Speech and Language Processing

Words and Transducers

Chapter 3 of SLP

More on text searching

- Searching for *woodchuck* (singular) and *woodchucks* (plural)
  - Regular expression /woodchucks?/
- What about:
  - fox -> foxes, peccary -> peccaries, fish -> fish, goose -> geese
- Morphological parsing
  - Recognizing that a word breaks down into component morphemes and building a structured representation of this fact

Morphological parsing

- Where needed?
  - Web search (for morphologically complex languages)
    - Search for inflected forms of the base form the user typed in
  - Part-of-Speech tagging
  - Dictionaries for spell-checking

Morphological parsing

- Why not store all word forms in a dictionary?
  - Many formations are predictable and productive
    - Automatically includes any new word
    - New words constantly enter into a language
- Better to separate the lexicon and morphological rules

Words

- Finite-state methods are particularly useful in dealing with a lexicon
- Many devices, most with limited memory, need access to large lists of words
- And they need to perform fairly sophisticated tasks with those lists
- So we'll first talk about some facts about words and then come back to computational methods

English Morphology

- Morphology is the study of the ways that words are built up from smaller meaningful units called morphemes
- We can usefully divide morphemes into two classes
  - Stems: The core meaning-bearing units
  - Affixes: Bits and pieces that adhere to stems to change their meanings and grammatical functions

Example

- Word form: cats
  - Stem: cat
  - Suffix: s
- Word form: foxes
  - Stem: fox
  - Suffix: es
- Word form: rewrites
  - Stem: write
  - Prefix: re
  - Suffix: s

English Morphology

- We can further divide morphology up into two broad classes
  - Inflectional
  - Derivational

Inflectional Morphology

- Inflectional morphology concerns the combination of stems and affixes where the resulting word:
  - Has the same word class as the original
  - Serves a grammatical/semantic purpose that is
    - Different from the original
    - But is nevertheless transparently related to the original

Nouns and Verbs in English

- Nouns are simple
  - Markers for plural and possessive
- Verbs are only slightly more complex
  - Markers appropriate to the tense of the verb

Regulars and Irregulars

- It is a little complicated by the fact that some words misbehave (refuse to follow the rules)
  - Mouse/mice, goose/geese, ox/oxen
  - Go/went, fly/flew
- The terms regular and irregular are used to refer to words that follow the rules and those that don't

Regular and Irregular Verbs

- Regulars…
  - walk, walks, walking, walked, walked
- Irregulars
  - eat, eats, eating, ate, eaten
  - catch, catches, catching, caught, caught
  - cut, cuts, cutting, cut, cut

Inflectional Morphology

- So inflectional morphology in English is fairly straightforward
- But is complicated by the fact that are irregularities

Derivational Morphology

- Derivational morphology is the messy stuff that no one ever taught you.
  - Quasi-systematicity
  - Irregular meaning change
  - Changes of word class

Derivational Examples

- Verbs (V) and Adjectives (A) to Nouns (N)
  - nominalization

-ation	computerize (V)	computerization (N)
-ee	appoint (V)	appointee (N)
-er	kill (V)	killer (N)
-ness	fuzzy (A)	fuzziness (N)

Derivational Examples

- Nouns (N) and Verbs (V) to Adjectives (A)

-al	computation (N)	computational (A)
-able	embrace (V)	embraceable (A)
-less	clue (N)	clueless (A)

Example: *Compute*

- Many paths are possible…
- Start with compute
  - Computer -> computerize -> computerization
  - Computer -> computerize -> computerizable
- But not all paths/operations are equally good (allowable?)
  - Clue
    - Clue -> *clueable

Morphological parsing

- Our goal is to convert input like:
  - cats => cat + N + PL
  - cat => cat + N +SG
  - cities => city + N + PL
  - geese => goose + N +PL
  - merging => merge + V + PresPart
- We need a **morphological parser/analyzer**

Morphological parser

1. Lexicon
   - the list of stems and affixes
2. Morphotactics
   - Explains which classes of morphemes can follow other class of morphemes inside a word
3. Orthographic rules
   - Spelling rules used to model the changes that occur in a word

