Ling/CSE 472: Introduction to Computational Linguistics

4/22/15

Computational phonology

Overview

- Term projects: timeline
- Representing sounds
- Computational phonology: tasks
- FSTs for phonological rules
- Rule ordering and two-level phonology
- Optimality Theory: OT
- Machine learning of phonological rules
- Next time: TTS

Term projects: Timeline

- 4/24: Plan for final project
- 5/29: Write-up outline + stage 1 results
- 6/3, 6/5: Presentations
- 6/8 (2:30pm): Final project (executable + writeup)

Term projects: Specifications

- Evaluated in terms of precision and recall
- Comparison to baseline
- Two or more stage experiment where stage 2 tries to improve on stage 1 by changing the methodology in some way and measuring against the same gold standard (comparative evaluation)
- Must deal with natural language
- The write up is ***very important***

Due 4/24

- Decide if you'll work alone or with a partner
- Specify:
    - Task to be attempted
    - Data to be used
    - Means of measuring P & R
    - Any additional metrics
- For partner projects: Who will do what

Before 4/20

- Be in contact with us (Olga, Emily) about your ideas, so we can help make sure they are feasible

- Use Canvas to discuss

- Explore what data are available:

  - https://vervet.ling.washington.edu/db/livesearch-corpus-form.php

  - Anything from LDC we can get, if we don’t have it already, but leave time for this

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Computational phonology: Representing sounds

- Orthographic systems are not always transparent representations of pronunciation.
    - Examples?
- Why/when would we need to know how a word is pronounced?

Phonetics

- The study of the speech sounds of the world's languages

- Speech sounds can be described by their place and manner of articulation, plus some other features (oral/nasal, length, released/unreleased). [articulatory phonetics]

- Also: acoustic phonetics and perceptual phonetics

Phonetics

- Alphabetic writing systems represent the speech sounds used to make up words, but imperfectly:
    - Predictable phonological processes not represented (examples?)
    - Historical muddling of systems is common (examples?)
- IPA: An evolving standard with the goal of transcribing the sounds of all human languages.
- ARPAbet: A phonetic alphabet designed for American English using only ASCII symbols.

Phonological rules

- Much of the distribution of actual speech sounds in any given language is predictable.

- Particular phones can be grouped into equivalence classes (allophones) that appear in phonologically describable environments.

- Phonological and morphophonological rules relate underlying representations to surface forms.

- Computational phonology: What kinds of rules are required to model NL phonological systems, and how can they be implemented (with finite-state technology or otherwise)?

Computational phonology: Tasks

- Given an underlying form, what is its pronunciation?
- Given a surface form (pronunciation), what is the underlying form?
- Given an underlying (or surface) form, where are the syllable boundaries?
- Given a database of underlying and surface forms, what are the rules that relate them?
- Given a transcribed or written but otherwise unannotated corpus, what are the morphemes in it (and which ones are different forms of the same morpheme)?

