Natural Language Processing (NLP): Overview & Tools

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Dept. of Linguistics, Indiana University

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Natural Language Processing

Natural Language Processing (NLP): "The goal of this . . . field is to get computers to perform useful tasks involving human language" (Jurafsky & Martin 2009, p. 1)

Applications include:

- conversational agents / dialogue systems
- machine translation
- question answering
- ...

We will focus on natural language understanding (NLU): obtaining linguistic information (meaning) from input (text)

What do we need NLP for?

- One hand: we intend to do NLP, i.e., automatically analyze natural language for the purposes of providing meaning (of a sort) from a text
- Other hand: use NLP tools to pre-process data, i.e., provide sentence-level grammatical information:
  - Segment sentences
  - Tokenize words
  - Part-of-speech tag words
  - Syntactically (and semantically?) parse sentences
  - Provide semantic word senses
  - Provide named entities
  - Provide language models

This kind of (pre-)processing is the focus for today

Why (not) (just) surface features?

Surface features can be very useful

- Function words: small, closed set that recur a lot
- Ease of use: data-driven patterns emerge without writing out patterns by hand
- Hypothesis: people differ in specific word choices

Surface features can be limited:

- Data sparsity: surface features may not be seen again, especially with small training data
- Morphological complexity: word similarity can be "hidden"
- Hypothesis: people differ in deeper linguistic properties

Where we're going

We are going to focus on:

- what the general tasks are & what the uses are
- what kinds of information they generally rely on
- what tools are available

We'll look at POS tagging, parsing, word sense assignment, named entity recognition, & semantic role labeling

- We'll focus on English, but try to note general applicability

Many taggers/parsers have *pre-built* models; others can be *trained* on annotated data

- For now, we'll focus on pre-built models

Wikis with useful technology information

Places you can get your own information:

- Our very own IU CL wiki, which includes some people's experiences with various tools
  - http://cl.indiana.edu/wiki
  - Always feel free to add your own experiences to help the next person who wants to use that tool
- ACL wiki & resources
  - http://www.aclweb.org/aclwiki/index.php?title=Main_Page
  - http://www.aclweb.org/aclwiki/index.php?title=ACL_Data_and_Code_Repository
  - http://www.aclweb.org/aclwiki/index.php?title=List_of_resources_by_language
  - ACL software registry: http://registry.dfki.de/

General NLP packages

- Stanford NLP: http://nlp.stanford.edu/software/ (see esp. the CoreNLP package)
- EmoryNLP (NLP4J): http://nlp.mathcs.emory.edu
- ClearNLP: http://www.clearnlp.com
- FreeLing: http://nlp.lsi.upc.edu/freeling/
- LingPipe: http://alias-i.com/lingpipe/
- OpenNLP: http://opennlp.apache.org/index.html
- Natural Language Toolkit (NLTK): http://www.nltk.org/
- Illinois tools: http://cogcomp.cs.illinois.edu/page/software
- DKPro: https://www.ukp.tu-darmstadt.de/research/current-projects/dkpro/
  - Includes text classification tool built on top of weka

Topic #1: Language modeling

Language models store lots of text in *n*-gram form, using it to assign probabilities to new sequences of text

- Tend to be fast & surprisingly accurate

Some packages:

- KenLM Language Model Toolkit: https://kheafield.com/code/kenlm/
- MIT Language Modeling Toolkit: https://code.google.com/p/mitlm/
- SRI Language Modeling Toolkit: http://www.speech.sri.com/projects/srilm/
- CMU-Cambridge Statistical Language Modeling Toolkit v2: http://www.speech.cs.cmu.edu/SLM/toolkit.html

Why *n*-grams?

The packages themselves may or may not help us, but the idea of surface *n*-grams likely will

- Core idea: sequences of words approximate syntactic & some semantic constraints
  - e.g., Who uses *of the* more? (*of*: nominals, *the*: concrete objects/ideas)
  - e.g., *my life* vs. *your life*
- *n*-grams also are at the core of other technologies: POS tagging, distributional semantics, etc.

