Words:
Computational Morphology and Phonology

CMSC 35100
Natural Language Processing
April 8, 2003

Roadmap

- Words: Surface variation and automata
  - FSTs and Morphological/Phonological Rules
    - Morphology: Implementing spelling change
      - Fox example
      - Automatic acquisition
    - Phonology:
      - Brief! Introduction to Phonetics and Phonology
        - Phone classes
      - Implementing letter to sound rules (FST)
        - Fox redux

Surface Variation: Morphology

- Searching for documents about
  - “Televised sports”
- Many possible surface forms:
  - Televised, televise, television, ..
  - Sports, sport, sporting
- Convert to some common base form
  - Match all variations
  - Compact representation of language

Surface Variation: Pronunciation

- Regular English plural: +s
- English plural pronunciation:
  - cat+s -> cats where s=*s*, but
  - dog+s -> dogs where s=*z*, and
  - base+s -> bases where s=iz
- Phonological rules govern morpheme combination
  - +s -> *s*, unless [voiced]^s -> *z*, or [sibilant]^s->iz
- Common lexical representation
  - Mechanism to convert appropriate surface form

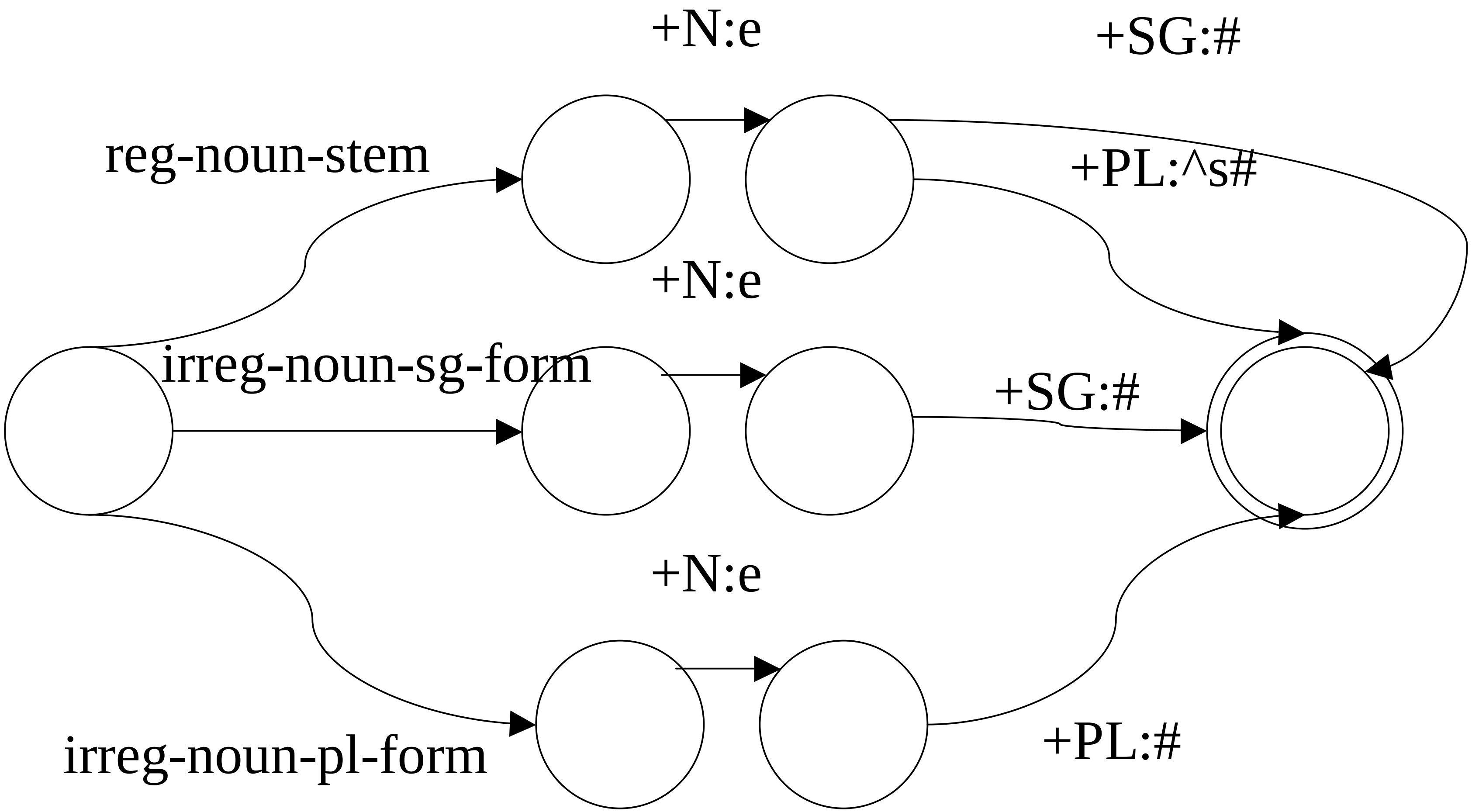
Two-level Morphology

- Morphological parsing:
  - Two levels: (Koskenniemi 1983)
    - Lexical level: concatenation of morphemes in word
    - Surface level: spelling of word surface form
  - Build rules mapping between surface and lexical
- Mechanism: Finite-state transducer (FST)
  - Model: two tape automaton
  - Recognize/Generate pairs of strings

FSA -> FST

- Main change: Alphabet
  - Complex alphabet of pairs: input x output symbols
  - e.g. i:o
    - Where i is in input alphabet, o in output alphabet
- Entails change to state transition function
  - Delta(q, i:o): now reads from complex alphabet
- Closed under union, inversion, and composition
  - Inversion allows parser-as-generator
  - Composition allows series operation