SPE/FST rules

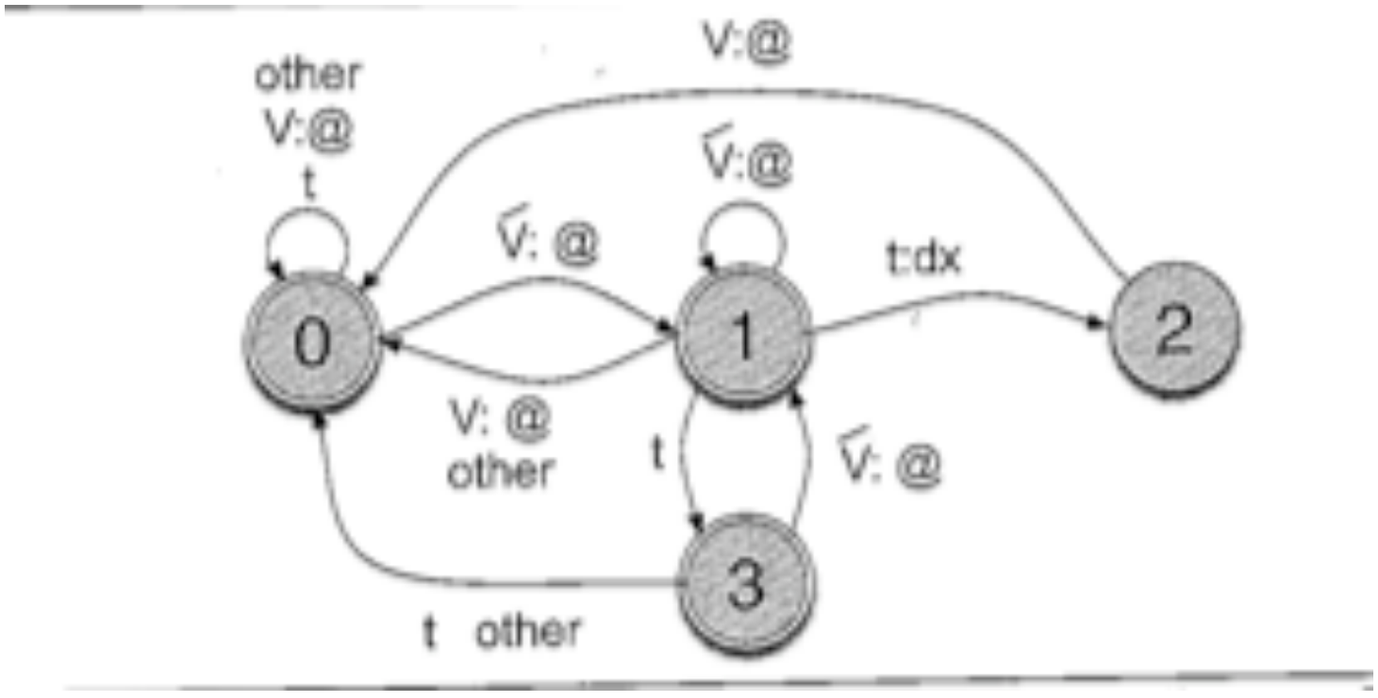
- Flapping rule: $/\mathrm{t}/ \rightarrow [\mathrm{dx}] \; / \; \acute{\mathrm{V}} \_\_ \; \mathrm{V}$

- “accepts any string in which flaps occur in the correct places, and rejects strings in which flapping doesn’t occur, or in which flapping occurs in the wrong environment”

- What strings should we use to test these claims?

Flapping rule as FST

- Fig 11.1, pg 362 of J&M. “other” is any feasible pair not used elsewhere in the transducer; “@” is any symbol not used elsewhere.



Rule ordering

- Rules can feed or bleed each other, but creating or destroying the next rule's environment.

- A long standing issue in phonology is whether rule systems require extrinsic ordering, or whether all ordering is intrinsic

- Example: faks+z ('foxes')

$$\epsilon \rightarrow [\text{barred i}] \; / \; [+\text{sibilant}] \; \hat{} \; \_\_ \; \text{z} \; \#$$

$$/\text{z}/ \rightarrow [\text{s}] \; / \; [-\text{voice}] \; \hat{} \; \_\_ \; \text{z} \; \#$$

More elaborate rule ordering: Yawelmani Yokuts

- Vowel harmony: suffix vowels agree in backness and roundness with the preceding stem vowel, if the vowels are of the same height.
- Lowering: Long high vowels become low.
- Shortening: Long vowels in closed syllables become short.
- Order: Harmony, Lowering, Shortening:
  - /ʔu:t’+it/ → [ʔo:t’ut]
  - /sudu:k+hin/ → [sudokhun]
- How do we know what the underlying forms are?
- How do these examples show that that’s the order?

Modeling rule ordering

- Cascaded or composed FSTs
- But: Most phonological rules are independent of each other.
- Koskenniemi's two-level rules run in parallel and finesse the issue of ordering by potentially referring to both underlying and surface forms.
- Example: Fig. 11.6

More on two level rules

- Two level rules can refer to upper or lower tape (or both) for both left and right context.

- Different types of two level rules differentiated by when they apply: a is realized as b whenever it appears in the context c d, only in that context, always and only, or never.

- XFST allows both approaches. Composing FSTs out of notionally ordered rules can be easier for linguists to maintain.

Another approach: Optimality Theory (OT)

- Grammar consists of GEN and EVAL
- GEN takes an underlying form and produces all possible surface forms.
- EVAL consists of a set of ranked constraints and an algorithm for choosing the best candidate.
- The best candidate is the one who's highest constraint violation is lower than any of the others. In the case of a tie, the next constraint violations are considered.
- Constraints are meant to be universal, ranking language-specific ⇒ 'factorial typology'

Example tableau

/?ilk-hin/	*Complex	FaithC	FaithV
?ilk.hin	*!		
?il.khin	*!		
?il.hin		*!	
?i.lik.hin			*
?ak.pid		*!	