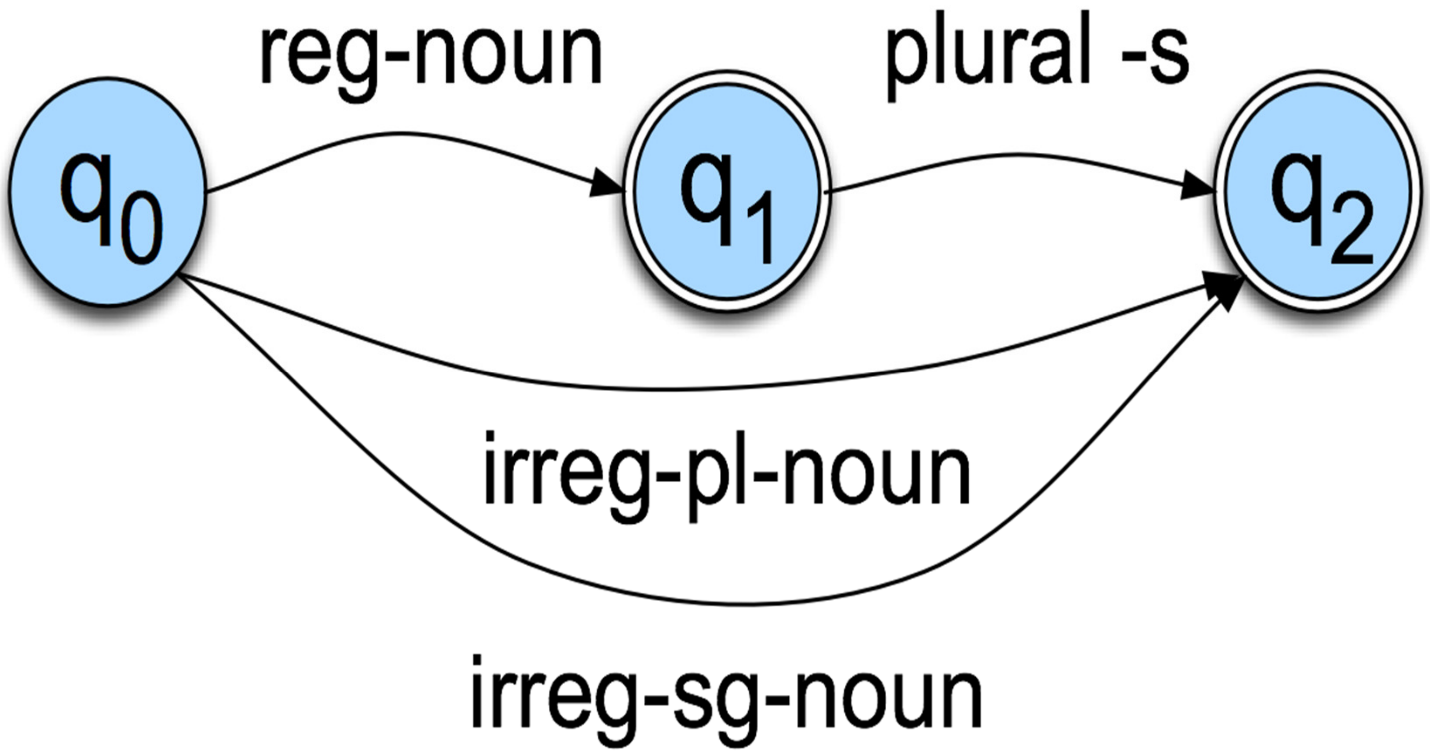
Morpholgy and FSAs

- We'd like to use the machinery provided by FSAs to capture these facts about morphology
  - Accept strings that are in the language
  - Reject strings that are not
  - And do so in a way that doesn't require us to in effect list all the words in the language

