Morphology parsing

Informatics 2A: Lecture 7

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(This lecture is taken directly from Jurafsky & Martin chapter 3.)

Morphological parsing: the problem

In many languages, words can be made up of a main stem (carrying the basic dictionary meaning) plus one or more affixes carrying grammatical information. E.g. in English:

Surface form:	cats	walking	smoothest
Lexical form:	cat+N+PL	walk+V+PresPart	smooth+Adj+Sup

Morphological parsing is the problem of extracting the lexical form from the surface form.

Should take account of:

- Irregular forms (e.g. goose $\rightarrow$ geese)
- Systematic rules (e.g. 'e' inserted before suffix 's' after s,x,z,ch,sh: fox $\rightarrow$ foxes, watch $\rightarrow$ watches)

Why bother?

- NLP tasks involving meaning extraction will often involve morphology parsing.
- But even a humble task like spell checking can benefit: e.g. is ‘walking’ a possible word form?

Why not just list all derived forms separately in our wordlist (e.g. walk, walks, walked, walking)?

- Might be OK for English, but not for a morphologically rich language — e.g. in Turkish, can pile up to 10 suffixes on a verb stem, leading to 40,000 possible forms for some verbs.
- Even for English, morphological parsing makes adding new words easier (e.g. ‘frape’).
- Morphology parsing is just more interesting than brute listing!

Parsing and generation

Parsing here means going from the surface to the lexical form. E.g. foxes $\rightarrow$ fox +N +PL.

Generation is the opposite process: fox +N +PL $\rightarrow$ foxes. It's helpful to consider these two processes together.

Either way, it's often useful to proceed via an intermediate form, corresponding to an analysis in terms of morphemes (= minimal meaningful units) before orthographic rules are applied.

Surface form:	foxes
Intermediate form:	fox ^ s #
Lexical form:	fox +N +PL

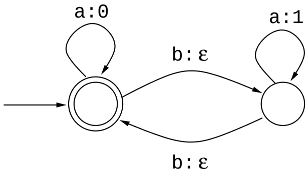
(^ means morpheme boundary, # means word boundary.)

N.B. The translation between surface and intermediate form is exactly the same if 'foxes' is a 3rd person singular verb!

Finite-state transducers

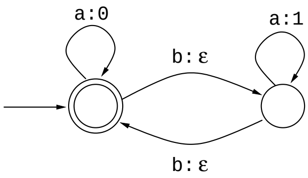
We can consider ϵ-NFAs (over an alphabet Σ) in which transitions may also (optionally) produce *output* symbols (over a possibly different alphabet Π).

E.g. consider the following machine with input alphabet $\{a, b\}$ and output alphabet $\{0, 1\}$:



Such a thing is called a finite state transducer.
In effect, it specifies a (possibly multi-valued) translation from one regular language to another.

Clicker exercise



What output will this produce, given the input *aabaaabbab*?

1. 001110
2. 001111
3. 0011101
4. More than one output is possible.

Formal definition

Formally, a finite state transducer T with inputs from Σ and outputs from Π consists of:

- sets Q, S, F as in ordinary NFAs,
- a transition relation $\Delta \subseteq Q \times (\Sigma \cup \{\epsilon\}) \times (\Pi \cup \{\epsilon\}) \times Q$

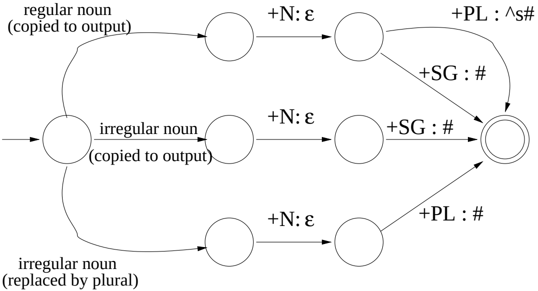
From this, one can define a many-step transition relation $\hat{\Delta} \subseteq Q \times \Sigma^* \times \Pi^* \times Q$, where $(q, x, y, q') \in \hat{\Delta}$ means "starting from state q, the input string x can be translated into the output string y, ending up in state q'." (Details omitted.)

Note that a finite state transducer can be run in either direction! From T as above, we can obtain another transducer $\overline{T}$ just by swapping the roles of inputs and outputs.

Stage 1: From lexical to intermediate form

Consider the problem of translating a lexical form like 'fox+N+PL' into a sequence of morphemes, taking account of irregular forms like goose/geese.

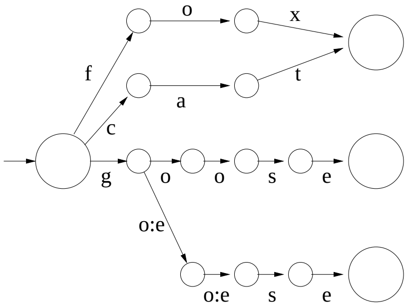
We can do this with a transducer of the following schematic form:



We treat each of $+$N, $+$SG, $+$PL as a single symbol. The 'transition' labelled $+PL : \hat{}s\#$ abbreviates three transitions: $+PL : \hat{}$, $\epsilon : s$, $\epsilon : \#$.