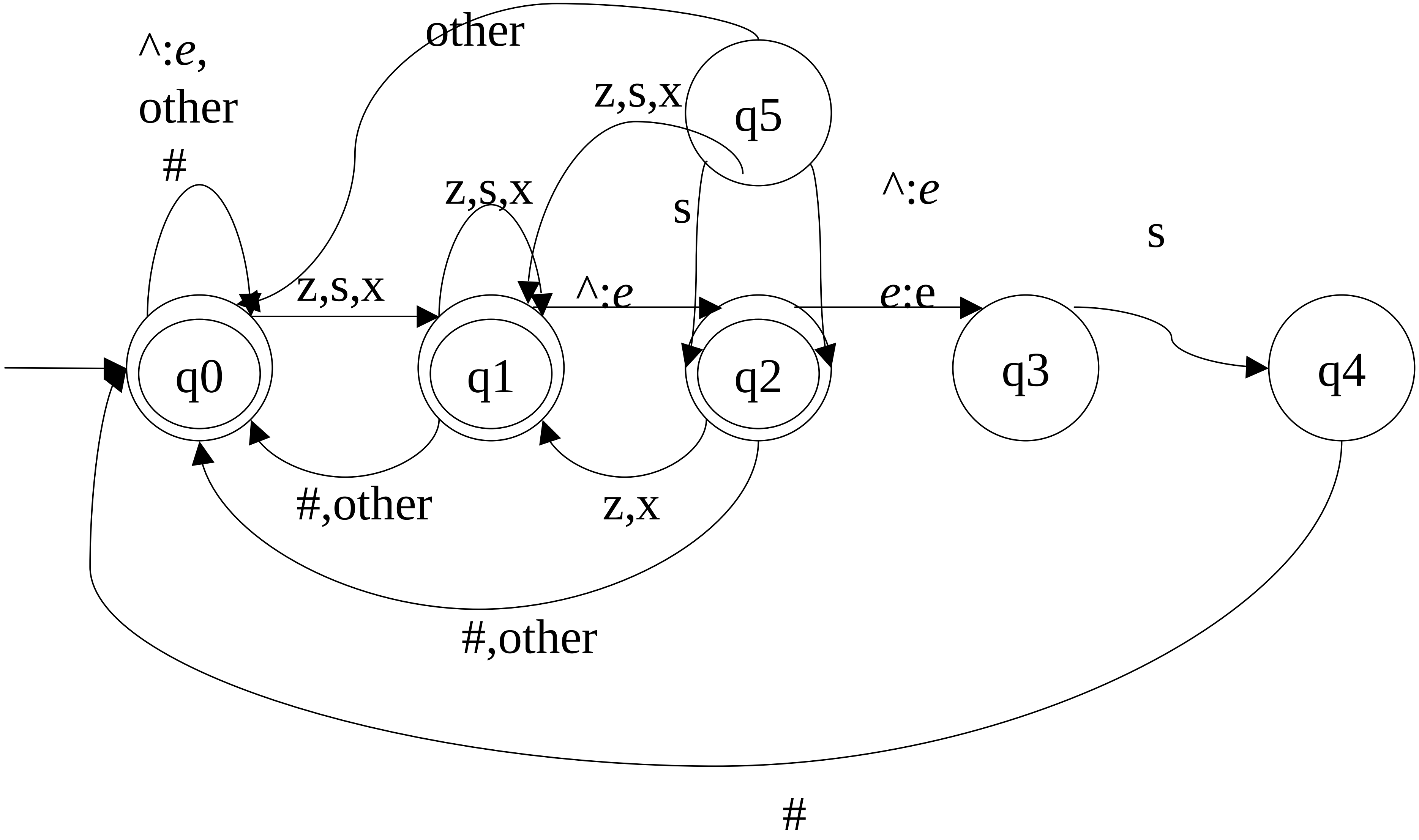
Simple FST for Plural Nouns



Rules and Spelling Change

- Example: E insertion in plurals
  - After x, z, s...: fox + -s -> foxes
- View as two-step process
  - Lexical -> Intermediate (create morphemes)
  - Intermediate -> Surface (fix spelling)
- Rules: (a la Chomsky & Halle 1968)
  - Epsilon -> e/{x,z,s}^__s#
    - Rewrite epsilon (empty) as e when it occurs between x,s,or z at end of one morpheme and next morpheme is -s

E-insertion FST



Accepting Foxes

Lexical	f	o	x	+N	+PL		
Intermediate	f	o	x	^	s	#	
Surface	f	o	x	e	s		

Implementing Parsing/Generation

- Two-layer cascade of transducers (series)
  - Lexical -> Intermediate; Intermediate -> Surface
    - I->S: all the different spelling rules in parallel
- Bidirectional, but
  - Parsing more complex
    - Ambiguous!
      - E.g. Is fox noun or verb?

Shallow Morphological Analysis

- Motivation: Information Retrieval
  - Just enable matching – without full analysis
- Stemming:
  - Affix removal
    - Often without lexicon
    - Just return stems – not structure
  - Classic example: Porter stemmer
    - Rule-based cascade of repeated suffix removal
      - Pattern-based
    - Produces: non-words, errors, ...

Automatic Acquisition of Morphology

- “Statistical Stemming” (Cabezas, Levow, Oard)
  - Identify high frequency short affix strings for removal
  - Fairly effective for Germanic, Romance languages
- Light Stemming (Arabic)
  - Frequency-based identification of affixes
- Minimum description length approach
      - (Brent and Cartwright1996, DeMarcken 1996, Goldsmith 2000)
  - Minimize cost of model + cost of lexicon | model
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Computational Phonology & TTS

- Range of correspondences between sound and text
  - Writing systems from logographic to phonetic
- Question: How are words pronounced via phones?
  - Phones (basic speech units)
    - Crucial for TTS and ASR
  - Challenge: Variability!
    - Phones pronounced differently in different contexts (e.g. [t])

