Computational Linguistics

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What is this course about?

Natural language processing: A subfield of computer science, and in particular artificial intelligence, that is concerned with computational processing of natural languages, emulating cognitive capabilities without being committed to a true simulation of cognitive processes, in order to provide such novel products as computers that can understand everyday human speech, translate between different human languages, and otherwise interact linguistically with people in ways that suit people rather than computers.

What is this course about?

Computational linguistics: An approach to linguistics that employs methods and techniques of computer science. A formal, rigorous, computationally based investigation of questions that are traditionally addressed by linguistics: What do people know when they know a natural language? What do they do when they use this knowledge? How do they acquire this knowledge in the first place?

Natural language processing applications

- Machine translation
- Natural language interfaces to computer systems
- Speech recognition
- Text to speech generation
- Automatic summarization
- E-mail filtering
- Intelligent search engines

Example of an application: machine translation

The spirit is willing but the flesh is weak

The vodka is excellent but the meat is lousy

Example of an application: machine translation

From http://babelfish.altavista.com/,
using technology developed by SYSTRAN

Example of an application: machine translation

Language is one of the fundamental aspects of human behavior and is a crucial component of our lives. In written form it serves as a long-term record of knowledge from one generation to the next. In spoken form it serves as our primary means of coordinating our day-to-day behavior with others. This book describes research about how language comprehension and production work.

Example of an application: machine translation

Il linguaggio è una delle funzioni fondamentali di comportamento umano ed è un componente cruciale delle nostre vite. Nella forma scritta serve da record di lunga durata di conoscenza da una generazione al seguente. Nella forma parlata serve da nostri mezzi primari di coordinazione del nostro comportamento giornaliero con altri. Questo libro descrive la ricerca circa come la comprensione di una lingua e la produzione funzionano.

Example of an application: machine translation

The language is one of the fundamental functions of human behavior and is a crucial member of our screw. In the written shape servants from record of long duration of acquaintance from one generation to following. In the shape speech she serves from our primary means of coordination of our every day behavior with others. This book describes the search approximately as the understanding of a language and the production work.

Comparison

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Comparison

This book describes research about how language comprehension and production work

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Example of an application: question answering

From http://www.ask.com/ and http://www.ajkids.com/
who was the second president of the United States?
who was the US president following Washington?

Why are the results so poor?

- Language understanding is complicated
- The necessary knowledge is enormous
- Most stages of the process involve *ambiguity*
- Many of the algorithms are computationally intractable

What kind of knowledge is required?

- Phonetic and phonological knowledge
- Morphological knowledge
- Syntactic knowledge
- Semantic knowledge
- Pragmatic knowledge
- Discourse knowledge
- World knowledge

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Phonetics and phonology

Phonetics studies the sounds produced by the vocal tract and used in language, including the physical properties of speech sounds, their perception and their production

Phonology studies the module of the linguistic capability that relates to sound, abstracting away from their physical properties. Defines an inventory of basic units (*phonemes*), constraints on their combination and rules of pronunciation

Problems in phonological processing

Homophones (homonyms): words that are pronounced alike but are different in meaning or derivation or spelling:
weak — week
to — too — two
הקלה — ה+קלה — ה+כלה

Free variation: alternation of sounds with no change in meaning: the different pronunciations of the guttural sounds in Hebrew

Problems in phonological processing

Allophones: variants of phonemes that are in complementary distribution: little

Phonotactic constraints: restrictions on the distribution (occurrence) of phonemes with respect to one another: הצטלם — התעלם

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Morphology

Morphology studies the structure of words.

Morpheme: a minimal sound-meaning unit. Can either be *bound* (not a word) or *free* (word).
Free morphemes: book, ספר
Bound morphemes: books, ספרים

Affix: a morpheme which is added to other morphemes, especially roots or stems.

- **suffixes** follow the root/stem
- **prefixes** precedes the root/stem
- **infixes** are inserted into the root/stem

Morphology

Derivational morphology: words are constructed from roots (or stems) and derivational affixes:
inter+national → international
international+ize → internationalize
internationalize+ation → internationalization
שלם → שלמות

Inflectional morphology: inflected forms are constructed from base forms and inflectional affixes: ספר+ים → ספרים

Problems in morphological processing

Ambiguity: The various analyses of the word שבתה:

שבתה: [+verb][+base]הבש[+root]הבש[+binyan]+Pa'al[+person/gender/numb
שבתה: [+verb][+base]תבש[+root]תבש[+binyan]+Pa'al[+person/gender/numb

