Natural Language Processing (NLP)

- NLP is the application of a computational theory of human language
- Language is the predominant repository of human interaction and knowledge
- Goal of NLP: programs that “listen in”
- The AI Challenge: the Turing test
- Lots of speech and text data available
NLP: Lots of Applications

- Doc classification
- Doc clustering
- Spam detection
- Information extraction
- Summarization
- Machine translation
- Cross Language IR
- Multiple language summarization
- Language generation
- Plagiarism or author detection
- Error correction, language restoration
- Language teaching
- Question answering
- Knowledge acquisition (dictionaries, thesaurus, semantic lexicons)
- Speech recognition
- Text to Speech
- Speaker Identification
- (multi-modal) Dialog systems
- Deciphering ancient scripts

Natural Language: What is it?

- Answers from linguistics
  Natural Language (NL) vs. Artificial Language
- NL is complex, displays recursive structure
- Learning of language is an inherent part of NL
- Language has idiosyncratic rules and a complex mapping to thought
Language has structure

• Finnish word structure
  – talossansakaanko ‘not in his house either?’
  – kynässänsäkäänkö ‘not in his pen either?’

• English phrase structure
  – It is likely that John went home.
  – That John went home is likely.
  – OK: Where is it likely that John went t?
  – Not OK: *Where is that John went t likely?

Language is recursive

• Combine the following two sentences:
  – The clown watches the ballerina
    NP₁ V₁ NP₂
  – The musician hits the clown
    NP₃ V₂ NP₄

• Many possible combinations of the two sentences:
  – The clown watches the ballerina and the musician hits the clown

• Use a modifier to combine them:
  – The clown who the musician hits watches the ballerina
    NP₁/₄ NP₃ V₂ V₁ NP₂
  – The musician hits the clown who watches the ballerina
    NP₃ V₂ NP₄/₁ V₁ NP₂
Language is recursive

- Finite resources but possibly infinite utterances (via recursion)
- **Sparse** language:
  - A sparse language is a set of strings where the number of strings of length $n$ is bounded by a polynomial function of $n$
  - Regular and context-free languages are **dense** as shown by Chomsky, Flajolet, Incitti

Language is Parsed

- Google's Computer Might Betters Translation Tool
  - New York Times March 8, 2010
- Number of Lothian patients made ill by drinking rockets
  - Edinburgh Evening News, March 4, 2010
- Violinist linked to JAL crash blossoms
  - [http://languagelog.ldc.upenn.edu/nll/?p=1693](http://languagelog.ldc.upenn.edu/nll/?p=1693)
Language is ambiguous

- Lung cancer in women mushrooms
  - Mushrooms is noun or a verb?
- Teacher Strikes Idle Kids
  - Strikes is a verb or a noun?
- Two sisters reunited after 18 years in checkout counter
  - Is it reunited in checkout counter or 18 years in checkout counter?
- Ban on nude dancing on governor's desk
  - Another case of “if-then-else” ambiguity
- British Left Waffles on Falkland Islands
  - Is it British/Noun Left/Verb or British Left/NP Waffles/Verb?

Ambiguity (cont’d)

- Kids make nutritious snacks
  - make can mean different things, which is it?
- Iraqi Head Seeks Arms
  - Arms can mean different things, which is it?
- Two Soviet Ships Collide, One Dies
  - What does one refer to in this case?
- Chef throws his heart into feeding needy
  - Throws his heart is not decomposed normally in this case: idiom finding
Ambiguity (cont’d)

• Island Monks Fly in Satellite to Watch Pope Funeral
  (“Monks in Space” languagelog.com/archives/002045.html)
  – “fly in” vs. “fly [OBJ in Satellite]” hidden segmentation
  – the verb desert, not the noun desert
• McDonald's fries the holy grail for potato farmers
  – http://languagelog.ldc.upenn.edu/nll/?p=1762

Ambiguity (cont’d)

• We saw her duck (Zwicky & Sadock)
  – “saw [NP her duck]” vs. “saw [S her duck]” duck: Noun/Verb, her: ambiguous pronoun
• Leahy wants FBI to help corrupt Iraqi police force (CNN, Dec 13, 2006)
  – the adjective corrupt, not the verb corrupt
• Last Alder Hey hospital child remains buried
• Red tape holds up new bridges
Ambiguity (cont’d)

- Massive fish kill blankets Arkansas River
  – CNN 3 January 2011
- Suspect In Mumbai Attacks A Thorn In U.S.-India Ties
  – NPR 15 November 2010
- Baby Steps to New Life-Forms
  – New York Times 27 May 2010

Ambiguity (cont’d)

- Ambiguity can occur locally or globally
- Here’s an example of local ambiguity:
  – First black woman elected to Congress
  – First black woman elected to Congress dies
- dies causes a reanalysis of the structure of the sentence
  – before dies we analyze elected as the main verb
  – after we see dies we analyze elected as a sub-clause modifying the word elected
• **Phonetics** acoustic and perceptual elements

• **Phonology** inventory of basic sounds (phonemes) and basic rules for combination
  – e.g. vowel harmony. **Anupu** is pronunciation of **Anoop** in Classic Period Mayan

• **Morphology** how morphemes combine to form words, relationship of phonemes to meaning
  – e.g. **delight-ed** vs. **de-light-ed**

• **Syntax** sentence (utterance) formation, word order and the formation of constituents from word groupings
  – e.g. The clown who the musician hits watches the ballerina

• **Semantics** how do word meanings recursively compose to form sentence meanings (from syntax to logical formulas)
  – e.g. Everyone is not here => what does this mean? Nobody / Not everyone is here.

• **Pragmatics** meaning that is not part of compositional meaning,
  – e.g. This professor dresses even worse than Anoop!

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**Terminology: Grammar**

• Grammar can be prescriptive or descriptive

• *Descriptive grammar* is a **model** of the form and meaning of a speaker of a language

• Grammar books for learning a language are *prescriptive grammars*, usually style manuals or rules for how to write clearly

• Except for some NLP apps like grammar checking or teaching, we are usually interested in creating models of language
General Approach

“Generative” Model

Algorithm

Application to Natural Language

Phonology / Morphology / Syntax / Semantics / Pragmatics

Formal Languages and NLP

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<th>NLP</th>
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<td>Language (possibly infinite)</td>
<td>Text Data, Corpus (finite)</td>
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<td>Grammar</td>
<td>Grammar (usually inferred from data, produces infinite set)</td>
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Some definitions

- **Classification**: assigning to the input one out of a finite number of classes, e.g.: Document -> spam, formalization -> Noun

- **Sequence learning/Tagging**: assigning a sequence of classes, e.g.: I/ Pron can/Modal open/Verb a/Det can/Noun

- **Parsing**: assigning a complex structure, e.g.: formalization -> (Noun (Verb (Adj formal) -ize) -ation)

- **Grammar development**: human driven creation of a model for some linguistic data

- **Transduction**: transforming one linguistic form to another, e.g. summarization, translation, tokenization

- **Tracking/Co-reference**: after detecting an entity (say a person) tracking that entity in subsequent text; co-reference of a pronoun to its antecedent; “lexical chains” of similar concept

- **Clustering**: unsupervised grouping of data using similarity, constructing “phylogenetic” trees