CS4442/9542b
Artificial Intelligence II
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Lecture 8

Natural Language Processing

Introduction

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Outline

- Introduction to Natural Language Processing (NLP)
  - What is NLP
  - Applications of NLP
  - Why NLP is hard
  - Brief history of NLP
- Linguistic Essentials

Natural Language Processing

- Computers would be more useful if they could handle our email, do our library research, talk to us, etc …
- But computers are fazed by natural human language
  - or at least their programmers are, most avoid the language problem by using mice, menus, drop boxes
- How can we tell computers about language?
  - or help them learn it as kids do?
- Can machines understand human language?
  - define ‘understand’
  - understanding is the ultimate goal
  - however, one doesn’t need to fully understand to be useful
- NLP is also known as Computational Linguistics (CL), Human Language Technology (HLT), Natural Language Engineering (NLE)

Application: Question Answering

- IBM's Watson Won Jeopardy on February 16, 2011!

WILLIAM WILKINSON'S
"AN ACCOUNT OF THE PRINCIPALITIES OF
WALLACHIA AND MOLDOVIA"
INSPIRED THIS AUTHOR'S
MOST FAMOUS NOVEL

→ Bram Stoker (Dracula)

Application: Information Extraction

Subject: **curriculum meeting**

Date: January 15, 2012

To: Dan Jurafsky

Hi Dan, we've now scheduled the curriculum meeting.

It will be in Gates 159 tomorrow from 10:00-11:30.

-Chris

Event: Curriculum mt
Date: Jan-16-2012
Start: 10:00am
End: 11:30am
Where: Gates 159

Application: Information Extraction & Sentiment Analysis

Attributes:

- zoom
- affordability
- size and weight
- flash
- ease of use

Size and weight

- ✓ nice and compact to carry!
- ✓ since the camera is small and light, I won't need to carry around those heavy, bulky professional cameras either!
- ✗ the camera feels flimsy, is plastic and very light in weight you have to be very delicate in the handling of this camera

Application: Machine Translation

- Fully automatic

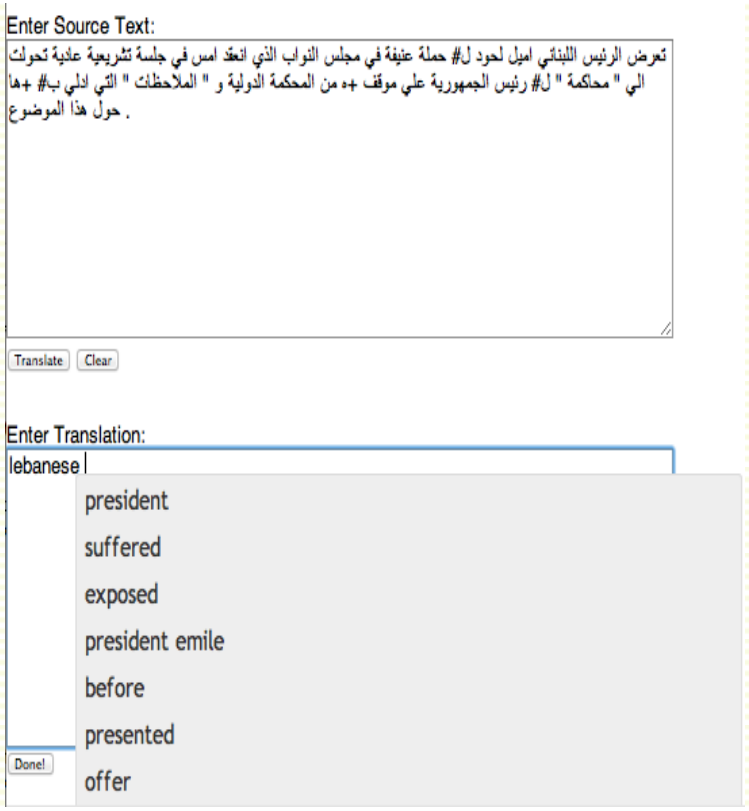
Enter Source Text:

这 不过 是 一 个 时间 的 问题 .

Translation from Stanford's *Phrasal*:

This is only a matter of time.

- Helping human translators



Where is Language Technology

- Goals can be very far reaching
  - True text understanding and interpretation
  - Real-time participation in spoken dialogs
  - High quality machine translation
- Or very application oriented
  - Finding the price of products on the web
  - Analyzing reading level or authorship statistically
  - Sentiment detection about products or stocks
  - Extracting names, facts or relations from documents
- These days, the latter predominate
  - As NLP becomes increasingly possible, it becomes increasingly engineering-oriented

Where is Language Technology

mostly solved

Spam detection

Let's go to Agra! ✓

Buy V1AGRA … ✗

Part-of-speech (POS) tagging

ADJ	ADJ	NOUN	VERB	ADV
Colorless	green	ideas	sleep	furiously.