Topic #2: POS Tagging

Idea: assign a part-of-speech to every word in a text

- (Supervised) Taggers work by:
  - looking up a set of appropriate tags for a word in a dictionary
  - using local context to disambiguate from among the set
- Sequence modeling (HMMs, CRFs) are thus popular

Some examples illustrating the utility of local context:

- `for the man`: noun or verb?
- `we will man`: noun or verb?
- `I can put`: verb base form or past?
- `re-cap real quick`: adjective or adverb?

Bigram or trigram tagging is quite popular

- Take L545/L645 if you want to know more

Motivation for POS tags

What are POS tags good for in our intended downstream applications?

- First step towards knowing the meaning, e.g., for word senses (e.g., *leaves*)
- Help identify function words & content words (e.g., for stylometry)
- POS sequences (*n*-grams) may be indicative of style
  - POS *n*-grams approximate syntax

Note that POS tags are generally very fast to obtain & are generally accurate (for English, on well-formed data)

Challenges for POS tagging

General challenges:

- Ambiguity
  - e.g., *still* as noun, verb, adverb, adjective, ...
- Unknown words
  - Programs use things like suffix tries to guess at the possible POS tags for unknown words

These challenges are exacerbated in the following areas:

- Morphologically-rich languages
- Data which is not well-edited (e.g., web data)

POS taggers

- TnT: http://www.coli.uni-saarland.de/~thorsten/tnt/
  - Trainable; models for German & English
- TreeTagger: http://www.ims.uni-stuttgart.de/projekte/corplex/TreeTagger/
  - Trainable; models for English, German, Italian, Dutch, Spanish, Bulgarian, Russian, & French; unix, mac, PC
- Qtag: http://www.english.bham.ac.uk/staff/omason/software/qtag.html
  - Trainable; models for German & English
- LingPipe: http://alias-i.com/lingpipe/index.html
  - Has a variety of NLP modules
- OpenNLP: http://opennlp.sourceforge.net/
  - Models for English, German, Spanish, & Thai; Has a variety of NLP modules

POS taggers (2)

- ACOPOST: http://acopost.sourceforge.net/
  - Trainable; integrates different technologies
- Stanford tagger: http://nlp.stanford.edu/software/tagger.shtml
  - Trainable; models for English, Arabic, Chinese, & German
- CRFTagger: http://crftagger.sourceforge.net/
  - English
- Can also use SVMTool (http://www.lsi.upc.edu/~nlp/SVMTool/) or CRF++ (http://crfpp.sourceforge.net/) for tagging sequential data, or fnTBL for classification tasks (http://www.cs.jhu.edu/~rflorian/fntbl/index.html)

Specialized POS taggers

Twitter tagger:

- CMU Ark: http://www.ark.cs.cmu.edu/TweetNLP/
- GATE: https://gate.ac.uk/wiki/twitter-postagger.html (also available to plug into Stanford tagger)

Biomedical tagger:

- GENIA tagger: http://www.nactem.ac.uk/tsujii/GENIA/tagger/
- cTAKES (clinical Text Analysis and Knowledge Extraction System): https://ctakes.apache.org/index.html

Topic #3: Parsing

Parsers attempt to build a tree, based on some grammar

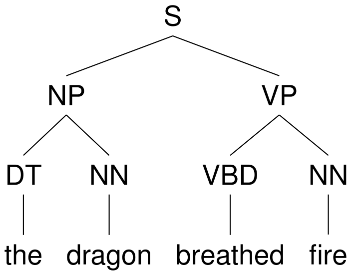
- Efficiency based on many things, including the manner in which the tree is built
- They often disambiguate by using probabilities of rules

