Computational Morphology and Syntax of Natural Languages

Daniel Zeman
http://ufal.mff.cuni.cz/course/npfl094
zeman@ufal.mff.cuni.cz
NPFL094

- Presentations and talks will be in English
  - Unless all students understand Czech
- Questions welcome in both Czech and English
- And I have many examples from Czech 😊
Caution

- No class on
  November 2
  December 21
Getting Credits

• 2-3 smaller tasks
  – homework style
  – less flexible deadlines

• Alternatively: one larger project
  – ask me if interested
  – can be combined with your mgr. (or bc.) thesis
An “Unbalanced” Course

• 1/3 linguistics, 2/3 tools
• 1/3 lab work, 2/3 lectures
• ¾ morphology, ¼ syntax
• Mostly rule-based
  – almost no machine learning
  – no neural networks
Outline: Morphology

• Morphemic segmentation
  – un + beat + able

• Phonology ("morphonology") and orthography
  – baby + s = babies

• Inflectional vs. derivational morphology

• Morphological analysis: word form → lemma + morphosyntactic features (tag)

• Tagging (context-aware disambiguation)

• Unsupervised affix detection in corpus

• Mining of word forms from corpus
Morphological Analysis

• **Input:**
  – word form (token)

• **Output:**
  – set (possibly empty) of analyses
  – an analysis:
    • lemma (base form of the lexeme)
    • tag (morphological, POS)
      – part of speech
      – features and their values
MA Example

• Language: Czech
• Input: malými
• Output (only one selected analysis here):
  – lemma = malý (“small”)
  – tag = AAFP71A
    • part of speech = AA (adjective / přídavné jméno)
    • gender = F (feminine / ženský)
    • number = P (plural / množné)
    • case = 7 (instrumental / 7. pár)
    • degree of comparison = 1 (positive / 1. stupeň) …
MA Example

- Language: English
- Input: *flies*
- Output:
  - lemma 1 = *fly-1* (to move in the air)
  - tag 1 = VBZ (verb, present tense 3rd person singular)
  - lemma 2 = *fly-2* (an insect)
  - tag 2 = NNS (noun, plural)
- Output is not disambiguated with respect to context
MA versus Tagging

• By *tagging* we usually mean context-based disambiguation

• Most taggers employ statistical methods

• Taggers may or may not work on top of MA
  – MA may provide readings not known from training
  – If a tagged corpus is available but MA is not, a tagger can still be trained on the corpus
Morphemic Segmentation

• **Morpheme** is the smallest unit of language that conveys some meaning

• Morphemic segmentation = finding morpheme boundaries within words

• Typically part of MA:
  – input: *closed*
  – identify the morphemes: *close + d*
  – interpret them: *verb (close) + past tense*
  – output: *close + VBD*
Morphemic Segmentation

• Sometimes it is useful to know the morphemes even if we cannot interpret them
  – Data sparseness, e.g. in machine translation:
    • en: city
    • cs alignments in parallel corpus: město (nom/acc/voc sg, 42×), města (gen sg, nom/acc/voc pl, 40×), městě (loc sg, 32×), měst (gen pl, 9×), městské (adj, 7×), městem (ins sg, 7×), městských (adj, 4×), městská (adj, 4×), městský (adj, 2×), městu (dat sg, 2×), městech (loc pl, 2×)
    • missing cs: městům (dat pl), městy (ins pl), městského, městskému, městském, městským, městští, městskými, městskou (adj remaining forms)
Morphemic Segmentation

- Sometimes it is useful to know the morphemes even if we cannot interpret them
  - Data sparseness, e.g. in machine translation

- **Stemming** = stripping all morphemes but the *stem*
  - IN: *The British players were unbeatable.*
  - OUT: *the Brit play were beat.*

- **Lemmatization** = replacing all words with their lemmas (as with tagging, disambiguation may be assumed)
  - OUT: *the British player be (un)beatable.*
Inflection vs. Derivation

• **Derivational morphology:**
  – New lemma!
  – Often (but not always) new part of speech.

• **Inflectional morphology:**
  – Set of forms of one lemma (lexeme)
  – The set is called *paradigm*

• The borderline is sometimes quite fuzzy
Outline: Syntax

- Constituency vs. dependency
- Context-free grammars
- Transition network grammars
- Shallow parsing (chunking)
- Chart parsers
- Dependency parsers (Malt, MST)
- Clause boundaries
A record date has n't been set.
The governor couldn't make it, so the lieutenant governor welcomed the special guests.
Applications of Morphology

• First step before broader NLP applications:
  – Input for (syntactic) parsing
  – Machine translation
    • Rule-based MT: full-fledged analysis and generation
    • Statistical MT: fighting data sparseness
  – Finding word boundaries (Chinese, Japanese)
  – Dictionaries
Applications of Morphology

• Text-to-speech systems (speech synthesis)
  – Morphology affects pronunciation
    • English *th* is normally pronounced θ or δ
    • However, not in *boathouse* (*boat + house*)
    • Czech *proudít* =
      – *proud* + *it* (“stream” + INF = “flow”)
      – *pro* + *ud’* + *it* (“through” + “smoke” + INF = “smoke thoroughly”)

• Speech recognition
  – Morphology allows for smaller dictionaries
Applications of Morphology

• Word processing
  – Spell checking dictionaries
  – Inputting Japanese text
    • Two kana syllabic scripts and kanji (Chinese characters)
    • Typically, people type in kana and system converts to kanji whenever necessary
    • Disambiguation needed!
    • Bound morphemes remain in kana (morpho rules)
Applications of Morphology