Named entity recognition (NER)

PERSON	ORG	LOC
Einstein met with UN officials in Princeton		

making good progress

Sentiment analysis

Best roast chicken in San Francisco!

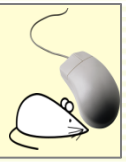
The waiter ignored us for 20 minutes.

Coreference resolution

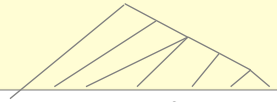
Carter told Mubarak he shouldn't run again.

Word sense disambiguation (WSD)

I need new batteries for my ***mouse***.



Parsing



I can see Alcatraz from the window!

Machine translation (MT)

第13届上海国际电影节开幕...

The 13th Shanghai International Film Festival...

Information extraction (IE)

You're invited to our dinner party, Friday May 27 at 8:30

Party
May 27
add

still really hard

Question answering (QA)

Q. How effective is ibuprofen in reducing fever in patients with acute febrile illness?

Paraphrase

XYZ acquired ABC yesterday

ABC has been taken over by XYZ

Summarization

The Dow Jones is up

The S&P500 jumped

Housing prices rose

Economy is good

Dialog

Where is Citizen Kane playing in SF?

Castro Theatre at 7:30. Do you want a ticket?

Brief NLP History

- 1950's, empirical approach:
  - data-driven, co-occurrences in language are important sources of information: " You shall know a word by the company it keeps", J. Firth, 1957
  - First speech systems (Davis et al. Bell labs)
  - Text authorship (Hamilton vs. Madison), solved based on patterns of word occurrences in 1941 by F. Mosteller and F. Williams
  - Machine translation: toy system, basically word-substitution, on machines less powerful than pocket calculators
  - Little understanding of natural language syntax and semantics
  - Problem soon appeared intractable: can't store enough data on computers

Brief NLP History

- 1960's and 1970's
  - Data-driven approach falls out of favor
  - Language is to be analyzed at deeper level than surface statistics
  - N. Chomsky:
    1. "Colorless green ideas sleep furiously"
    2. "Furiously sleep ideas green colorless"
    - Neither (1) nor (2) will never occur. Yet (1) is grammatical, while (2) is not. Therefore (1) should have higher probability of occurrence than (2)
    - However, since neither (1) nor (2) will ever occur, they will both be assigned the same probability of 0
    - The criticism is that the data driven approach will always lack suffer from the lack of data, and therefore doomed to failure
  - Knowledge-based (rule based) approach becomes dominant, human expert encodes relevant information
    - Development of linguistic
    - Complex language models, parsing, CF grammars
    - Applications in toy domains

Brief NLP History

- Drawbacks of knowledge-based (rule-based) approach:
  - Rules are often too strict to characterize people's use of language (people tend to stretch and bend rules in order to meet their communicative needs.)
  - Need expert people to develop rules (knowledge acquisition bottleneck)
- 1980's: the empirical revolution
  - In part motivated by success in speech recognition
    - Based on learning from lots of data
  - Corpus-based (data-driven) methods become central
  - Sophisticated machine learning algorithms are developed to learn from the data
  - Linguistics (the rules) is still used
  - Deep analysis often traded for robust and simple approximations

Why is NLP difficult?

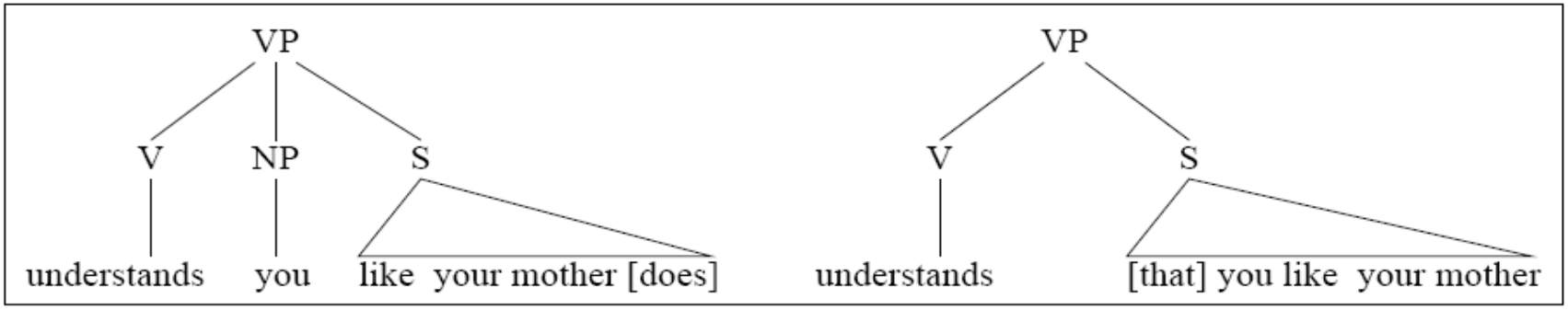
- Key problem: language is **ambiguous** at all levels
  - Semantic (word meaning)
  - Syntactic (sentence structure)
  - Acoustic (parsing of speech signal)
- To resolve these ambiguities we often need to use complex knowledge about the world
- Other difficulties
  - Language only reflects the surface of meaning
    - humor, sarcasm, “between the lines” meaning
  - Language presupposes communication between people
    - Persuading, insulting, amusing them
  - Lots of subtleties

