Treebanks and evolutionary simulation for explaining typological patterns

Treebanks and Linguistic Theory 7
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Linguistic typology

- Linguistic typology studies linguistic variation across time and space
- How do human languages differ? How are they the same? Are there true language universals? Are there broad tendencies?
- Even more importantly, why? Where do the observed patterns come from?
- Relation to human cognition and the 'language faculty'

Linguistic typology

- Typological databases provide the raw material for typological theorizing
- Phonetics and phonology
  - Phoneme inventories
  - Syllable types and phonotactics
- Morphology
  - Surrey Syncretism Database
- Syntax
  - World Atlas of Language Structures
  - Utrecht Typological Database System

Linguistic typology

- Standardized metalanguage ('basic linguistic theory')
- Typological databases list properties at the level of languages or language families
  - WALS entry for English
  - 'English has SVO word order'
  - 'Dutch has no dominant word order'
- Language databases record facts about linguistic competence
- They necessarily abstract away from a lot of messy details

Evolutionary phonology

- Evolutionary phonology (Juliette Blevins) accounts for phonological patterns via sound changes
- Multiple sources for sound pattern similarity (Blevins 2007)
  - Cognitive Factors
  - Direct inheritance
  - Indirect inheritance
  - Phonetic factors
  - Language-specific factors
  - Chance

Evolutionary phonology

- Devoicing of word final obstruents (*b*, *d*, *g* → *p*, *t*, *k*)
- Final devoicing is phonetically a very natural sound change
- Many evolutionary pathways will lead to final devoicing
- The need to maintain lexical contrast will sometimes work against the tendency towards final devoicing
- No natural sound changes lead directly to final voicing, but under the right circumstances it could arise anyway (Breton, Lezgian)

Explanation

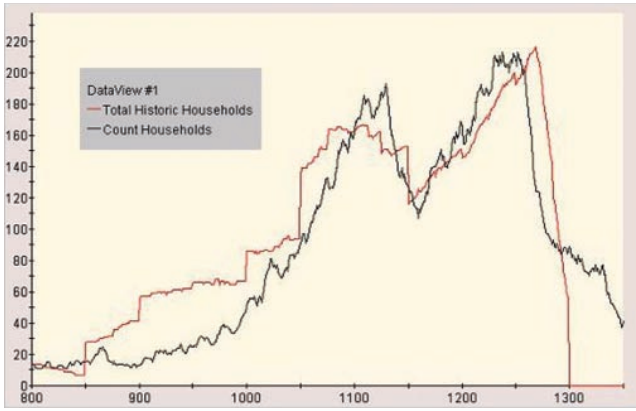
- Does EP really *explain* the observed variation?
- Generative social science (Epstein 1999) "If you didn't grow it, you didn't explain it."
- "The Generativist's Question: How could the decentralized local interactions of heterogeneous autonomous agents generate the given regularity?"
- "To explain a macroscopic regularity *x* is to furnish a suitable microspecification that suffices to generate it. The core request is hardly outlandish: To explain a macro-*x*, please show how it could arise in a plausible society. Demonstrate how a set of recognizable – heterogeneous, autonomous, boundedly rational, locally interacting – agents could actually get there in reasonable time." Epstein (2006:51)

Explanation

- The Anasazi inhabited the American Southwest from c. 1800 BC, experienced a 'Golden Age' beginning c. 900 AD, and disappeared c. 1300 AD
- Various explanations (climate change, internal social changes, external pressure from other groups), all supported by the archeological and geological record
- Axtell, *et al.* (2002) ran detailed agent-based simulations of Kayenta Anasazi (Long House Valley, AZ) agriculture and household creation using reconstructed climate data
- The simulations include many variables, but do not take into account institutional factors (social structure, property rights)

Explanation

- The simulation results are a close (but not perfect) fit to the actual population distribution