Implementing OT

- Explicit interpretation of constraints
- GEN: a regular relation (FST)
- EVAL: Cascade the constraints, but with ‘lenient composition’, defined in terms of priority union (Karttunen 1998)
  - .P. (priority union): Q .P. R = Q | [~[Q.u] .o. R]
  - ‘Take all mappings from Q and those from R that don’t conflict.’
  - .0. (lenient composition): R .0. C = [R .o. C] .P. R
  - ‘Compose GEN with a constraint, but for inputs that have no perfect output, pass them through unchanged.’

Counting violations

- OT is finite-state under one important condition: There is a finite upper bound on the number of violations to be considered.

- The winning candidate is the one with the least violations of the highest-ranked constraint.

- Lenient composition alone isn’t enough to capture this.

- Instead: separate constraints for each number of violations

- Need to decide ahead of time how many to put in

Counting violations

- “It is curious that violation counting should emerge as the crucial issue that potentially pushes optimality theory out of the finite-state domain thus making it formally more powerful than rewrite systems and two-level models. It has never been presented as an argument against the older models that they do not allow unlimited counting. Is the additional power an asset or an embarrassment?” (Karttunen 1998, p.11)

Learning Rankings

- Tesar & Smolensky (1993, 1998): Error-Driven Constraint Demotion, learns ordinal rankings.

- Boersma (1997, 1998, 2000): Gradual Learning Algorithm learns stochastic rankings, can handle optionality and variation, as well as noisy training data.

Learning Rules

- Machine learning systems automatically induce a model for some domain, given some data and potentially other information.

- Supervised algorithms are given correct answers for some of the data and use the answers to induce generalizations to apply to further data.

- Unsupervised algorithms works only from data, plus potentially some learning biases.

Learning rules

- Ex: Gildea & Jurafsky (1996) specialize a learning algorithm for a subtype of FSTs to learn two-level phonological transducers from a corpus of input/output pairs.

- Learning biases: Faithfulness and Community

Reading questions

- How should we understand "the output from one rule affects the input to another rule"? Does it mean, for example, the output of attaching "s" to "pitch", which is "pitches", affects the input of pronunciation rule, so in the end the word should be pronounced as "p iy ch ix z" instead of "p iy ch e s"?

- Why there is no completely agreed-upon definition of syllable boundaries? Why it is so hard to decide how many syllables appear in certain words?

- How to measure the sonority of a sound?

- The book describes how phonological parsing can be done over specific sounds, looking to be IPA consonants/vowels and syllables. Can phonology account for other sound differentiation (such as stress or intonation) or would that be covered elsewhere?

Reading questions

- I found it difficult to equate the finite state machines that were used as examples of harmony and English flapping with the equivalent phonological rules and would like to review these in class, and also how they relate to the idea of two-level morphology.

- What is the difference between a:b <= c _ d and a:b <=> c _ d rules for two-level morphology? To me, their descriptions sound like the same thing worded differently.

- In the rule type table on page 363 I was confused by the distinction between the -> and <-> rules even though I know one is obligatory and one is not, mostly because the wording of the interpretations seemed very similar ("a may be realized as b only in the context c_d" vs. "a must be realized as b in context c_d and nowhere else").

p.363 rule types

- a:b <= c_d a is **always** realized as b in the context c_d
- a:b => c_d a may be realized as b **only** in the context c_d
- a:b <=> c_d a must be realized as b in the context c_d and nowhere else
- a:b /<= c_d a is never realized as b in the context c_d

Reading questions

- Do computational models for syllabification vary within a language depending on which accent they model?

- Have there been any attempts to pair syllabification programs with morphological parsers? A lot of affixes also mark syllable boundaries, and it seems like doing this would often allow you to avoid hand-coding language-specific syllable rules to get the proper result (e.g., wea-kness vs weak-ness).

Reading questions

- I'm not sure I understand Optimality Theory even after reading the chapter. Does it mean that you create every possible stem+affix combination, and then pick the best one according to some heuristics? And is this process then repeated for different parts of the word?

- I do not really get the theory itself. Was it just an example that gives us rules that we do not need to fully understand at this moment?

Reading questions

- Is there a reason that the GEN function in OT must produce "all imaginable surface forms, even those that couldn't possibly be a legal surface form for the input"? It seems like this creates the need for the faithfulness constraints, which end up being considered 'lenient' anyway.

- What is an example of two constraints in Stochastic OT overlapping in their distribution? How is it that a lower-ranked constraint can override a higher-ranked constraint? And how do we know which constraint is ranked higher than the other constraint?

Reading questions

- Maybe this is overly broad but I'm curious about what principles machine learning works on. What is usually meant by a machine learning algorithm, for example? How is machine learning implemented? I think unsupervised learning seems self-explanatory as a concept even though I don't know how it actually happens, but how is machine learning "supervised"?