Linguistics 219 Phonological Theory III
B. Hayes Spring 2019

Class 2, 3/4/2018: Interpreting Results; Cluster Analysis; The Framework Bazaar

1. Assignments

- Read Zuraw and Hayes (2017)
  - Covers the framework bazaar and makes an argument about who wins!
  - On web site.
- Start on your homework — medial clusters.
  - This is probably the biggest homework and is due in 12 days, Monday April 16.

2. What have we got so far?

- Linguistics extends its goals:
  - from its ur-homeland in providing satisfying accounts of patterns in a data corpus
  - … to attempts at prediction
- We are seeking a good framework of constraint-based linguistics, hoping to make predictions.
- Criteria:
  - Should be grounded in what mathematically-qualified people have found about valid inductive reasoning and predictive models — hence mostly likely probability theory.
  - Should account for variation in output and ambivalence in judgment, likewise, therefore probability.
  - Ambivalence in judgment = incomplete basis for belief, which fits with the Jaynesian view of what probability is.
- Maxent has sound mathematical foundations and seems a good thing to try.
  - It combines evidence from multiple sources (in linguistics, called "ganging")
  - It demands more evidence to approach certainty.
  - We can borrow work by computer scientists[1] we can use algorithms to match quantitative data optimally — cf. last time, hand-setting vs. machine-setting the weights for Tapping.

3. How to cite maxent framework

- My personal practice is to cite:
  - Smolensky, Paul (1986) Information processing in dynamical systems: Foundations of Harmony Theory. In Parallel Distributed Processing: Explorations

[1] The big papers appear to be: Berger, Adam; Stephen Della Pietra; and Vincent Della Pietra. 1996. A maximum entropy approach to natural language processing. Computational Linguistics 22. 39-71. and Della Pietra, Stephen, Vincent J Della Pietra & John D Lafferty. 1997. Inducing features of random fields. IEEE Transactions on Pattern Analysis and Machine Intelligence 19. 380–393.

in the Microstructure of Cognition, Vol. 2: Psychological and Biological Models, ed. by James L. McClelland, David E. Rumelhart and the PDP Research Group, 390-431. Cambridge, MA: MIT Press. All the math is here — just no language!

- Goldwater, Sharon & Mark Johnson. 2003. Learning OT Constraint Rankings Using a Maximum Entropy Model. In Jennifer Spenader, Anders Eriksson & Östen Dahl (eds.), Proceedings of the Stockholm Workshop on Variation within Optimality Theory, 111–120. Stockholm: Stockholm University. Brought the framework back to notice, reanalyzing examples from Boersma and Hayes (2001.

4. Return to our /f/ Voicing example

- We seek a model that includes constraints embodying various factors:
  - Why should [v] be favored in general?
  - Why should [f] be favored in general?
  - What circumstances totally rule out [v]?
  - What circumstances make [v] especially likely?
- We can now easily implement this with our data file, obtaining predictions about every word — existing, or wug words like *heaf*.
  - These attempt to be a model of the native speakers *tacit degree of belief* that a noun ending in [f] should take a [v] plural.

5. Looking at the output of the grammar

- Do a probability sort within categories and plot.
  - with more refined data, a scattergram is appropriate
- Are the forms predicted to be impossible, impossible?
- What are the most likely [f] plurals to be pronounced innovatively with [v]?
- What of Berko's *heaf* form, where we already have a modest real probability value?
- What distinctions are made among the existing forms?

6. Significance testing for maxent models

- There are many ways to do this.
- The simplest is the **likelihood ratio test**.
- Double the improvement a new constraint makes in likelihood, use **chidist(x, y)**, where
  - x is the doubled improvement
  - y is usually 1; but if you're interested in the improvement from adding a batch of constraints, y is the number you are adding.

7. Logistic regression

- Maxent when there are just two viable candidates is called **logistic regression**.
- This opens up many further options.
  - Software, e.g. R.[2]

[2] A fine program for maxent in general is the Maxent Grammar Tool by Wilson and George, on my web site.

- Different significance tests
- Above all, random effects — Jesse Zymet's dissertation topic ("lexical propensity")

PREPARING FOR THE HOMEWORK: MEDIAL CLUSTER ANALYSIS

8. A recent personal experience

- My appointment with a thoughtful grad student at Cornell.
- Says,
  - "Everybody thinks the Syllable Contact Law is relevant to my language's phonology, but I'm not so sure."
  - "It seems to me that other, independently motivated constraints will do the work we attribute to the Law, which is then perhaps not needed."
- I think we need some way of testing such claims, in principle more precisely than "satisfying account"!
- Perhaps creating a complete model, assigning a probability to every logically possible medial cluster, might help — does Syllable Contact Law help, at a statistically significant level?