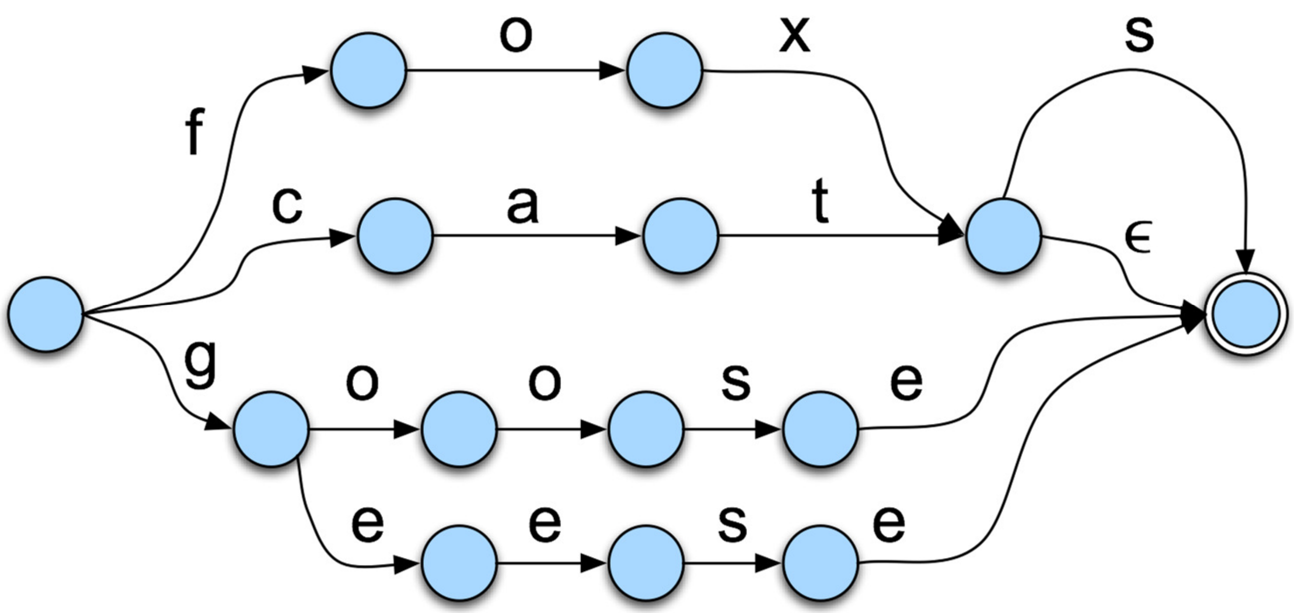
Finite-State Lexicon construction

- Start simple
- Regular singular nouns are ok
- Regular plural nouns have an -s on the end
- Irregulars are ok as is

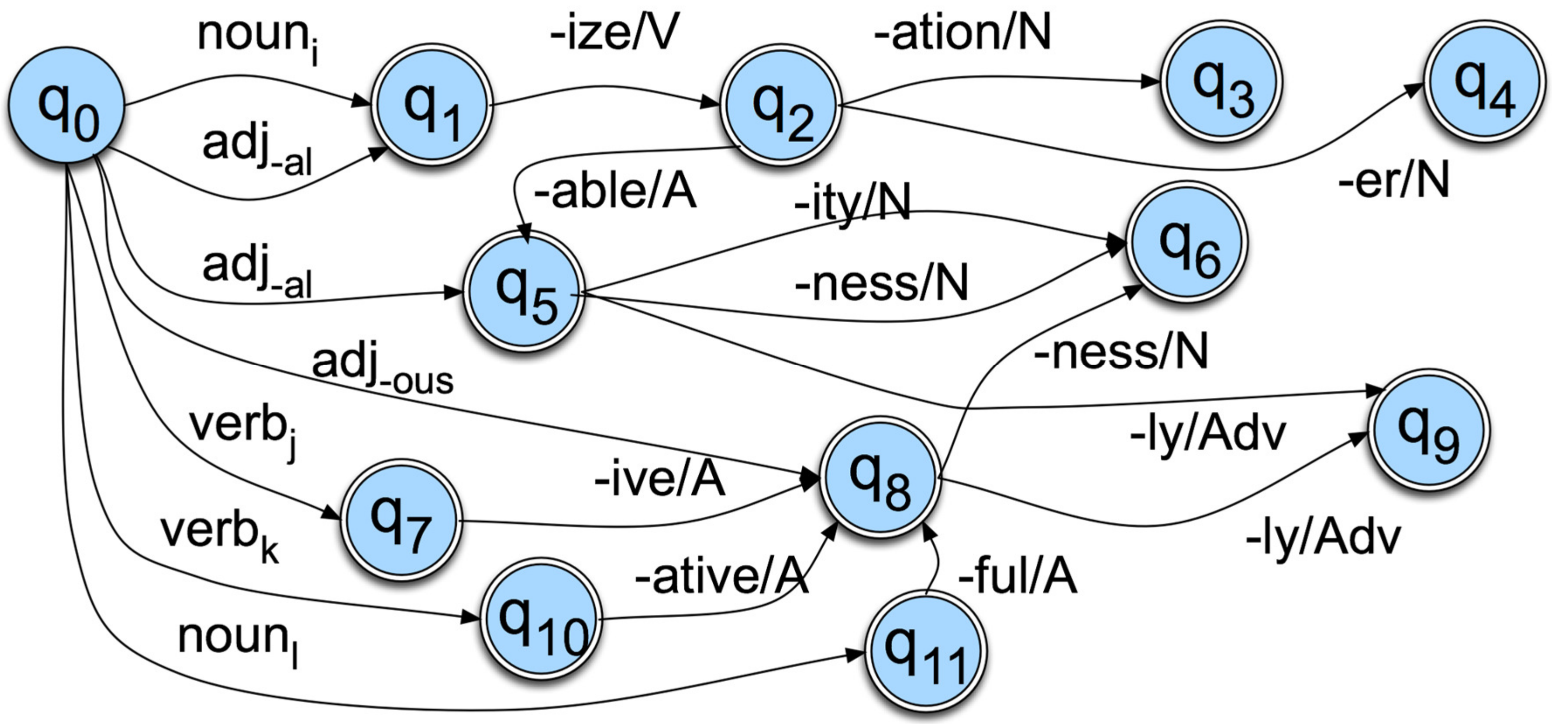
Simple Rules



Now Plug in the Words



Derivational Rules



If everything is an accept state
how do things ever get rejected?

