Tagging, Tagsets, and Morphology

The task of (Morphological) Tagging

- Formally: $A^+ \rightarrow T$
  - A is the alphabet of phonemes (A^+ denotes any non-empty sequence of phonemes)
    - often: phonemes ~ letters
  - T is the set of tags (the "tagset")
- Recall: 6 levels of language description:
  - phonetics ... phonology ... morphology ... syntax ... meaning ...

    - a step aside: tagging
- Recall: $A^+ \rightarrow 2^{(L,C_1,C_2,\ldots,C_n)} \rightarrow T$

  morphology tagging: ***disambiguation*** (~ "select")

Tagging Examples

- Word form: $A^+ \rightarrow 2^{(L,C_1,C_2,...,C_n)} \rightarrow T$
  - He always <u>books</u> the violin concert tickets early.
    - MA: books → {(book-1,Noun,Pl,-,-),(book-2,Verb,Sg,Pres,3)}
    - tagging (disambiguation): ... → (Verb,Sg,Pres,3)
  - ...was pretty good. <u>However</u>, she did not realize...
    - MA: However → {(however-1,Conj/coord,-,-,-),(however-2,Adv,-,-,-)}
    - tagging: ... → (Conj/coord,-,-,-)
  - [æ n d] [g i v] [i t] <u>[t u:]</u> [j u:] ("and give it to you")
    - MA: [t u:] → {(to-1,Prep),(two,Num),(to-2,Part/inf),(too,Adv)}
    - tagging: ... → (Prep)

Tagsets

- General definition:
  - tag ~ $(c_1,c_2,...,c_n)$
  - often thought of as a flat list

    $T = \{t_i\}_{i=1..n}$

    with some assumed 1:1 mapping

    $T \leftrightarrow (C_1,C_2,...,C_n)$
- English tagsets (see MS):
  - Penn treebank (45) (VBZ: Verb,Pres,3,sg, JJR: Adj. Comp.)
  - Brown Corpus (87), Claws c5 (62), London-Lund (197)

Other Language Tagsets

- Differences:
  - size (10..10k)
  - categories covered (POS, Number, Case, Negation,...)
  - level of detail
  - presentation (short names vs. structured ("positional"))
- Example:

  POSSN VAR
  GENDER
  POS PERSON
  CASE
  NEG

  - Czech: `AGFS3----1A----`

  VOICE
  POSSG
  DCOMP
  SUBPOS
  TENSE
  NUMBER

Tagging Inside Morphology

- Do tagging first, then morphology:
- Formally: $A^+ \rightarrow T \rightarrow (L,C_1,C_2,\ldots,C_n)$
- Rationale:
  - have $|T| < |(L,C_1,C_2,\ldots,C_n)|$ (thus, less work for the tagger) and keep the mapping $A^+ \mathrm{x} T \rightarrow (L,C_1,C_2,\ldots,C_n)$ unique.
- <u>Possible for some languages only</u> ("English-like")
- Same effect within "regular" $A^+ \rightarrow 2^{(L,C1,C2,\ldots,Cn)} \rightarrow T$:
  - mapping $R : (C_1,C_2,\ldots,C_n) \rightarrow T_{reduced}$,

    then (new) unique mapping U: $A^+ \times T_{reduced} \rightarrow (L,T)$

Lemmatization

- Full morphological analysis:

  MA: $A^+ \rightarrow 2^{(L,C1,C2,\ldots,Cn)}$

  (recall: a lemma $l \in L$ is a lexical unit (~ dictionary entry ref)
- Lemmatization: reduced MA:
  - L: $A^+ \rightarrow 2^L$: $w \rightarrow \{l; (l,t_1,t_2,\ldots,t_n) \in MA(w)\}$
  - again, need to disambiguate (want: $A^+ \rightarrow L$)

    (special case of word sense disambiguation, WSD)
  - "classic" tagging does not deal with lemmatization