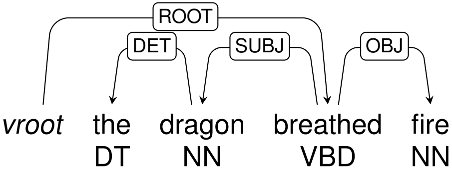
Again, take L545/L645 for more details

Constituencies & Dependencies

Rough idea of the difference:

Constituency:





Dependency:

Constituency parsing

Goal is to obtain phrases

- Structured prediction: dealing with embedded / recursive structures
- Parsing can be slow, but tends to be fairly accurate
  - POS tags obtained while parsing more accurate than with a standalone POS tagger

Usefulness for downstream applications:

- Identifying sequences, e.g., named entities
- Identifying complexity, e.g., depth of embedding
- Identifying particular types of constructions, e.g., relative clauses

Challenges in parsing

In addition to things like lexical ambiguity & unknown words, additional challenges include:

- Structural ambiguity: e.g., *They saw the man in the park with a telescope*
- Garden paths: e.g., *The horse raced past the barn fell*

Again, out-of-domain data poses a challenge

- Note that for morphologically-rich languages, parsing is underdeveloped & some of the work is in the morphology

Dependency parsing

Dependency parsing is the task of assigning dependency (grammatical) relations to a sentence

- Provides quick access to semantic relations (“who did what to whom”)
- Can be done on top of constituency parsing or on its own
  - Formally, dependency parsing is simpler: assign a single head & relation for every word (single-head constraint)

Useful applications:

- Pretty close to the same set as with constituencies ...

Constituency Parsers

- LoPar: http://www.ims.uni-stuttgart.de/tcl/SOFTWARE/LoPar.html
  - Trainable; models for English & German
- BitPar: http://www.ims.uni-stuttgart.de/tcl/SOFTWARE/BitPar.html
  - Trainable; models for English & German
- Charniak & Johnson parser: http://www.cs.brown.edu/people/ec/#software
  - Trainable; mainly used for English

Constituency Parsers (2)

- Collins/Bikel parser:
  http://people.csail.mit.edu/mcollins/code.html
  http://www.cis.upenn.edu/~dbikel/software.html
  - Trainable on English, Chinese, and Arabic; designed for Penn Treebank-style annotation
- Stanford parser:
  http://nlp.stanford.edu/downloads/lex-parser.shtml
  - Trainable; models for English, German, Chinese, & Arabic; dependencies also available
- Berkeley parser:
  http://code.google.com/p/berkeleyparser/
  - Trainable; models for English, German, and Chinese

Dependency parsers

Recent parsers, which generally include other NLP tools:

- Mate Parser: https://code.google.com/p/mate-tools/
- TurboParser: http://www.ark.cs.cmu.edu/TurboParser/
- ZPar: http://sourceforge.net/projects/zpar/
- Stanford Neural Network Parser: http://nlp.stanford.edu/software/nndep.shtml

Classic dependency parsers:

- MaltParser: http://w3.msi.vxu.se/~nivre/research/MaltParser.html
  - Trainable; models for Swedish, English, & Chinese
- MSTParser: http://sourceforge.net/projects/mstparser
  - Trainable; has some models for English & Portuguese
- Link Grammar parser: http://www.abisource.com/projects/link-grammar/
  - English only

CCG parsers: http://groups.inf.ed.ac.uk/ccg/software.html

- Primarily for English, although can be trained on German CCGbank

Topic #4: Semantics

Semantics is the study of meaning in language

We'll break it down into:

- Lexical semantics: word meaning
  - Semantic spaces: word meaning derived from data
- Compositional semantics: sentence meaning

and look at technology for all of them

Semantic class assignment

Word sense disambiguation

Word sense disambiguation (WSD): for a given word, determine its semantic class

- `bank.01`: They robbed a bank and took the cash.
- `bank.02`: They swam awhile and then rested on the bank.

Lexical resources define the senses, e.g.

