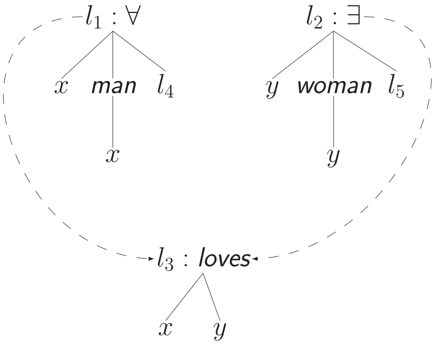
- *every man loves a woman* has two parses: unintuitive
- 6 quantifiers $\Rightarrow$ 756 parses!!
- Unsophisticated interaction with pragmatics
  - Generate all possible LFs
  - Filter out inadmissible ones

An Alternative: Underspecified Semantics

- Use syntax to accumulate a set of *constraints* on the *form* of the logical form.
  - A partial description of trees such as these...



The Underspecified Logical Form



This description is satisfied by two 'trees':

1. $l_4 = l_2$ and $l_5 = l_3$
2. $l_4 = l_3$ and $l_5 = l_1$

More Challenges: Semantic Dependencies between an NL Phrase and its Context

Pronouns

John owns a car. It is red.

wrong: $\exists x(car(x) \wedge own(j, x)) \wedge red(y)$

complex construction: $\exists x(car(x) \wedge own(j, x) \wedge red(x))$

Time

John entered the room. He lit a cigarette. It was pitch dark.

Presuppositions

John's son is bald.
If baldness is hereditary, then John's son is bald.
If John has a son, then John's son is bald.

Dynamic Semantics: E.g., DRT

- The meaning of an expression depends on its *context*.
- An expression *changes* that input context into a different output one:
  - Existentials change the context by adding new entities to it for interpreting subsequent expressions.

DRT: The Successes

Pronouns

A man walks. He talks.
Few farmers own a donkey. ?It's fed twice a day.

Tense

Max stood up. John greeted him.
Max entered the room. It was pitch dark.

Presuppositions

If baldness is hereditary, then John's son is bald.
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Problems

Need Pragmatics!

Counterexamples

John can open Bill's safe. He knows the combination.
Max fell. John pushed him.
If John scuba dives, he'll bring his son. *vs.*
If John scuba dives, he'll bring his regulator.

Need to resolve semantic underspecification to pragmatically preferred values.

The Semantics/Pragmatics Interface

- Pragmatics is the study of what people meant, but didn't explicitly say.
- Linguistic form underdetermines content;
  Pragmatics: commonsense reasoning about the *context* provides more specific content:
  - Lexical content
  - World knowledge
  - conventions of language use
  - beliefs and intentions of dialogue participants
- The process of constructing the 'intended' LF involves *defaults*.

Interaction between context and interpretation must be automated.

Conclusions

Computational semantics and pragmatics:

- automatic construction of semantic representations for NL expressions (in context)
- automatic inferences over the representations

Major Issues:

- Ambiguity of various kinds:
  - lexical, syntactic, semantic scope
- Interface between LF from linguistic form and context of use (essential for modelling *anaphora*).

Tools used include:

Information: syntax, world knowledge, lexical semantics, corpora,. . .

Inference: logic (model checkers and theorem proving), machine learning, statistics. . .