Morphology and Finite State Machines

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SEPTEMBER 8, 2014

Roadmap

By the end of this class you should . . .

- Be able to write FSAs and FSTs
- Give examples of inflectional and derivational morphology
- Understand the challenges of morphology

Outline

Typical Pipeline for nlp Tasks

1. Find the "units of meaning"
2. Do "shallow" analysis (POS tagging)
3. Do sentence-level analysis (parsing, SRL)
4. Do document-level analysis (topic models, classification)
5. Extrinsic task (question answering)

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This class is (mostly) about English . . .

But if we were in Turkey, Finland, or Egypt, this part of the class would take weeks or months. An important step that is really easy in English.

Why morphology

Morpheme

Smallest unit of language that carries meaning

- "books": two morphemes ("book" and "s"), one syllable
- "unladylike": three morphemes, four syllables
- To do an analysis of language, we must do an analysis of the most fundamental unit of language!
- This subfield of linguistics is called morphology

Definitions

Derivational

You have a **new** word **derived** from an existing word that alters the **meaning**

- Nominalization: computerization, appointee, killer
- Adjectivization: computational, clueless, embraceable

Inflectional

You have a **variation** of a word that expresses **grammatical** contrast

- tense, number, person
- word class doesn't change
- "The pizza guy comes at noon" (from "come")

Definitions

- **Root**: common to a set of derived or inflected forms
- **Stem**: root or roots of a word together with derivational affixes
- **Affix**: bound morpheme that comes after or within a root or stem
- **Clitic**: a morpheme that functions like a word but doesn't appear on its own (e.g., the 've in "**I**'ve")

Examples

- Rechts+schutz+ver+sicher+ungs+gesell+schaft+en: Legal protection insurance policy (German)
- uygar+laş+tır+ama+dık+larımız+dan+mış+sınız+casına: Behaving as if you are among those whom we could not cause to become civilized (Turkish)

- "tú amaste" "ellos aman" "yo amaría" (Spanish)
- "I eat", "he eats", "they're eating", "I ate" (English)
- "wo ai", "ni ai", "ni.men ai" (Chinese)

Comparative Morphology

- Chinese is very easy
- English is fairly simple and regular
  - Few irregular verbs, but they're frequent
  - Derivational morphology is very productive (e.g., "faxed", "Skyped", "Brittaed")

Outline

Why Morphology

Finite State Automaton

Finite State Transducer

A Simple Problem

- We want to know whether a word is in a language or not
  - We'll get to transforming string to morpheme in a bit
- For English, it's possible to get by just with making a list
- Much harder for other languages
- Even for English, you miss out on derivations and inflections

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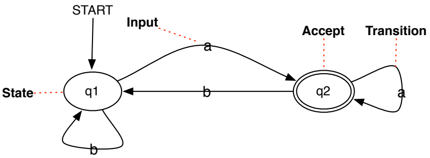
- For English, it's possible to get by just with making a list
- Much harder for other languages
- Even for English, you miss out on derivations and inflections
- Turn to a tool called Finite State Automaton (FSA)

Defining FSAs



FSA over alphabet $\{a, b\}$

- We define a language to be a set of strings over some alphabet Σ
- A set of states Q
- a designated start state q_0
- a set of accepting final states $F \subset Q$
- edges: given current state q_i and input $x \in \Sigma$, gives new state q_j

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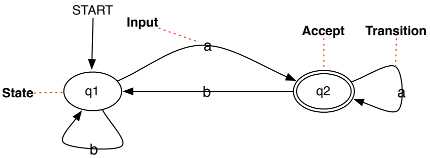

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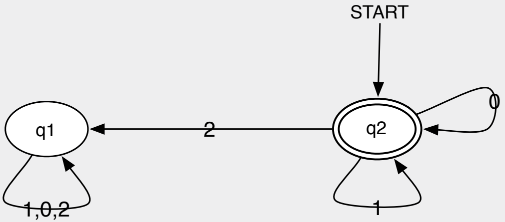
- Important tip: every state should have an edge for every element in alphabet