• Word processing: find & replace terms
  – Czech: kniha (book) ⇒ dílo (work)
    • knihy ⇒ díla, knize ⇒ dílu, knihu ⇒ dílo, kniho ⇒ dílo, knihou ⇒ dílem, knih ⇒ děl, knihám ⇒ dílům, knihách ⇒ dílech, knihami ⇒ díly

• Document retrieval
  – Keywords in query are typically base forms
  – The forms in documents are inflected
Morphology-Based Typology

• Isolating languages
  – Chinese: ㄍㄡ ㄅㄨ̀ ㄉㄧ ㄔㄢ ㄑㄧㄥㄘㄞ
    = dog not like eat vegetable

• Inflectional languages
  – Romance and Slavic languages: Spanish \textit{pued}+\textit{es} = \textit{poder} +
    present indicative, 2\textsuperscript{nd} person, singular

• Agglutinative languages
  – Turkish: \textit{çöplüklerimizdekilerdenmiyd}i = \textit{çöp} + \textit{lük} + \textit{ler} + \textit{imiz} +
    \textit{de} + \textit{ki} + \textit{ler} + \textit{den} + \textit{mi} + \textit{y} + \textit{di} = “was it from those that were in
    our garbage cans?”

• Polysynthetic languages
  – Eskimo languages
Polysynthetic Languages

- Found in Siberia and the Americas
- Intricately compose words of many lexical morphemes that are not easily told apart
  - Typically include both subject- and object-verb agreement.
- That’s why linguists decided not to separate them orthographically
- Nevertheless, words usually are separated. They are just long
- One long word may cover a whole sentence in other languages
- Chukchi example (Skorik 1962: 102):
  - T-ə-meyy-ə-levt-pəyt-ə-rkən.
  - 1.SG.SUBJ-great-head-hurt-PRES.1
  - “I have a fierce headache.”
Morphological Devices (Overview)

- Affixes (prefixes and suffixes): concatenative morphology
- Compounding
- Infixation
- Circumfixation
- Root and pattern (templatic) morphology
- Reduplication
- Subsegmental morphology
- Zero morphology
- Subtractive morphology
Affixation

- Most common way of inflection and derivation
- Three morpheme types:
  prefix + radix (stem) + suffix
  - en: *dog + s = dogs*
    - plural suffix –*s*
  - de: *mach + st = machst*
    - suffix –*st* marks present indicative 2\textsuperscript{nd} person singular
  - en: *un + beat + able*
    - prefix *un*- negates the meaning
    - suffix –*able* converts verb to adjective, expressing applicability of the action of the verb to something
Infixation

• Languages of the Philippines, e.g. Bontoc:
  – fikas “strong” ⇒ f-um+ikas “be strong”
  – kilad “red” ⇒ k-um+ilad “be red”

• Could be analyzed as prefix to (stem minus the initial consonant)
Circumfixation

• Prefix + suffix act together as one morpheme
  – German: *legen* “lay down” ⇒ *ge+leg+t* “laid down”
  – Indonesian: *besar* “big” ⇒ *kə+besar+an* “bigness”

• Similar, but not the same as Czech superlatives
  – *nej* + *mlad* + ř + í “youngest”
  – superlative + stem + comparative + singular nominative
Templatic Morphology

• Semitic languages (Arabic, Hebrew, Amharic)
• Arabic:
  – root (usually 3 consonants): *ktb* “write”
  – vowel pattern: *aa* = active, *ui* = passive
  – template: CVCVC = first verb derivational class (binyan)
  – result: *katab* “write”, *kutib* “be written”
Reduplication

- Copy whole stem or part of it
  - Indonesian plural:
    - *orang* “man” ⇒ *orang+orang* “men”
  - Javanese habitual-repetitive:
    - *adus* ⇒ *odas+adus* “take a bath”
    - *bali* ⇒ *bola+bali* “return”
  - Yidin (an Australian language):
    - *gindalba* ⇒ *gindal+gindalba* “lizard”
- Reduplication cannot be modeled by finite-state automata!
Subsegmental Morphology

- Irish:
  - *cat* (/kat/) = “cat” (singular)
  - *cait* (/kat/) = “cats” (plural)

- The plural morpheme consists just of one phonological feature (“high”), resulting in palatalization.
Zero Morphology

- Zero (empty) morpheme, marked sometimes as 0, Ø, λ or ε
  - Czech feminine plural case endings for žena “woman”:
    - nom: žen+y = ženy
    - gen: žen+λ = žen
    - dat: žen+ám = ženám
    - acc: žen+y = ženy
    - voc: žen+y = ženy
    - loc: žen+ách = ženách
    - ins: žen+ami = ženami
Subtractive Morphology

- Koasati (a Muskogean language, southeast US):
  - singular verb: *pita*f↓i+n
  - plural: *pit+li+n
  - singular verb: *lasap+li+n
  - plural: *las+li+n

- Such examples are rare
- Moreover, one might argue that plural is the base form here
Compounding

• English: maximally two stems written together
• Germanic languages in general favor compounds
• de: *Hotentotenpotentatentantenatentäter*
  – *Hotentot + en + Potentat + en + Tante + n + Atentäter*
  – “Hottentot potentate aunt assassin”
  – “assassin of aunt of potentate of Hottentots”
Recommended Further Reading

- These books may be difficult to obtain from the MFF library. Reading them is not required.
  - James Allen: *Natural Language Understanding*. Benjamin/Cummings, USA, 1995