- WordNet: http://wordnet.princeton.edu
- BabelNet: http://babelnet.org
- SentiWordNet: http://sentiwordnet.isti.cnr.it

WSD software

- GWSD: Unsupervised Graph-based Word Sense Disambiguation http://web.eecs.umich.edu/~mihalcea/downloads.html
- SenseLearner: All-Words Word Sense Disambiguation Tool: http://web.eecs.umich.edu/~mihalcea/downloads.html
- KYOTO UKB graph-based WSD: http://ixa2.si.ehu.es/ukb/
- pyWSD: Python Implementation of Simple WSD algorithms: https://github.com/alvations/pywsd
- Various packages from Ted Pedersen, including Senseval systems: http://www.d.umn.edu/~tpederse/code.html

Semantic class assignment

Named entity recognition

Named entity recognition (NER): classify elements (words, phrases) into pre-defined entity classes

- Common categories include: PER(son), ORG(anization), LOC(ation), etc.
- May have hierarchical categories

Techniques often rely on phrase chunking & may involve using a gazetteer (external list of entities)

- From the list of general NLP tools above, Stanford, UIUC, & OpenNLP have NER modules

LIWC

A popular tool to use is LIWC (Linguistic Inquiry and Word Count)

- http://liwc.wpengine.com

Words are grouped into "psychologically-relevant categories" based on hand-crafted dictionaries

- It does not (admittedly) handle ambiguity
- it is proprietary

Statistical semantics

Distributional representations

Part of the motivation with using semantic classes is to group together relatively infrequent words

- i.e., get a handle on data sparsity

A long-standing hypothesis: the **distributional hypothesis**

- "[L]inguistic items with similar distributions have similar meanings"
  - https://en.wikipedia.org/wiki/Distributional_semantics
- These patterns can be learned in large, general (unannotated) corpora and applied to our problems
  - Roughly: the meaning of a word corresponds to its position in a vector space
- One package in Python is `gensim`
  - http://radimrehurek.com/gensim/

Consider also, e.g., Brown clustering (https://github.com/percyliang/brown-cluster)

Statistical semantics

Distributed representations

More recently, distributed representations of words, using neural networks, have been extremely popular

- key phrases: deep learning, word embeddings, recurrent neural networks
- A word is represented by a variety of dimensions, each one capturing potentially useful properties
  - http://aclweb.org/anthology/P/P10/P10-1040.pdf

Some resources:

- A general guide to distributed representations: http://www.cs.toronto.edu/~bonner/courses/2014s/csc321/lectures/lec5.pdf
- A practical guide to word vectors: https://www.kaggle.com/c/word2vec-nlp-tutorial/details/part-2-word-vectors
- The `word2vec` page: https://code.google.com/archive/p/word2vec/

Statistical semantics

Options to think about with word embeddings:

- Architecture
- Training algorithm
- Downsampling of frequent words
- Word vector dimensionality
- Context / window size
- Worker threads
- Minimum word count

See Kaggle page for tips ...

Semantic role labeling

Idea: The words of a sentence combine to form a meaning

- Hypothesis: the syntax and semantics can be built up in a corresponding fashion

Semantic role labeling is the task of assigning semantic roles to arguments in a sentence

e.g., for *John loves Mary*:

- *(to) love* is the predicate
- *John* is the agent (ARG0)
- *Mary* is the patient (ARG1)

Semantic role labelers

- Clear: http://www.clearnlp.com
- SENNA: http://ml.nec-labs.com/senna/
- UIUC: http://cogcomp.cs.illinois.edu/page/software_view/SRL
- SEMAFOR: https://code.google.com/p/semafor-semantic-parser/
- SwiRL: http://www.surdeanu.info/mihai/swirl/
- Shalmaneser: http://www.coli.uni-saarland.de/projects/salsa/shal/
- MATE: https://code.google.com/p/mate-tools/
- Turbo: http://www.ark.cs.cmu.edu/TurboParser/