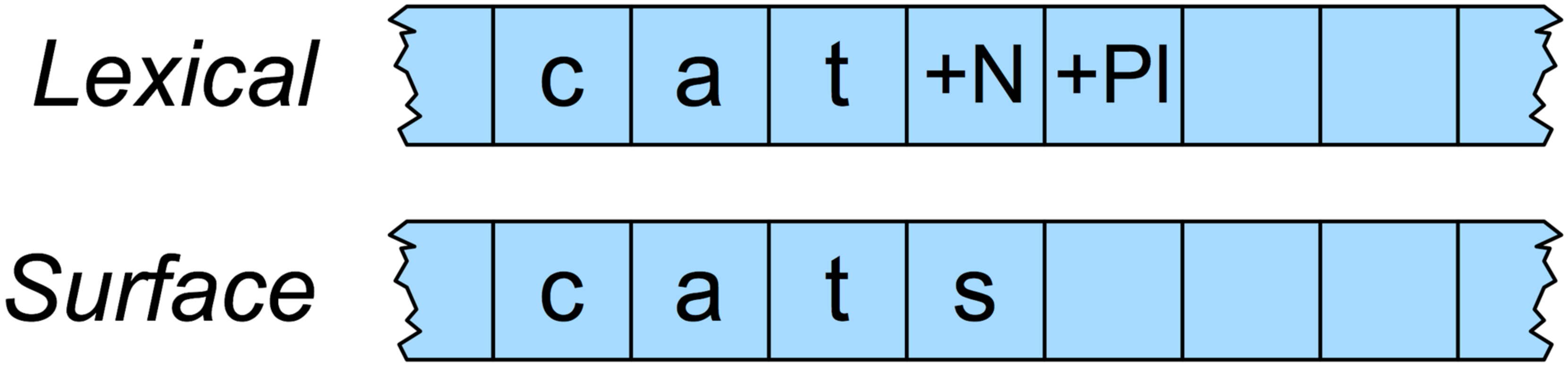
Parsing/Generation vs. Recognition

- We can now run strings through these machines to recognize strings in the language
- But recognition is usually not quite what we need
  - Often if we find some string in the language we might like to assign a structure to it (parsing)
  - Or we might have some structure and we want to produce a surface form for it (production/generation)
- Example
  - From "cats" to "cat +N +PL"

Finite State Transducers

- The simple story
  - Add another tape
  - Add extra symbols to the transitions
  - On one tape we read "cats", on the other we write "cat +N +PL"

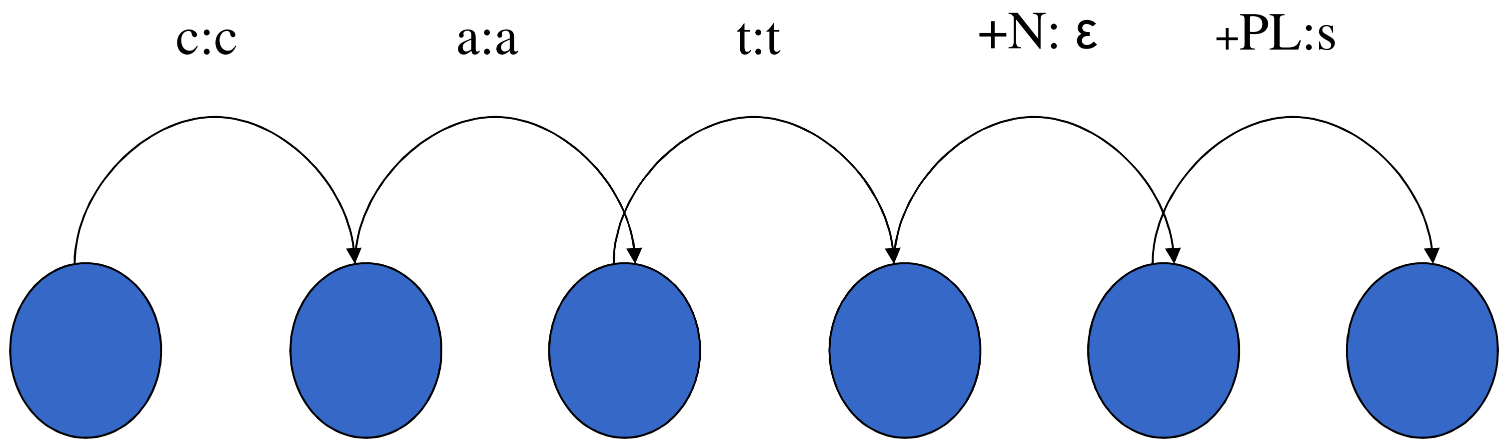
FSTs



Applications

- The kind of parsing we're talking about is normally called morphological analysis
- It can either be
  - An important stand-alone component of many applications (spelling correction, information retrieval)
  - Or simply a link in a chain of further linguistic analysis