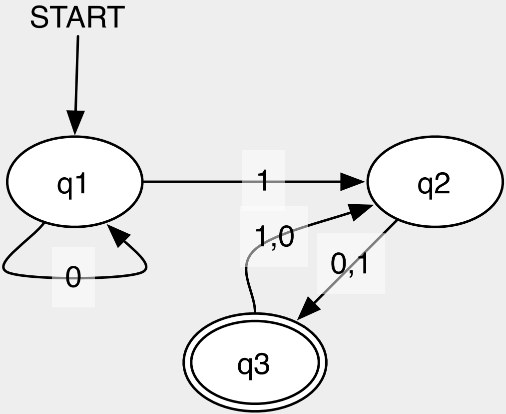
Examples

All binary strings



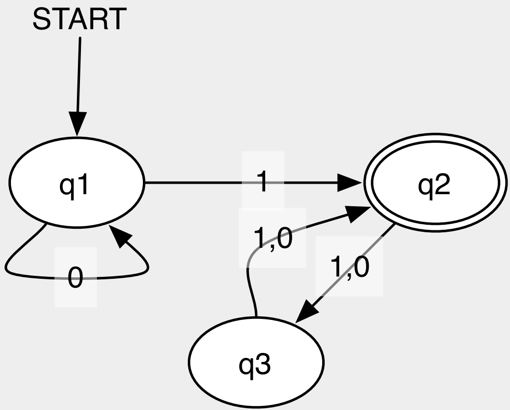
Examples

All non-zero binary strings of even length



Examples

All non-zero binary strings of odd length



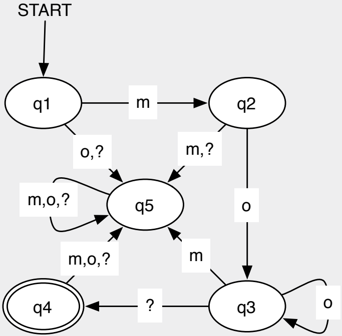
Examples

Suppose we wanted to accept the language of questioning cows

- every string must begin with a “m”
- every string must end with a question mark “?”
- there can only be “o” in between

Examples

Inquisitive cow



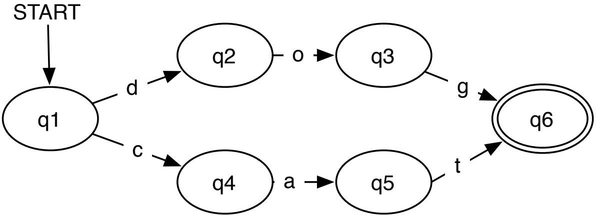
What can you do with FSAs

- Equivalence to regular expressions
- Intersection: given two languages (L_1, L_2), give $L_1 \cap L_2$
- Difference: given two languages (L_1, L_2), give $L_1 - L_2$
- Complementation: given a language L_1, give $\Sigma^* - L_1$
- Reversal: given a language L_1, give $\{x : x^R \in L_1\}$
- Concatenation: Given two languages (L_1, L_2), give $\{x : x = y + z, y \in L_1, z \in L_2\}$
- Closure: infinite repetition

Uhh ... what about morphology?

- We've been talking about toy languages, but it works for real languages too
- Why do you want to recognize languages?
  - Spell checkers
  - Language identification
  - Speech synthesis
- Suppose you have an FSA for English stems (one for nouns, verbs, adjectives, etc.)
- Now suppose that you have an FSA that can generate inflectional forms
- Combine them with union / concatenation!

Nouns and their plurals



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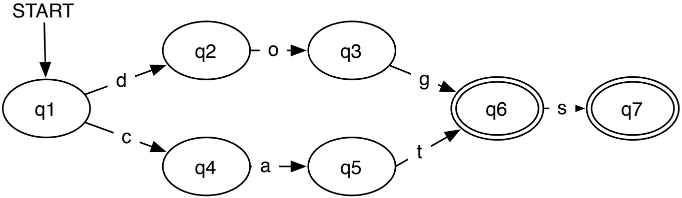
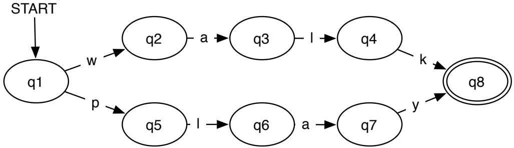