שבת+ה: [+noun][+base]תבש[+gender]+fem[+number]+sing[+possessiveSuffix

בתה+ש: [+subord]ש[+noun][+base]התב[+gender]+fem[+number]+sing
תה+ב+ש: [+subord]ש[+preposition]ב[+noun][+base]הת[+gender]+masc[+numb

(ה)+תה+ב+ש: [+subord]ש[+preposition]ב[+def][+noun][+base]הת[+gender]

בת+ה+ש: [+subord]ש[+noun][+base]תב[+gender]+fem[+number]+sing[+possess

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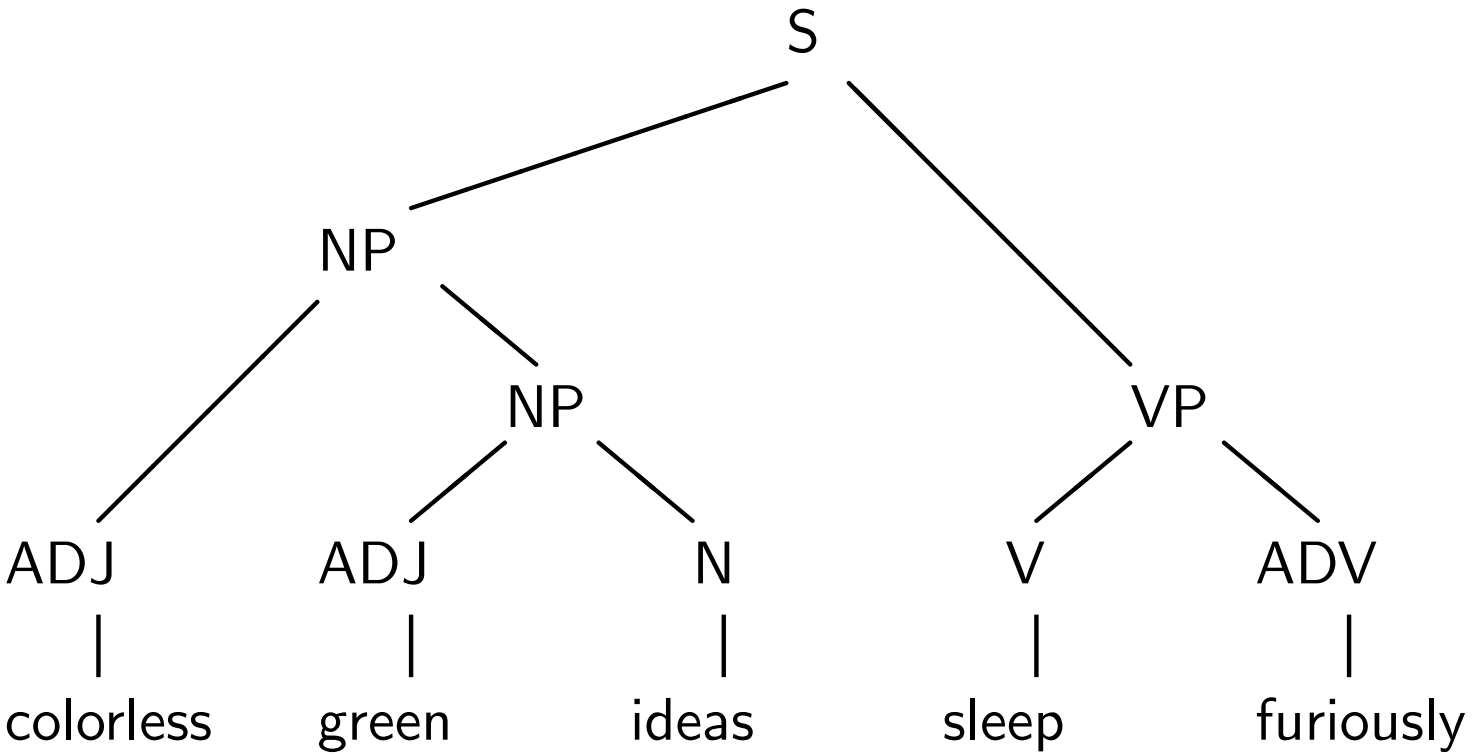
Syntax

Natural language sentences have *structure*.

Young green frogs sleep quietly
Colorless green ideas sleep furiously
Furiously sleep ideas green colorless

Syntax


S
NP
NP
VP
ADJ
ADJ
N
V
ADV
colorless
green
ideas
sleep
furiously

Problems of syntactic processing

Expressiveness: what formalism is required for describing natural languages?

