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Introduction to Artificial Intelligence
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Overview: Natural Language Processing

What is Natural Language Processing?

- The study of human languages and how they can be represented computationally and analyzed and generated algorithmically
  - *The cat is on the mat* → on (mat, cat)
  - on (mat, cat) → *The cat is on the mat*

- Studying NLP involves studying natural language, formal representations, and algorithms for their manipulation

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What is Natural Language Processing?

- Building computational models of natural language for comprehension and production

Other Names:
- Computational Linguistics (CL)
- Human Language Technology (HLT)
- Natural Language Engineering (NLE)
- Speech and Text Processing

Engineering Perspective

- Use CL as part of a larger application:
    - Spoken dialogue systems for telephone services
    - Components of web search or document retrieval services
        - Machine translation
        - Question/answering systems
        - Text Summarization
    - Interface for intelligent tutoring/training systems
- Emphasis on
    - Robustness (doesn't collapse on unexpected input)
    - Coverage (does something useful with most inputs)
    - Efficiency (speech; large document collections)

Spoken Dialog in a Language Training Application

Cognitive Science Perspective

- Goals
    - Gain an understanding of how people comprehend and produce language.
    - A model that explains actual human behaviour

Solution must:
    explain psycholinguistic data
    be verified by experimentation

Theoretical Linguistics Perspective

- In principle, coincides with the Cognitive Science Perspective
  – CL can potentially help test the empirical adequacy of theoretical models.
- Linguistics is typically a descriptive enterprise
  – Building computational models of the theories allows them to be empirically tested.
  – E.g., does your grammar correctly parse all the grammatical examples in a given test suite, while rejecting all the ungrammatical examples?

Language as Goal-Oriented Behaviour

- We speak for a reason, e.g.,
  – get hearer to believe something
  – get hearer to perform some action
  – impress hearer

Examples

(1) It's hot in here, isn't it?

(2) Can you book me a flight to London tomorrow morning?

(3) P: What time does the train for Washington, DC leave?
     C: 6:00 from Track 17.

Typical Focus

- Language Production
  - Must determine how to use linguistic strategies to achieve desired effects
- Language Understanding
  - Must use linguistic knowledge to recognise speaker's underlying purpose

Knowledge needed
to produce and understand language

- **Phonetics and phonology:** how words are related to sounds that realize them
- **Morphology:** how words are constructed from more basic meaning units
- **Syntax:** how words can be put together to form correct utterances
- **Lexical semantics:** what words mean
- **Compositional semantics:** how word meanings combine to form larger meanings
- **Pragmatics:** how situation affects interpretation of utterance
- **Discourse structure:** how preceding utterances affects processing of next utterance

Knowledge needed:
Phonetics and Phonology

- Speech sounds, their production, and the rule systems that govern their use

  - Sýn vs. Sín (him vs. hymn) (when heard)
  - Da**g**ur, Dö**gg**
  - Vi**ll**a (mannsnafn), Vi**ll**a (eitthvað rangt)
  - Á **bílastæðinu** við húsið – Á bílastæðinu við **húsið**
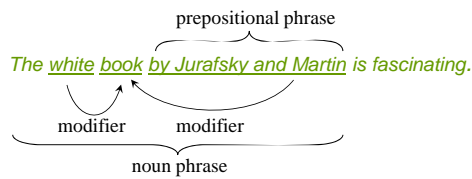 - Maturinn kominn! – Maturinn kominn?

Knowledge needed:
Morphology

- How words are constructed from more basic units, called morphemes

friend + *ly* = *friendly*

noun

Suffix *-ly* turns noun into an adjective (and verb into an adverb)
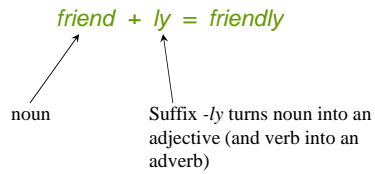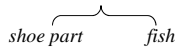

Knowledge needed:
Syntax

- How words can be put together to form legal sentences in the language
- What structural role each word plays in the sentence
- What phrases are subparts of other phrases

prepositional phrase

The white book by Jurafsky and Martin is fascinating.

modifier   modifier

noun phrase

Knowledge needed:
Semantics

- What words mean (Lexical Semantics)
- How word meanings combine in sentences to form sentence meanings (Compositional Semantics)
- The sole died

shoe part   *fish*

Syntax and semantics work together!
   (1) What does it taste like?
   (2) What taste does it like?