Paradigm Economy Principle

- Carstairs-McCarthy: There are as many inflection classes as there are realizations of the paradigm cell with the most realizations (Paradigm Economy Principle)
- Hungarian (factoring out phonologically conditioned allomorphy):

Sing	1	***-ok***	***-om***
	2	-sz	-ol
	3	***-Ø***	***-ik***
Pl	1	-unk	-unk
	2	-tok	-tok
	3	-nak	-nak

Paradigm Economy Principle

- It's not clear that this relation between number of markers and number of classes is 'surface true' in all languages:
  - Lots of footnotes and qualifications and riders and codicils
- But, inflectional class systems are reliably less complicated than they could be.
- Tundra Nenets has 14 NOM.SG. forms and 29 ACC.PL. forms, and 94 pairs (more than 29, but much fewer than 14×29=8,120)
- Why?

Paradigm Economy Principle

- What is the Paradigm Economy Principle a constraint on? (Carstair-McCarthy's "Two questions with one answer")
- Representations (Müller 2006)
  - Paradigm economy reveals something about the mental representation of morphology (genetic)
  - But, what about exceptions?
- Usage (Plank 1991)
  - Paradigm economy is a side effect of how language is learned or used (epigenetic)
  - But, why have inflectional classes at all?

Paradigm Economy Principle

- A usage-based theory of paradigm economy has to spell out:
  - Exactly what notion of 'simplicity' is relevant, and
  - How that then leads to the observed cross-linguistic patterns
- A paradigm can satisfy the paradigm economy without being particularly simple
- It's not a limitation on the number of classes
- It's not a memory restriction
- Why should language be simple, anyway?

The Paradigm Cell Filling Problem

- It is implausible that speakers of languages with complex morphology and multiple inflection classes encounter every inflected form of every word
- **Paradigm Cell Filling Problem**: Given exposure to a novel inflected word form, what licenses reliable inferences about the other word forms in its inflectional family?
- As languages depart from what Lounsbury's (1953) "fictive agglutinative ideal", predicting forms by analogy becomes increasingly important
- Complex paradigms are organized in a way to make the PCFP tractable (Ackerman, Blevins & Malouf 2009; Stump & Finkal 2009)

Finnish

(following the classification in Pihel & Pikamäe 1999:758-771)

Nom Sg	**Gen Sg**	**Part Sg**	**Part Pl**	**Iness Pl**	
ovi	oven	ovea	ovia	ovissa	'door' (8)
kieli	kielen	kieltä	kieliä	kielissä	'language' (32)
vesi	veden	vettä	vesiä	vesissä	'water' (10)
lasi	lasin	*las**ia***	*las**eja***	*las**eissa***	'glass' (4)
nalle	nallen	nallea	*nall**eja***	*nall**eissa***	'teddy' (9)
kirje	kirjeen	kirjettä	kirjeitä	*kirj**eissä***	'letter' (78)

- To deduce the Finnish nominative for *pantti* 'pants', it is enough to know the partitive singular *panttia* (on analogy with with *lasi*~*lasia* 'cup')
- Knowing the partitive plural *pantteja* restricts class membership to either 4 or 9
- Knowing the inessive plural *pantteissa* restricts membership to 4, 9, or 78

Paradigm entropy

- The **conditional entropy** is the uncertainty in one random variable on average, given that we know the value of another random variable

$$\begin{aligned} H(Y|X) &= -\sum_{x\in X} p(x) \sum_{y\in Y} p(y|x) \log_2 p(y|x) \\ &= H(X,Y) - H(X) \end{aligned}$$

- The conditional entropy of one cell given another is a measure of inter-predictability with a paradigm (Ackerman, Blevins, and Malouf 2009)
- In our Finnish partial paradigm, H(GEN.SG.)=1.792 bits but H(GEN.SG.|NOM.SG.)=1.333 bits