      Phonology models this variatiion

Phonetics & Transcription

- Word pronunciation model:
  - String of symbols representing phone
- Phone transcription:
  - International Phonetic Alphabet (IPA)
    - Goal: Transcription of all languages
      - Sounds and transcription rules
  - ARPABET: ASCII –based 1- or 2- character system
    - More English-focused, computational
  - NOT identical to alphabet in general
    - E.g. a -> aa or ax ar ae

ARPAbet Snippet

– - iy: bee

– - ih: hit

– - ey: day

– -eh: bet

– -ae: cat

– -aa: father

– -ao: dog

– -ow: show

– -uw: sue….

– -p: put

– -t: top

– -th: thin

– -dh: this

– -jh: jay

– -zh: ambrosia

– -dx: butter

– -nx: winter

– -el: little….

Fast Phonology

Consonants: Closure/Obstruction in vocal tract

- Place of articulation (where restriction occurs)
  - Labial: lips (p, b), Labiodental: lips & teeth (f,v)
  - Dental: teeth: (th,dh)
  - Alvoelar:roof of mouth behind teeth (t.d)
  - Palatal: palate: (y); Palato-alvoelar: (sh, jh, zh)…
  - Velar: soft palate (back): k,g ; Glottal
- Manner of articulation (how restrict)
  - Stop (t): closure + release; plosive (w/ burst of air)
  - Nasal (n): nasal cavity
  - Frictative (s,sh,) turbulence: Affricate: stop+fricative (jh, ch)
  - Approximant (w,l,r)
  - Tap/Flap: quick touch to alvoelar ridge

Fast Phonology

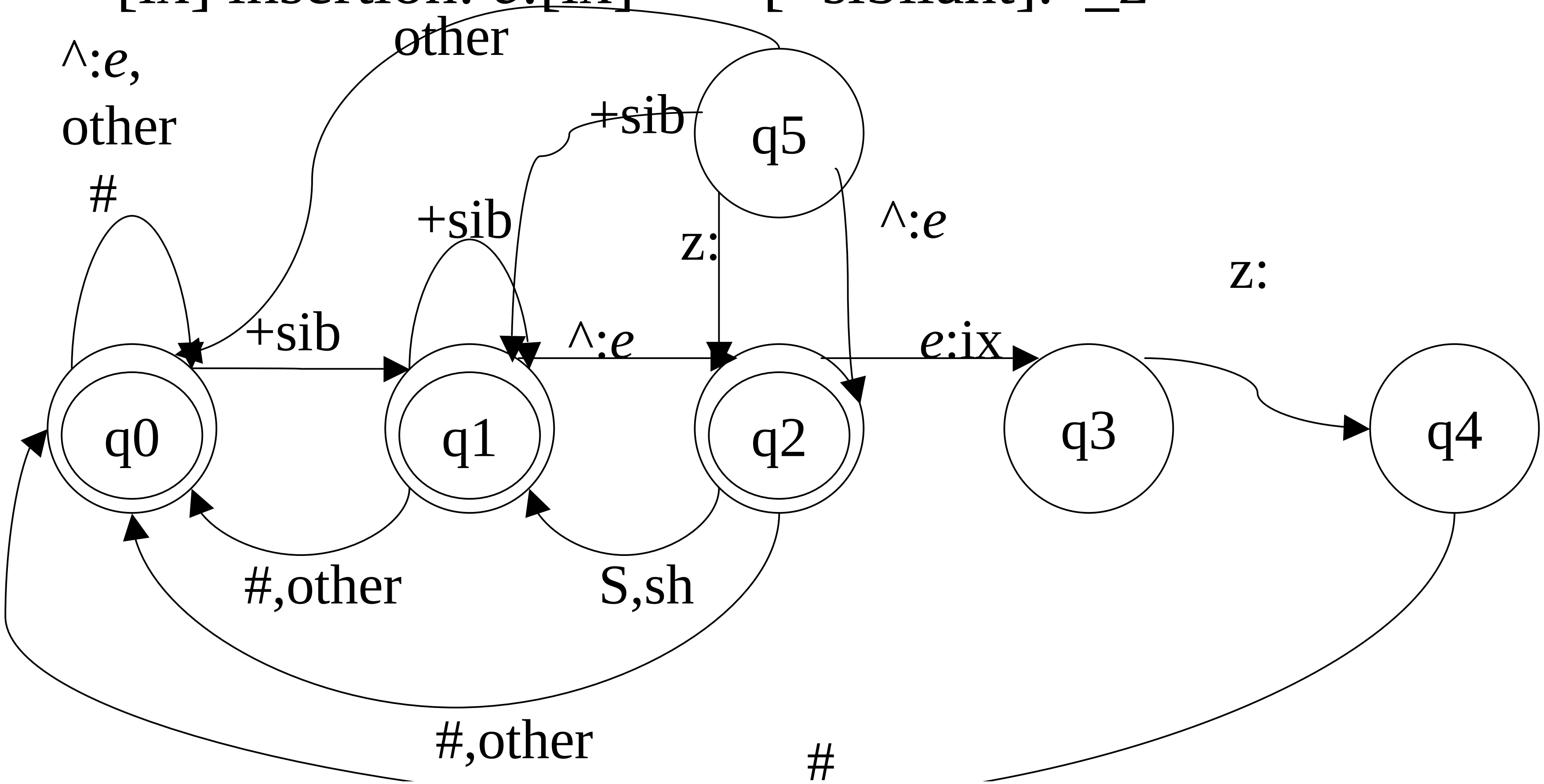
- Vowels: Open vocal tract: Articulator position
  - Vowel height: position of highest point of tongue
    - Front (iy) vs Back (uw)
    - High: (ih) vs Low (eh)
    - Diphthong: tongue moves: (ey)
  - Lip shape
    - Rounded: (uw)