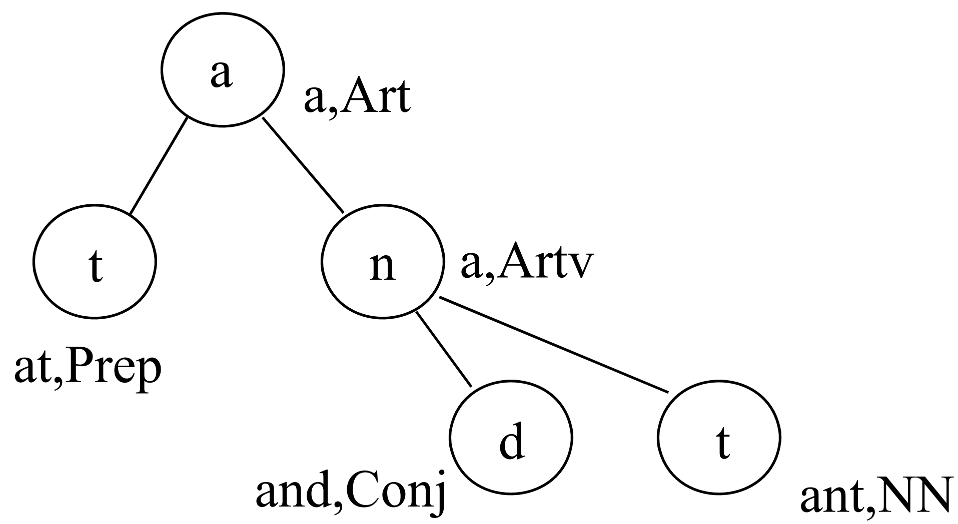
    (assumes lemmatization done afterwards somehow)

Morphological Analysis: Methods

- Word form list
  - books: book-2/VBZ, book-1/NNS
- Direct coding
  - endings: verbreg:s/VBZ, nounreg:s/NNS, adje:er/JJR, ...
  - (main) dictionary: book/verbreg, book/nounreg,nic/adje:nice
- Finite state machinery (FSM)
  - many “lexicons”, with continuation links: reg-root-lex → reg-end-lex
  - phonology included but (often) clearly separated
- CFG, DATR, Unification, ...
  - address linguistic rather than computational phenomena
  - in fact, better suited for morphological synthesis (generation)

Word Lists

- Works for English
  - "input" problem: repetitive hand coding
- Implementation issues:
  - search trees
  - hash tables (Perl!)
  - (letter) trie:
- Minimization?



Word-internal[1] Segmentation (Direct)

- Strip prefixes: (un-, dis-, ...)
- Repeat for all plausible endings:
  - Split rest: root + ending (for every possible ending)
  - Find root in a dictionary, keep dictionary information
    - in particular, keep inflection class (such as reg, noun-irreg-e, ...)
  - Find ending, check inflection+prefix class match
  - If match found:
    - Output root-related info (typically, the lemma(s))
    - Output ending-related information (typically, the tag(s)).

[1]Word segmentation is a different problem (Japanese, speech in general)

Finite State Machinery

- Two-level Morphology
  - phonology + "morphotactics" (= morphology)
- Both components use finite-state automata:
  - phonology: "two-level rules", converted to FSA
    - e:0 $\Leftrightarrow$ _ +:0 e:e r:r
  - morphology: linked lexicons
    - root-dic: book/"book" $\Rightarrow$ end-noun-reg-dic
    - end-noun-reg-dic: +s/"NNS"
- Integration of the two possible (and simple)

Finite State Transducer

- FST is a FSA where
  - symbols are pairs (r:s) from a finite alphabets R and S.
- "Checking" run:
  - input data: sequence of pairs, output: Yes/No (accept/do not)
  - use as a FSA
- Analysis run:
  - input data: sequence of only s $\in$ S (TLM: surface);
  - output: seq. of r $\in$ R (TLM: lexical), + lexicon "glosses"
- Synthesis (generation) run:
  - same as analysis except roles are switched: S $\leftrightarrow$ R, no gloss

FST Example

- German umlaut (greatly simplified!):

  u ↔ ü if (but <u>not</u> only if) c h e r follows (Buch → Bücher)

  rule: u:ü ⇐ _ c:c h:h e:e r:r

  FST:

  Buch/Buch:

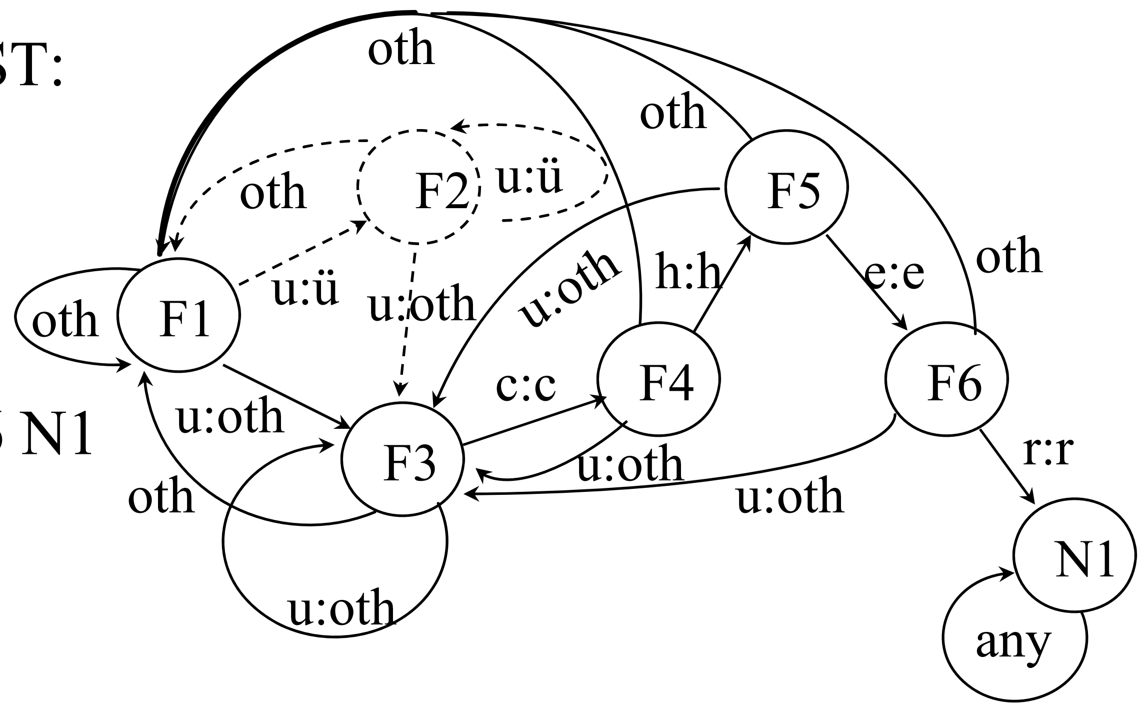
  F1 F3 F4 F5

  Bucher/Bucher:

  F1 F3 F4 F5 F6 N1

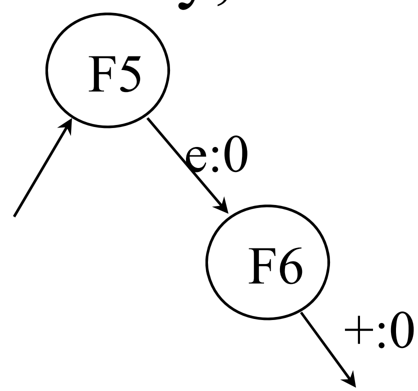
  Buch/Buck:

  F1 F3 F4 F1



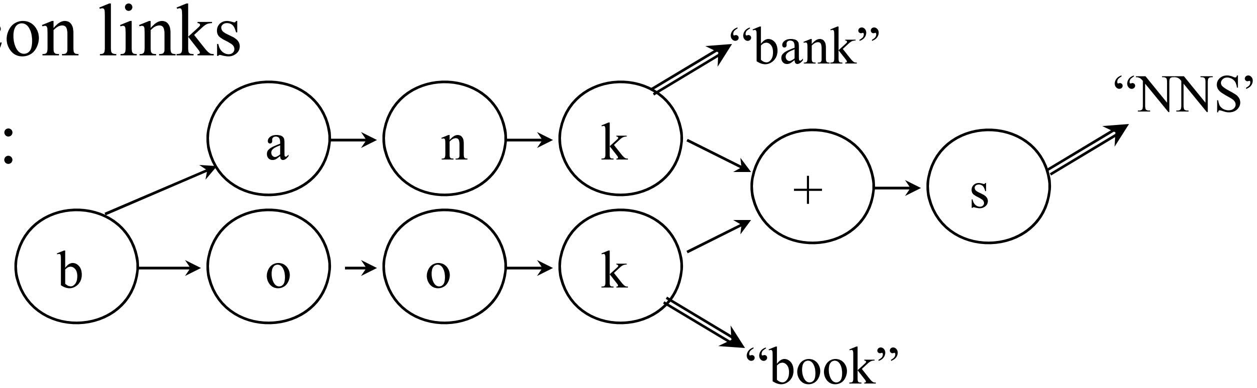
Parallel Rules, Zero Symbols

- Parallel Rules:
  - Each rule ~ one FST
  - Run in parallel
  - Any of them fails ⇒ path fails
- Zero symbols (one side only, even though 0:0 o.k.)
  - behave like any other



The Lexicon

- Ordinary FSA (“lexical” alphabet only)
- Used for analysis only (NB: disadvantage of TLM):
  - additional constraint:
    - lexical string must pass the linked lexicon list
- Implemented as a FSA; compiled from lists of strings and lexicon links
- Example:



TLM: Analysis

1. Initialize set of paths to P = {}.
2. Read input symbols, one at a time.
3. At each symbol, generate all lexical symbols possibly corresponding to the 0 symbol (voilà!).
4. Prolong all paths in P by all such possible (x:0) pairs.
5. Check each new path extension against the phonological FST and lexical FSA (lexical symbols only); delete impossible paths prefixes.
6. Repeat 4-5 until max. # of consecutive 0 reached.

TLM: Analysis (Cont.)

7. Generate all possible lexical symbols (get from all FSTs) for the current input symbol, form pairs.
8. Extend all paths from P using all such pairs.
9. Check all paths from P (next step in FST/FSA). Delete all outright impossible paths.
10. Repeat from 3 until end of input.
11. Collect lexical “glosses” from all surviving paths.

TLM Analysis Example

- Bücher:
  - suppose each surface letter corresponds to the same symbol at the lexical level, just ü might be ü as well as u lexically; plus zeroes (+:0), (0:0)
- Use the FST as before.
- Use lexicons:

root: Buch “book” ⇒ end-reg-uml

Bündni “union” ⇒ end-reg-s

end-reg-uml: +0 “NNomSg”

+er “NNomPl”

B:B $\xRightarrow{u}$ Bu:Bü ⇒ Buc:Büc ⇒ Buch:Büch ⇒ Buch+e:Büch0e ⇒ Buch+er:Büch0er

$\xRightarrow[ü]{}$ ~~Bü:Bü ⇒ Büc:Büc~~

TLM: Generation

- Do not use the lexicon (well you have to put the "right" lexical strings together somehow!)
- Start with a lexical string L.
- Generate all possible pairs l:s for every symbol in L.
- Find all (hopefully only 1!) traversals through the FST which end in a final state.
- From all such traversals, print out the sequence of surface letters.

TLM: Some Remarks

- Parallel FST (incl. final lexicon FSA)
  - can be compiled into a (gigantic) FST
  - maybe not so gigantic (XLT - Xerox Language Tools)
- “Double-leveling” the lexicon:
  - allows for generation from lemma, tag
  - needs: rules with strings of unequal length
- Rule Compiler
  - Karttunen, Kay
- PC-KIMMO: free version from www.sil.org (Unix,too)

References

- Manning-Schuetze:
  - Section 16.2
- Jelinek:
  - Chapter 13 (includes application to LM)
  - Chapter 14 (other applications)
- Berger & DellaPietras in CL, 1996, 1997
  - Improved Iterative Scaling (does not need $\Sigma_{i=1..N} f_i(y,x) = C$)
  - "Fast" Feature Selection!
- Hildebrand, F.B.: Methods of Applied Math., 1952