Semantics: Meaning independent of a larger context!

Knowledge needed:
Pragmatic Knowledge

- The meaning of words and phrases **in context**
  - George got married and had a baby.
  - George got bread and butter.

- Meaning often indicated by intonation/prosody:
  - German teachers
  - Bill doesn't drink because he's unhappy.
  - John only introduced Mary to Sue.
  - John called Bill a Republican and then he insulted him

Knowledge needed:
Pragmatic Knowledge

- What utterances mean in different *contexts*

  Jon was hot and desperate for a dunk in the river.

  Jon suddenly realised he didn't have any cash.

  He rushed to the <u>bank</u>.

  financial institution   river bank

Knowledge needed:
Discourse Structure

- Much meaning comes from simple conventions that we generally follow in discourse
- For example how we **refer** to entities

  - **Indefinite** *NPs* used to introduce new items into the discourse
    A woman walked into the cafe.
  - **Definite** *NPs* can be used to refer to subsequent references
    The woman sat by the window.
  - **Pronouns** used to refer to items already known in discourse
    She ordered a cappuccino.

Discourse Relations

- Relationships we infer between discourse entities
- Not expressed in either of the propositions, but from their juxtaposition

(a) Ég er glorsoltinn
(b) Förum á Sólon

(E.g. (b) is a "solution" in Rhetorical Structure Theory)

Discourse and Temporal Interpretation

Max fell.   John pushed him.

explanation

Syntax and semantics: "him" refers to Max

Lexical semantics and discourse: the pushing occurred before the falling.

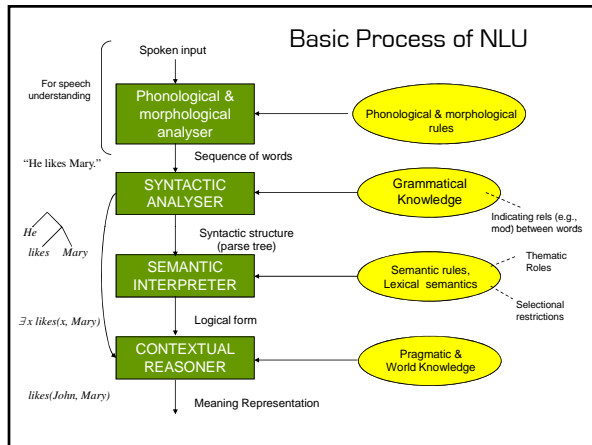
Discourse and World Knowledge

- What we know about the world and what we can assume our hearer knows about the world is intimately tied to our ability to use language

I took the cake from the plate and ate it.

Ambiguity

I made her duck.

- The categories of knowledge of language can be thought of as ambiguity-resolving components
- How many different interpretations does the above sentence have?
- How can each ambiguous piece be resolved?
- Does speech input make the sentence even more ambiguous?

Basic Process of NLU

Spoken input

For speech understanding

Phonological & morphological analyser ← Phonological & morphological rules

Sequence of words

"He likes Mary."

He likes Mary

SYNTACTIC ANALYSER ← Grammatical Knowledge — Indicating rels (e.g., mod) between words

Syntactic structure (parse tree)

SEMANTIC INTERPRETER ← Semantic rules, Lexical semantics — Thematic Roles / Selectional restrictions

Logical form

$\exists x\ likes(x, Mary)$

CONTEXTUAL REASONER ← Pragmatic & World Knowledge

likes(John, Mary)

Meaning Representation

It's not that simple

- Syntax affects meaning
   1. (a)   Flying planes is dangerous.
      (b)   Flying planes are dangerous.

- Meaning and world knowledge affects syntax
   2. * (a) Flying insects is dangerous.
      (b) Flying insects are dangerous.

   3. (a) I saw the Grand Canyon flying to LA.
      (b) I saw a condor flying to LA.

Dialog System

Words (Input) → Parsing → Syntactic Structure and Logical Form

Lexicon and Grammar

Words (Output) ← Realisation

Syntactic Structure and Logical Form

Contextual Interpretation → Final Meaning

Discourse Context

Utterance Planning

Meaning of Response

Application Context

Application Reasoning