Paradigm entropy

- To extend this to the whole paradigm, we calculate the **expected** conditional entropy

$$E[H(c|c)] = \sum_{c_1,c_2} p(c_1,c_2) H(c_2|c_1)$$

- The higher the expected conditional entropy, the more difficult it is on average to predict an unknown wordform, given a known wordform
- For the Finnish partial paradigm, the expected conditional entropy is 0.663 bits
- This is an **upper bound** on the actual entropy

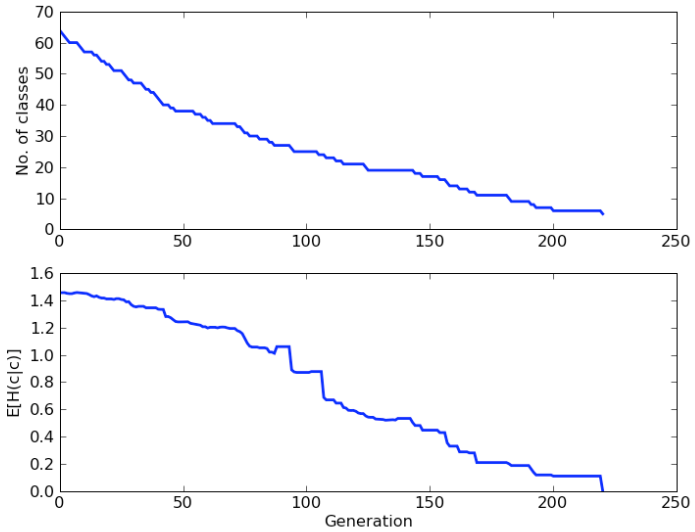
Paradigm Economy Principle

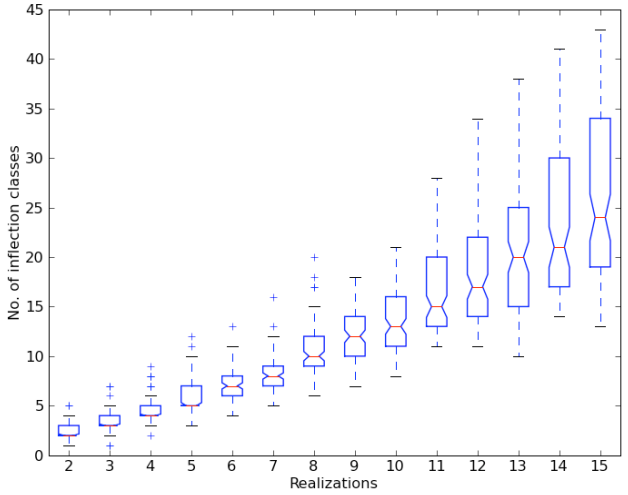
- **A hypothesis** (Plank 1991, Ackerman & Malouf 2008)

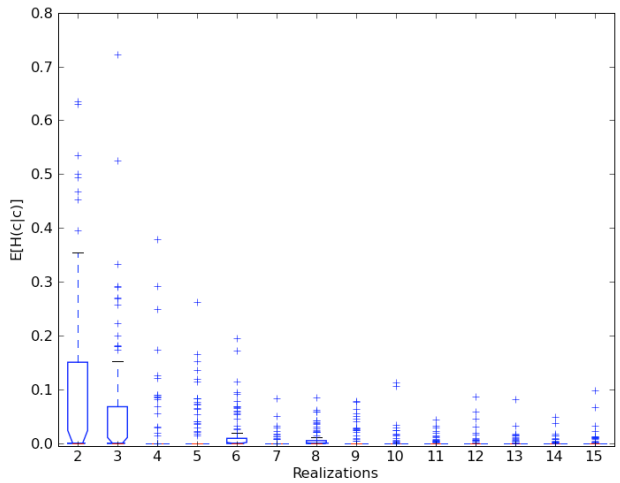
  Paradigms which satisfy the Paradigm Economy Principle are simpler w.r.t. the PCFP – and have lower expected conditional entropy – than paradigms that don't
- To test whether this is a possible explanation for the paradigm economy principle, we set up a simple evolution simulation
- Start with a maximally complex paradigm, with c cells, r realizations for each cell, and r^c inflection classes