Transitions



- c:c means read a c on one tape and write a c on the other
- +N:ε means read a +N symbol on one tape and write nothing on the other
- +PL:s means read +PL and write an s

Typical Uses

- Typically, we'll read from one tape using the first symbol on the machine transitions (just as in a simple FSA).
- And we'll write to the second tape using the other symbols on the transitions.

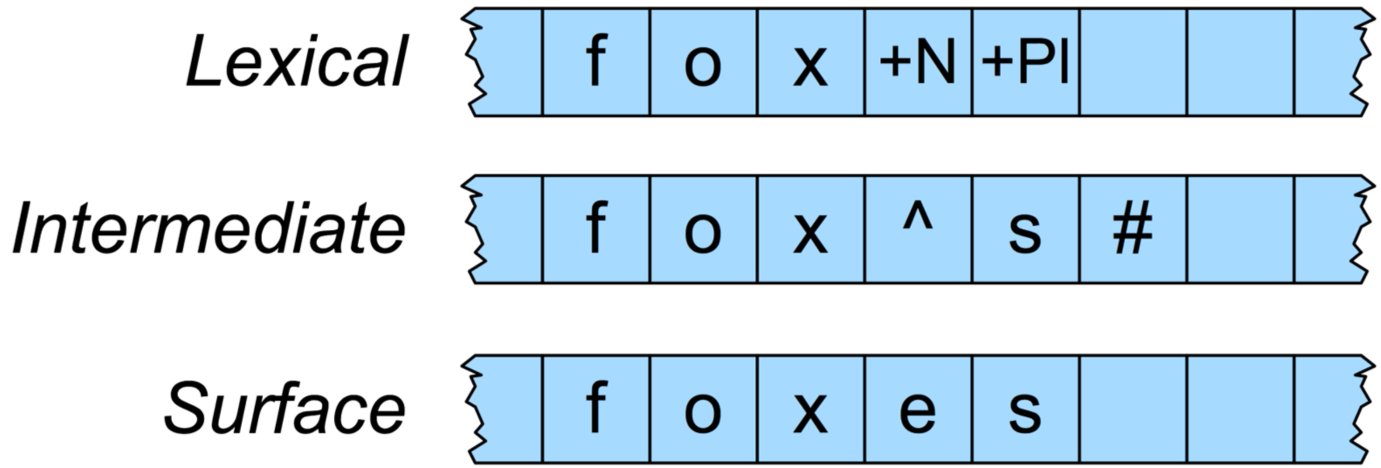
The Gory Details

- Of course, its not as easy as
  - “cat +N +PL” <-> “cats”
- As we saw earlier there are geese, mice and oxen
- But there are also a whole host of spelling/pronunciation changes that go along with inflectional changes
  - Fox and Foxes