The Stage 1 transducer fleshed out

The left hand part of the preceding diagram is an abbreviation for something like this (only a small sample shown):



Here, for simplicity, a single label u abbreviates $u : u$.

Stage 2: From intermediate to surface form

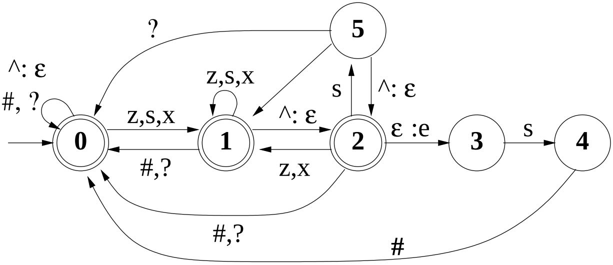
To convert a sequence of morphemes to surface form, we apply a number of orthographic rules such as the following.

- Consonant doubling: Single consonants b,s,g,k,l,m,n,p,r,s,t,v are doubled before suffix -ed or -ing. (beg $\rightarrow$ begged)
- E-insertion: Insert e after s,z,x,ch,sh before a word-final morpheme -s. (fox $\rightarrow$ foxes)

We shall consider a simplified form of E-insertion, ignoring ch,sh.

(Note that this rule is oblivious to whether -s is a plural noun suffix or a 3rd person verb suffix.)

A transducer for E-insertion



Here ? may stand for any symbol except z,s,x,ˆ,#.
(With each input #, we should output e.g. a space character.)

At a morpheme boundary following z,s,x, we arrive in State 2.
If the ensuing input sequence is s#, our only option is to go via states 3 and 4.

State 5 would allow e.g. 'exˆserviceˆmen#' to be translated to 'exservicemen'. Note that there's no #-transition out of State 5.

Putting it all together

FSTs can be cascaded: output from one can be input to another.

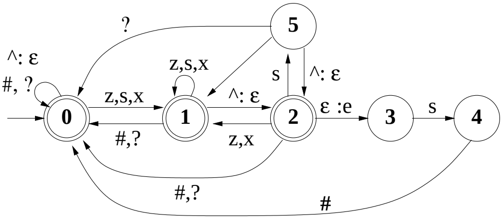
To go from lexical to surface form, use ‘Stage 1’ transducer followed by a bunch of orthographic rule transducers like the above.

The results of this generation process are typically deterministic (each lexical form gives a unique surface form), even though our transducers make use of non-determinism along the way.

Running the same cascade backwards lets us do parsing (surface to lexical form). Because of ambiguity, this process is frequently non-deterministic: e.g. ‘foxes’ might be analysed as fox+N+PL or fox+V+Pres+3SG.

Such ambiguities are not resolved by morphological parsing itself: left to a later processing stage.

Clicker exercise 2

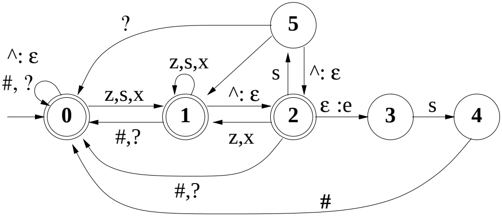


Apply this backwards to translate from surface to int. form.

Starting from state 0, how many sequences of transitions are compatible with the input string 'asses' ?

1. 1
2. 2
3. 3
4. 4
5. More than 4

Solution



On the input string 'asses', 10 transition sequences are possible!

- $0 \xrightarrow{a} 0 \xrightarrow{s} 1 \xrightarrow{s} 1 \xrightarrow{\epsilon} 2 \xrightarrow{e} 3 \xrightarrow{s} 4$, output ass^s
- $0 \xrightarrow{a} 0 \xrightarrow{s} 1 \xrightarrow{s} 1 \xrightarrow{\epsilon} 2 \xrightarrow{e} 0 \xrightarrow{s} 1$, output ass^es
- $0 \xrightarrow{a} 0 \xrightarrow{s} 1 \xrightarrow{s} 1 \xrightarrow{e} 0 \xrightarrow{s} 1$, output asses
- $0 \xrightarrow{a} 0 \xrightarrow{s} 1 \xrightarrow{\epsilon} 2 \xrightarrow{s} 5 \xrightarrow{\epsilon} 2 \xrightarrow{e} 3 \xrightarrow{s} 4$, output as^s^s
- $0 \xrightarrow{a} 0 \xrightarrow{s} 1 \xrightarrow{\epsilon} 2 \xrightarrow{s} 5 \xrightarrow{\epsilon} 2 \xrightarrow{e} 0 \xrightarrow{s} 1$, output as^s^es
- $0 \xrightarrow{a} 0 \xrightarrow{s} 1 \xrightarrow{\epsilon} 2 \xrightarrow{s} 5 \xrightarrow{e} 0 \xrightarrow{s} 1$, output as^ses
- Four of these can also be followed by $1 \xrightarrow{\epsilon} 2$ (output ^).

Reading

Relevant reading: Jurafsky and Martin chapter 3, sections 1–7.

Next time: What are the *limits* to the class of regular languages? How can we prove that a certain language is *not* regular?