9. The "Markedness Only" approach to phonotactics

- To my knowledge this was invented by Hayes and Wilson (2008), though the idea is pretty obvious.
  - Bruce Hayes and Colin Wilson. (2008) A maximum entropy model of phonotactics and phonotactic learning. *Linguistic Inquiry* 39, 379-440.
- Assign a probability to every form in GEN.
- Or, perhaps, every form in GEN less than 20 phonemes long…
- This can only use Markedness constraints — so things like Positional Faithfulness cannot be used.

10. How phonotactics is done in classical OT (Prince and Smolensky 1993)

- Rich Base: everything can be an input
- Grammar as filter: some inputs get changed to something else.
- The full set of "something elses" and survivors form the set of legal forms.
- I worry about the ability of this system to capture marginal cases: ?[pɔɪk] is mildly aberrant to me, but I have no inclination to repair it (e.g. to [paɪk]).

11. The goal at hand (homework)

- Suppose the Markedness Only theory of phonotactics is correct.
- Doing whole languages is a huge job (see Hayes/Wilson, and their software, which uses finite state machines to cover vast sets of strings).
- But medial consonant clusters: V<u>CC</u>V as manageable: GEN is only the square of the number of consonants.

- So: obtain a full, explicit, gradient analysis of some language's phonotactics, using maxent.

12. Step 1: obtain an electronic lexicon from the Internet

- You want phonemic listings (IPA not essential).
- Hopefully not too huge a consonant inventory
- Perhaps useful not to have too many VCCCV.
- I have found I sometime have to steal the data one letter at a time.

13. Sample solution

- I did **Warlpiri** (Australia, a focus of colleague Margit Bowler, outstanding linguists have worked on it for decades; good online resources and book references).
- I also made extensive use of the excellent 1980 MIT dissertation by David Nash, which covers the phonology and particularly the medial clusters.

14. Grabbing the dictionary

- Download the whole online dictionary one initial letter at a time.
- Discard all but the entries:
  - In Word, replace every space with a tab.
  - Paste into Excel, and keep only the first column.
  - Sort that column and discard crud.

15. Forming a list of medial clusters with counts

- Harvest the medial clusters:
  - Paste first column of spreadsheet into Word, then
  - Replace the long vowel digraphs *aa*, *ii*, *uu* with single symbols.
  - Replace every vowel with *tab vowel tab*
  - Paste result back into Excel and intervocalic consonants and clusters are all in the same column! (no vowel initial words or hiatus)
- Reduce the medial clusters, original a list of tokens, to single counted types
  - I use my Typizer, toy software I can share.
  - In Excel a pivot table will do it.
- Discard the singletons (VCV)
- Starting with a list of the consonant phonemes, make a list in Excel of all logical combinations.
- Plug in the frequencies for the attested and zeros elsewhere.
- Now you are ready to analyse!

16. Maxent analysis of clusters on a spreadsheet

- Add a lot of columns with feature values needed for both C1 and C2.
- Then use the formula = IF(AND(….), 1, 0) to assign constraint violations.

    - … can be references to feature values, or to segment identity.
- The rest is just plain phonology: use your brain/guile to find really good constraints, and watch the log likelihood go up.
- A scattergram of observed/predicted can lead to increased analytical excitement.
- It is useful to include a column that detects the biggest overgeneration error (higher predicted probability than observed probability).

THE FRAMEWORK BAZAAR

17. Historical theme

- As the "predictionist" approach increases (maybe) in influence, phonologists have gradually moved from models that are straightforward extensions of OT to models that are borrowed from probability and statistics.
- Perhaps this is right?
    - Why should *we* necessarily invent the best ways to go from data to prediction, when this is an issue addressed throughout science?
    - … admitting that, of course, language might be special…