Non-deterministic FSA

- Allow empty input
- Allows multiple “universes” for strings to follow
- If any accepts, then it is part of the language
- Book uses ϵ, I’ll use a blank edge

Non-deterministic composition



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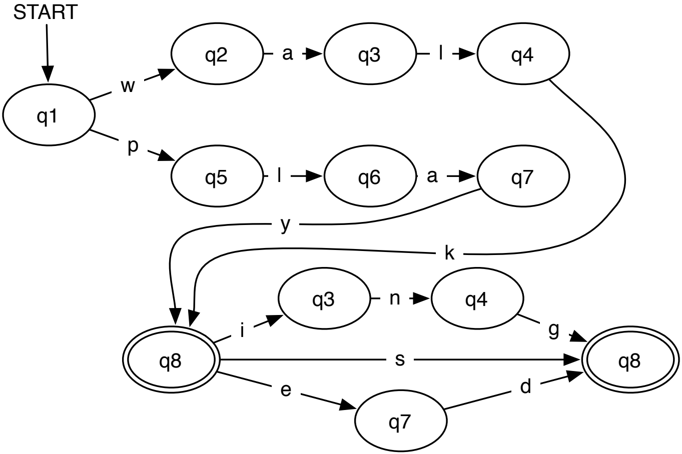

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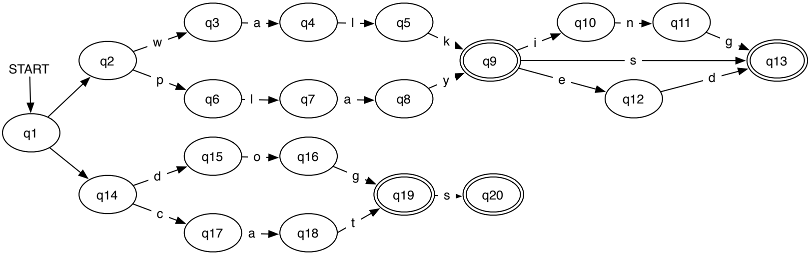

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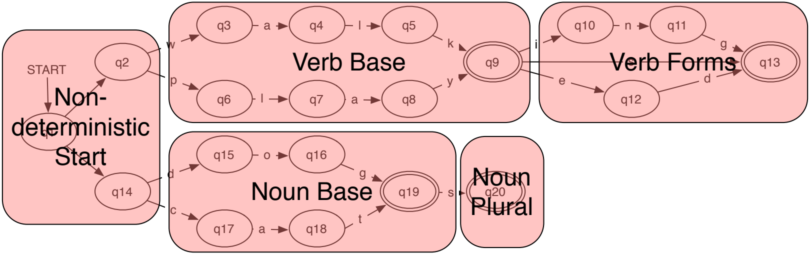


Outline

Why Morphology

Finite State Automaton

Finite State Transducer

FSA to FST

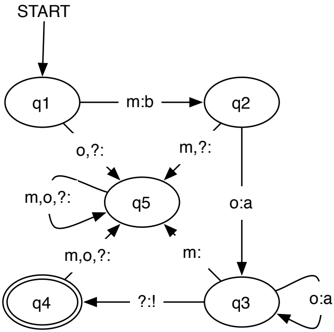
- FSA gives a binary output: is this a string or not
- What if we want to, for example, inflect words to reflect morphological variation? (Or vice-versa, given an inflected form, get back the stem.)
  - Useful for searching ("foxes" and "fox" are related)
  - Useful for generation: I want to say "go", but what's the third-person past tense?
- The answer is a finite state transducer

FST definition

- In addition to everything that you had from an FSA, now each transition also has an output (possibly empty)
- Think of this as "translating" an input string to an output

Example

- Turning the inquisitive cow into emphatic sheep
- Emphatic sheep strings start with "b" have any number of "a" and end with "!"



FSTs for Morphological Parsing

- Subject of first “real” homework
- Take input like “cat+N+PL”
- Produce output like “cats”
- Read chapter 3.5 very carefully
- Read assignment carefully

Rest of class . . .

Transducing Tolkein