Multi-Tape Machines

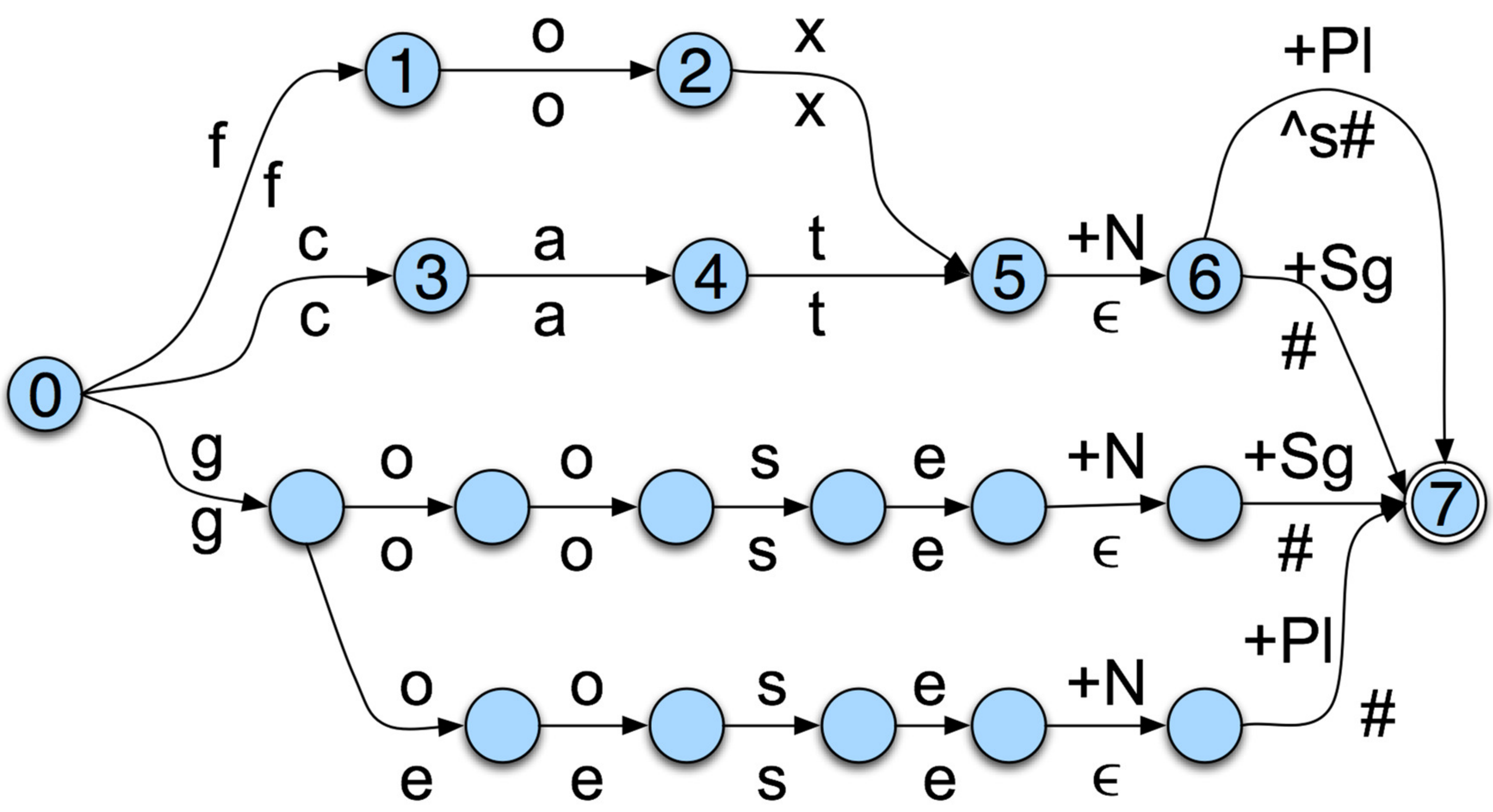
- To deal with these complications, we will add more tapes and use the output of one tape machine as the input to the next
- So to handle irregular spelling changes we'll add intermediate tapes with intermediate symbols

Multi-Level Tape Machines



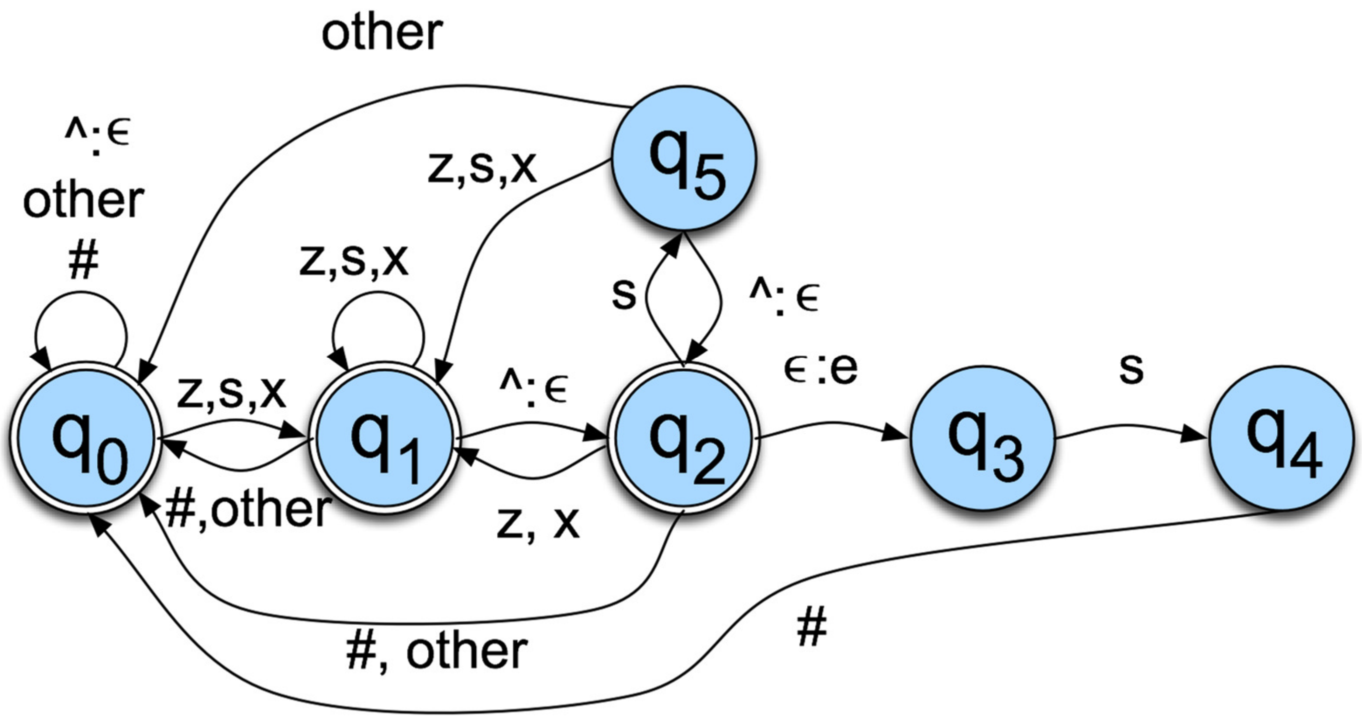
- We use one machine to transduce between the lexical and the intermediate level, and another to handle the spelling changes to the surface tape