Parsing: assigning structure to grammatical strings, rejecting ungrammatical ones.

- top–down vs. bottom–up
- right to left vs. left to right
- chart based vs. backtracking

Problems of syntactic processing

Ambiguity:

I saw the spy with the brown hat
I saw the bird with the telescope
I saw the spy with the telescope

Control:

Kim asked Sandy to call the plumber
Kim promised Sandy to call the plumber

Coordination:

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Semantics

Semantics assigns *meanings* to natural language utterances.
A semantic representation must be precise and unambiguous.
A good semantics is *compositional*: the meaning of a phrase is obtained from the meanings of its subphrases.

Problems of semantic processing

Word sense ambiguity: book; round; about; פגישה

Scope ambiguity:

every student hates at least two courses

every student doesn't like math

Problems of semantic processing

Co-reference and anaphora:

Kim went home after she robbed the bank
After she robbed the bank, Kim went home
In the next few paragraphs, some preliminary constraints are suggested and problems with them are discussed.
Language is one of the fundamental aspects of human behavior. In written form it serves as a long-term record of knowledge.

VP anaphora: Kim loves his wife and so does Sandy.

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Pragmatics

Pragmatics is the study of how more gets communicated than is said.

Pragmatics

Presupposition: the presuppositions of a sentence determine the class of contexts in which the sentence can be felicitously uttered:

The current king of France is bald
Kim regrets that he voted for Gore
Sandy's sister is a ballet dancer

Pragmatics

Implicature: what is conveyed by an utterance that was not explicitly uttered:

– How old are you? – Closer to 30 than to 20.

I have two children.

Could you pass the salt?

Pragmatics

Speech acts: the illocutionary force, the communicative force of utterances, resulting from the function associated with them:

I'll see you later

- prediction: I predict that I'll see you later
- promise: I promise that I'll see you later
- warning: I warn you that I'll see you later

I sentence you to six months in prison
I swear that I didn't do it
I'm really sorry!

Non-literal use of language: metaphor, irony etc.

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Discourse

A discourse is a sequence of sentences. Discourse has structure much like sentences do. Understanding discourse structure is extremely important for dialog systems.
An example dialog:

> *When does the train to Haifa leave?*
> *There is one at 2:00 and one at 2:30.*
> *Give me two tickets for the earlier one, please.*

Problems of discourse processing

Non-sentential utterances: *aha; to Haifa; the last one*

Cross-sentential anaphora

Reference to non-NPs:

Kim visited the University of Haifa.
It changed her life.
She does it every year.
It really surprised Sandy.
It was summer then.

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World knowledge

– Is the train to Haifa late? – It left Tel Aviv at 8:30.
Bill Clinton left for Vietnam today. This is the last foreign visit of the American president.

Processing Hebrew

- The script
- Writing direction
- Deficiencies of the Hebrew writing system
- Richness of the morphology
- Root-and-pattern word formation
- Lack of linguistic resources

Infrastructure for processing language

- Lexicons
- Dictionaries
- Morphological analyzers and generators
- Part-of-speech taggers
- Shallow parsers
- Syntactic analyzers
- Computational grammars

Hebrew processing: the state of the art

- Lexicons
- Dictionaries
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- Part-of-speech taggers
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- Computational grammars

Conclusions

- Natural languages are complex
- Applications which require deep linguistic knowledge still do not perform well
- Applications which can rely on shallow knowledge or on statistical approaches perform better
- Hebrew poses additional problems for language processing
- To build Hebrew language applications, essential linguistic resources must be developed

Structure of the course

Morphology

- introduction to morphology: word structure
- inflections and derivations
- finite-state automata
- finite-state transducers

Structure of the course

Syntax

- introduction to syntax: the structure of natural languages
- context-free grammars: grammars, forms, derivations, trees, languages
- parsing: top–down, CYK algorithm, Earley algorithm, bottom–up chart parsing
- the complexity of natural languages
- the limitations of CFGs
- unification grammars: feature structures and unification

Structure of the course

Other topics

- As time permits

Practicalities

Textbook: Nothing mandatory or even recommended. Some of the material can be found in Daniel Jurafsky and James H. Martin, *Speech and Language Processing*, Prentice-Hall, 2000.

Grading: 4–6 home assignments (approximately 33% of the final grade); mid-term exam (33%); final exam (33%)

Attendance: Optional but highly recommended.