Syntactic (Sentence Structure) Ambiguity

"At last, a computer that understands you like your mother"

- 1985 advertisement from a company claimed to program computer to understand human language

- At least three different interpretations:
  1. **The computer understands you as well as your mother understands you**
  2. **The computer understands that you like your mother**
  3. **The computer understands you as well as it understands your mother**
- Humans would rule out the last two interpretation from their knowledge of the world: we know advertisement is trying to convince us of something



different sentence structure leads to different interpretations

Semantic (Word Meaning) Ambiguity

"At last, a computer that understands you like your mother"

- Word "mother" has several meanings:
  - "a female parent"
  - "a cask or vat used in vinegar-making"

Acoustic Ambiguity

"At last, a computer that understands you like your mother"

- For speech recognition:
  - *"a computer that understands you like your mother"*
  - *a computer that understands your lie cured mother*

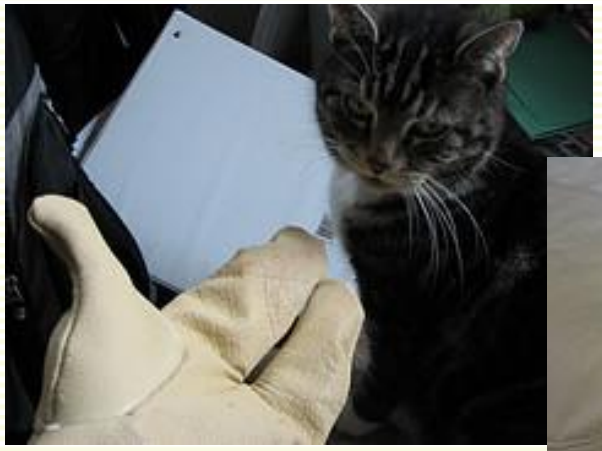
More Ambiguity

"At last, a computer that understands you like your mother"

- Even if we interpret this as "The computer understands you as well as your mother understands you" does that mean it understands you "well" or "not so well"
  - sarcasm

Another Example Syntactic Ambiguity

- How about simpler sentences?
- Even simple sentences are highly ambiguous
- "*Get the cat with the gloves*"



Headline Ambiguity

- Iraqi Head Seeks Arms
- Ban on Nude Dancing on Governor's Desk
- Juvenile Court to Try Shooting Defendant
- Teacher Strikes Idle Kids
- Kids Make Nutritious Snacks
- British Left Waffles on Falkland Islands
- Red Tape Holds Up New Bridges
- Bush Wins on Budget, but More Lies Ahead
- Hospitals are Sued by 7 Foot Doctors
- Stolen Painting Found by Tree
- Local HS Dropouts Cut in Half

Why else NLP Difficult?

- Non-standard English (language in the “wild”)
  - Great job @justinbieber! Were SOO PROUD of what youve accomplished! U taught us 2 #neversaynever & you yourself should never give up either♥
- Segmentation issues
  - break-up
  - The New York-New Haven railroad
  - The New York-New Haven railroad
- Idoims
  - dark horse, get cold feet, lose face, throw in the towel
- Neologisms
  - Unfriend, retweet, bromance
- Tricky entity names
  - where A Bug’s Life playing
  - when Let It Be was recorded

Tools and Resources Needed

- Probability/Statistical Theory:
  - Statistical Distributions, Bayesian Decision Theory.
- Linguistics Knowledge:
  - Morphology, Syntax, Semantics, Pragmatics…
- Corpora:
  - Bodies of marked or unmarked text
    - The more, the better
  - to train classifiers
  - to apply statistical methods