Lexical to Intermediate Level

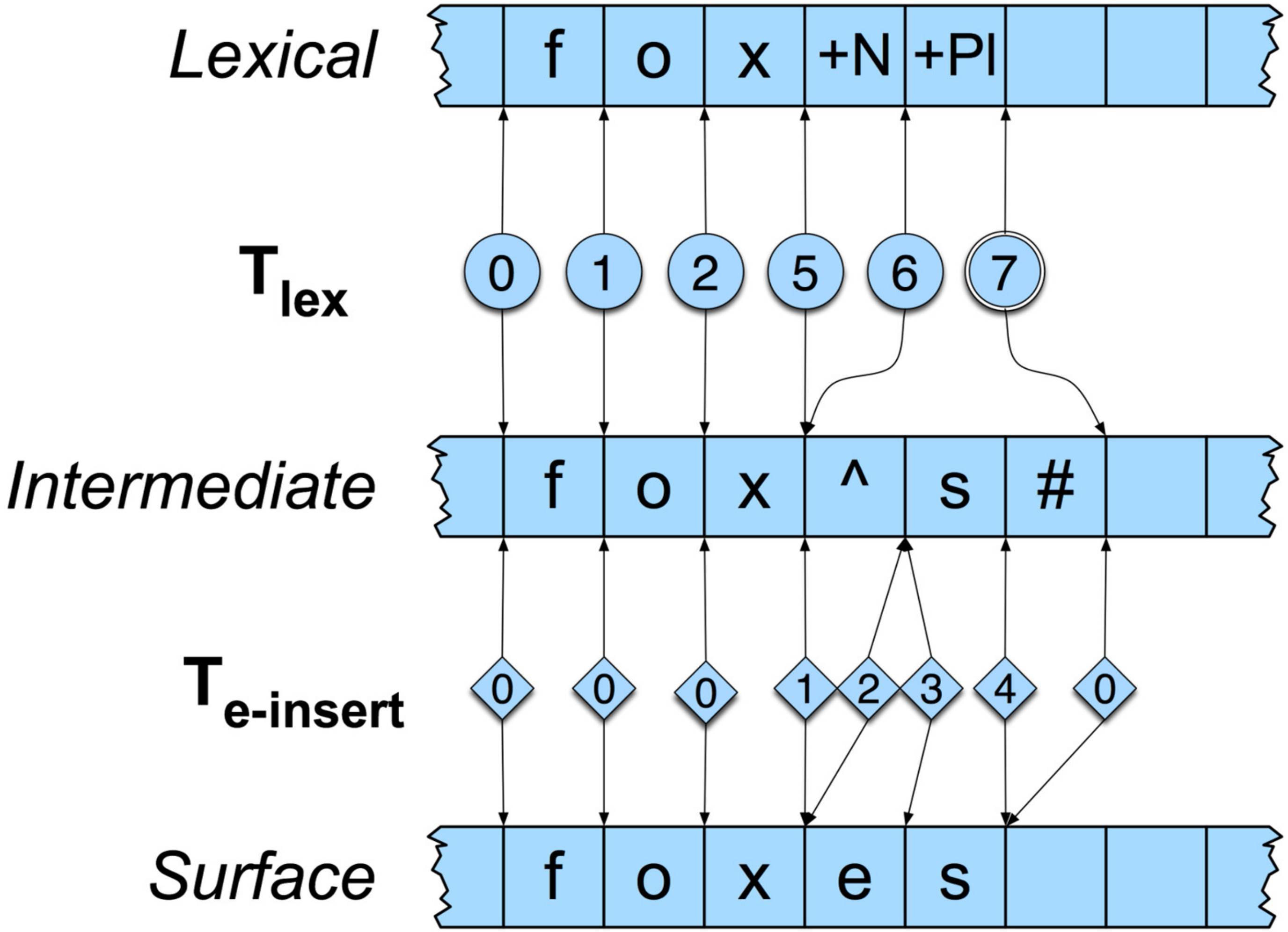


Intermediate to Surface

- The add an “e” rule as in fox^s# <-> foxes#



Foxes


Lexical
f
o
x
+N
+Pl
T lex
0
1
2
5
6
7
Intermediate
f
o
x
^
s
#
T e-insert
0
0
0
1
2
3
4
0
Surface
f
o
x
e
s

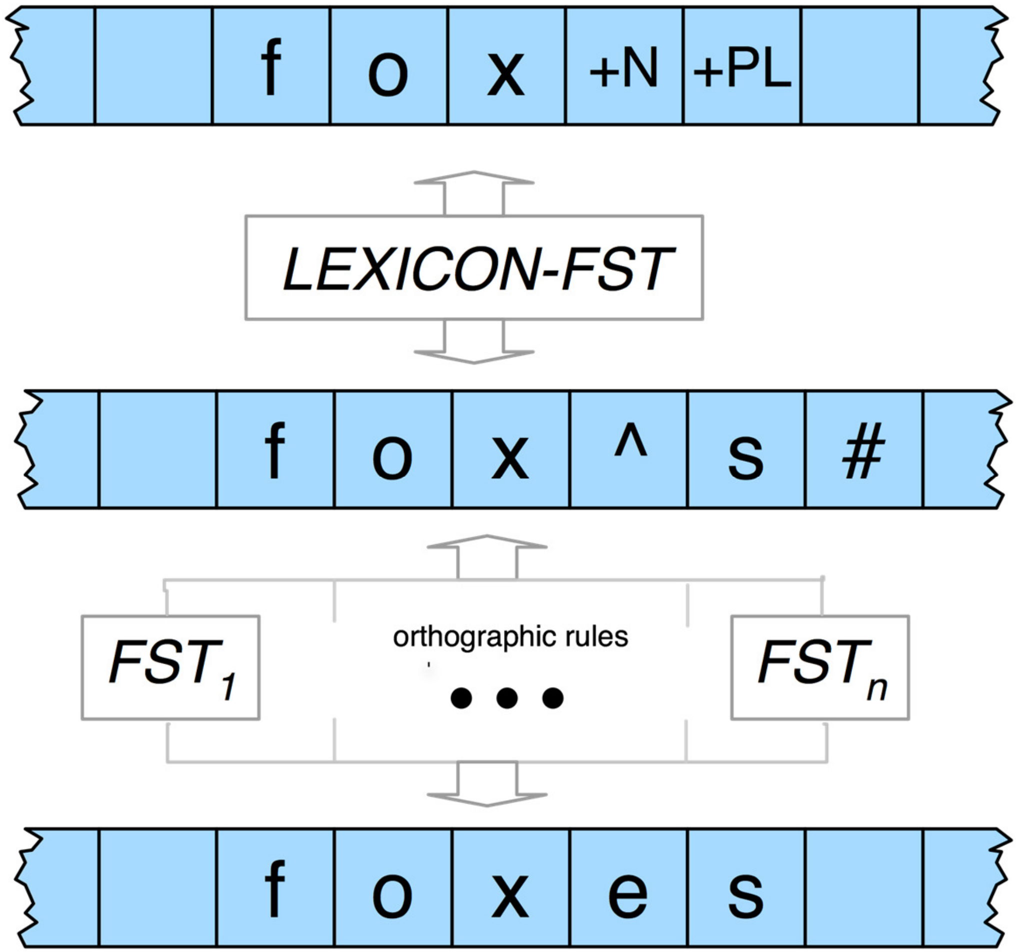
Note

- A key feature of this machine is that it doesn't do anything to inputs to which it doesn't apply.
- Meaning that they are written out unchanged to the output tape.

Overall Scheme

- We now have one FST that has explicit information about the lexicon (actual words, their spelling, facts about word classes and regularity).
  - Lexical level to intermediate forms
- We have a larger set of machines that capture orthographic/spelling rules.
  - Intermediate forms to surface forms

Overall Scheme



Cascades

- This is an architecture that we'll see again and again
  - Overall processing is divided up into distinct rewrite steps
  - The output of one layer serves as the input to the next
  - The intermediate tapes may or may not wind up being useful in their own right

HFST

- Helsinki Finite-State Transducer Technology
- http://www.ling.helsinki.fi/kieliteknologia/tutkimus/hfst/
- Includes demos to try