Simulation

- On each generation, we randomly modify the language according to the PCFP
  - Select one cell of one inflection class as given
  - Guess realization of another cell based on the given cell
  - Reconfigure inflection classes as necessary
- Occasionally, a new form is introduced to fill an unknown cell
- Continue until we go $2cr$ generations without reducing the expected conditional entropy







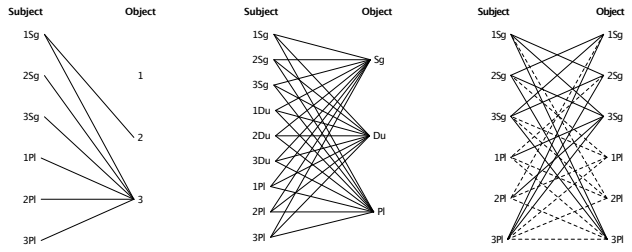
Simulation prospects

- We start with a plausible mechanism (small random changes to paradigms under the influence of PCFP)
- In our simulations, this leads to outcomes which are like real languages in some respects
- But, the average number of classes grows a little faster than the number of initial realizations
- And, the final state and entropy depend somwhat on the initial conditions and the distributions of forms
- Unlike the Anasazi case, we don't have enough information to fully evaluate the simulation results

Evolutionary typology

- If we want to explain typological patterns via simulation, we need detailed **quantitative** information about lots of languages
- For phonological simulations, segment and syllable inventories may be sufficient (Oudeyer 2002, Wedel & van Volkinburg 2009)
- For simple morphological patterns, lexicons with frequency information can be useful
- To look at the development of other morphological or syntactic constructions, we need linguistically annotated examples of language use in a natural context (i.e., treebanks)

Complexification



Hungarian Vogul, Tundra Nenets Mordvin

Locality

- **Morphosyntactic locality** (see also Sag 2004, 2008):

  '[L]ocality'. . . refers to the proximity of the agreeing element within the clause structure; a local agreement relation is one which holds between elements of the same simple clause, while a non-local agreement relation is one which may hold between elements of different clauses. (Bresnan and Mchomobo, 1987:52)

- We expect subject-verb agreement to be expressed locally within a clause
- Prenominal relative clauses form a clausal domain

Locality

- Quechua (Cole 1987:279; Cinque 2008)

  [nuna tanti-shqa-n] bestya
  man buy-PERF-3 horse.NOM
  'the horse which the man bought'

- Eastern Ostyak (Ackerman & Malouf 2004a):

  [wer-t-äm] kiriw
  make-PART-1SG boat
  'the boat which I will make'

- Eastern Armenian (Ackerman & Malouf 2004b):

  [gn-ac'-əs] hovanoc-ə
  buy-part-1SG umbrella-DEF
  'the umbrella which I bought'

Locality

- But, in a few languages, we find a surprising non-local pattern
- Tundra Nenets (Ackerman & Malouf 2004a):

  [ta-wi°] te-da
  give-PART deer-3SG
  'the deer s/he gave'

- Western Armenian (Ackerman & Malouf 2004b):

  [im əngeroč-ə nergayatsuts-adz] dəɣa-s
  1SG friend-DEF introduce-PPART boy-1SG
  'the boy that I introduced to the friend'

Conclusions

- Typologically unusual patterns arise through statistically unlikely evolutionary pathways; typologically usual patterns arise through statistically likely evolutionary pathways
- Simulation allows us to test hypotheses about different evolutionary constraints (language as a complex dynamic system)
- The raw material for (this kind of) typological theorizing needs to be treebanks, from as large and diverse a set of languages as possible
- Reasons to build a treebank, even if the market for QA or MT systems is vanishingly small