18. Anttilean strata

- Formally:
    - Assume strata of constraints, each ranked collective above the next one down, but with free ranking within strata.
    - Construct all grammars compatible with the strata.
    - Assume they are equiprobable
    - This generates probabilities.
- This idea was proposed by Arto Anttila, e.g. in
    - Anttila, Arto. 1997a. *Variation in Finnish phonology and morphology*. Doctoral dissertation, Stanford University, Stanford, Calif.
    - Anttila, Arto. 1997b. Deriving variation from grammar: A study of Finnish genitives. In *Variation, change and phonological theory*, ed. Frans Hinskens, Roeland van Hout, and Leo Wetzels.
- BH editorial opinion [caution: possible rant approaching!]: I'm not a fan:[3]
    - Probabilities form a coarse set, with just a few values.
    - Very poor at combining evidence from multiple sources.
    - Of all the frameworks tried by Zuraw and Hayes (2017), this performed by far the worst on their data — primarily, for reason just given.
    - Why assume that human children are such crummy learners, when empirical work shows a remarkable ability to match frequencies in ambient data?
    - (For frequency-matching citations, see Zuraw/Hayes readings.)

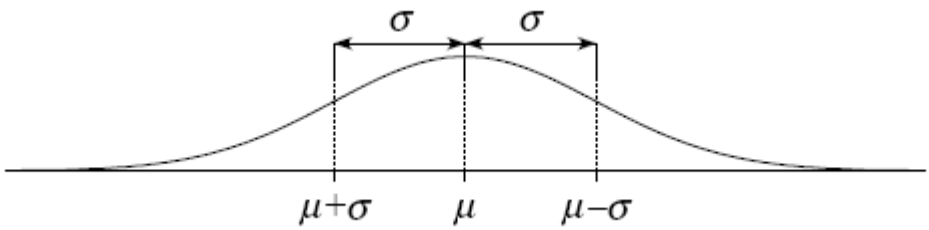
[3] It's very elegant work, and I *used* to be a fan! My objections are only empirical.

- Anttila (and his colleague Paul Kiparsky) repeatedly have emphasized the restrictiveness of this approach; but excess-power arguments are trumped, I think, by insufficient-power arguments.

19. Boersmian Stochastic OT

- Boersma dissertation (1998), applied to phonology in Boersma and Hayes (2001, *LI*)
- Every constraint has a number that represents its strength.

- Jiggle each such number whenever you use the grammar, assigning a bit of Gaussian noise.

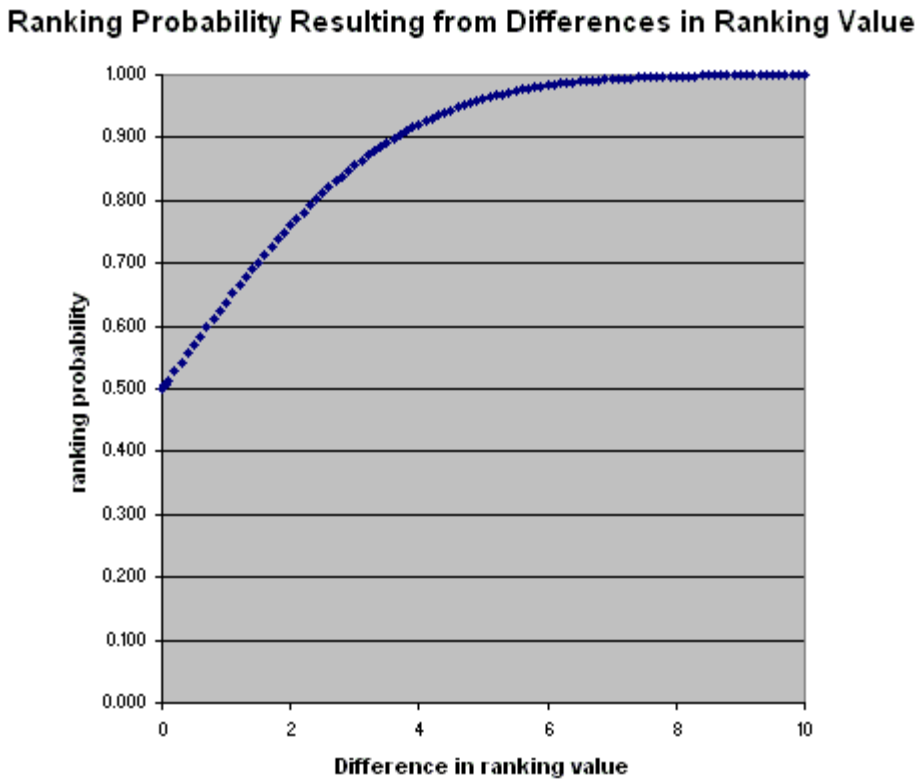


- Once you have jiggled, you get a complete constraint ranking, which generates a winner as in standard OT.