Phonological Variation

- Consider t in context:
  - -talk: t – unvoiced, aspirated
  - -stalk: d – often unvoiced
  - -butter: dx – just flap, etc
- Can model with phonological rule
  - Flap rule: {t,d} -> [dx]/V’__V
    - T,d becomes flap when between stressed & unstressed vowel

Phonological Rules & FSTs

- Foxes redux:
  - [ix] insertion: *e*:[ix] <-> [+sibilant]:^_z



Harmony

- Vowel harmony:
  - Vowel changes sound be more similar to other
    - E.g. assimilate to roundness and backness of preceding
    - Yokuts examples:
      - dub+hin -> dubhun
      - xil+hin -> xilhin
      - Bok’+al -> bok’ol
      - Xat+al -> xatal
- Can also be handled by FST

Text-to-Speech

- Key components:
  - Pronouncing dictionary
  - Rules
- Dictionary: E.g. CELEX, PRONLEX, CMUDict
  - List of pronunciations
    - Different pronunciations, dialects
    - Sometimes: part of speech, lexical stress
  - Problem: Lexical Gaps
    - E.g. Names!

TTS: Resolving Lexical Gaps

- Rules applied to fill lexical gaps
  - Now and then
- Gaps & Productivity:
  - Infinitely many; can’t just list
    - Morphology
    - Numbers
      - Different styles, contexts: e.g. phone number, date,..
    - Names
      - Other language influences

FST-based TTS

- Components:
  - FST for pronunciation of words & morphemes in lex
  - FSA for legal morpheme sequences
  - FSTs for individual pronunciation rules
  - Rules/transducers for e.g. names & acronyms
  - Default rules for unknown words

Modeling Lexicon

- Enrich lexicon:
  - Orthographic + Phonological
    - E.g. cat = c|k a|ae t|t; goose = g|g oo|uw s|s e|*e*