20. Part of a spreadsheet

http://www.linguistics.ucla.edu/people/hayes/GLA/RankingValuesToProbabilities.xls

Difference in ranking value	*Probability higher outranks lower*
0	0.5
0.1	0.51
0.5	0.57
1	0.64
5	0.96
10	0.9998
50	1.00000000



21. A personal evaluation of this

- It can combine evidence from multiple sources, but only in limited ways and circumstances.
  - See Zuraw/Hayes paper for detailed diagnosis of where/how it fails to do this.
  - In essence, free combination often requires a constraint to be in two places at once on the Boersmian scale.
- Setting the weights (a.k.a. ranking values) has proven to be very problematic.
  - No provably convergent algorithm exists.
  - The leading one, the Gradual Learning Algorithm, behave erratically; fails on simple grammars (Pater (2008, *LI*)), and often sends the weights off toward infinity as no convergence occurs. Plenty of frustration in my own personal history as a user.
- It still has defenders, notably the stalwart Giorgio Magri, who has tried to improve the Gradual Learning Algorithm.

22. Noisy harmonic grammar

- References:
  - Boersma, Paul, and Joe Pater. 2008/2016. Convergence properties of a gradual learning algorithm for Harmonic Grammar. Amsterdam and Amherst, MA: University of Amsterdam and University of Massachusetts ms. Rutgers Optimality Archive. Published 2016 in John McCarthy and Joe Pater, *Harmonic Grammar and Harmonic Serialism*

- Potts, Christopher, Joe Pater, Karen Jesney, Rajesh Bhatt & Michael Becker (2010). Harmonic Grammar with linear programming: From linear systems to linguistic typology. *Phonology* 27, 77-117. (non-stochastic version)

- This is a lot like maxent; again you calculate a Harmony score for every candidate.
- But you jiggle the harmony scores stochastically, deriving a winner for each evaluation time, just like in Stochastic OT.

23. Many varieties exist

- See
  - Bruce Hayes (2017) Varieties of Noisy Harmonic Grammar. *Proceedings of the 2016 Annual Meeting in Phonology*, USC.
- E.g., where do you put the noise?
  - On the constraint weights (= classical version)
  - In the tableau cells
  - On the harmony values (behaves amazingly like maxent)

24. Assessment

- I personally feel this framework is in contention:
  - Performs about as well in practice (I suspect) as maxent.
  - No proof of convergence for learning algorithm, but I have never seen it misbehave.
  - Combines evidence from multiple sources in making predictions (in the very same way as maxent, its partner in stochastic Harmonic Grammar).

RETURN FROM THE BAZAAR TO PONDER: WHAT ARE THE ISSUES IN FRAMEWORK CHOICE?

25. Ganging

- I've portrayed ganging as deeply rational and wholesome, but what are the linguistic facts?
- Perhaps one could say that ganging is increasingly noticed in phonology as people look for it.
- Some feel (unpublished work of Edward Flemming) that ganging is a property of optional phonology, and that "crystallized", obligatory phonology doesn't gang.
  - A tall order to explain, and worth pondering.

26. Harmonic bounding

- A harmonically bounded candidate in OT has a strict superset of the violations of a rival candidate.
- In classical OT, it can never win.
- In stochastic OT, it can never win.
- In maxent, it can, but never with the highest probability.

- Noisy Harmonic Grammar: usually it can (see Hayes paper), but there is one little-explored variant (Exponential Noisy Harmonic Grammar), in which it cannot.

27. Implication I

- Be very careful when you do analysis in maxent, because you must include harmonically bounded candidates in the candidate set.
    - We lose a luxury that we had in classical OT analysis.

28. Implication II

- It becomes empirically important whether harmonically bounded candidates win in real life.
- I think they can be found in:
    - Phonotactics (the Markedness-only approach)
    - Metrics (see Hayes and Moore-Cantwell 2012 *Phonology*, paper with Russ Schuh under revision)
    - Syntax-phonology interface: multiple phrasings from one syntactic structure.
- Harmonic bounding currently has Mom-and-apple-pie status (restrictiveness, ease of analysis) and it will take a lot of empirical argument for it to lose this status.