Locality and non-linear representations in phonology

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Introduction

The Big Picture

- What is the character of phonological generalizations?
  - **Well-formedness**
    blick vs. **bnick* (Chomsky and Halle, 1965)
  - **Transformations**
    write /raɪt/ →[raɪt]
    writer /raɪt+ər/ →[raɪɾər]
- How do we best characterize cross-linguistic variation in well-formedness patterns and transformations?
  - That is, what is a possible/impossible well-formedness pattern/transformation?
- How might they be learned?

Introduction

The Big Picture

- Criteria for evaluating a phonological theory
  a. Captures the attested generalizations
  b. Predicted typology is restricted in a principled way
  c. Has some learning model

Introduction

This talk

- Criteria for evaluating a phonological theory
  a. Captures the attested generalizations
  b. Predicted typology is restricted in a principled way
  c. Has some learning model
- This talk demonstrates that **tone well-formedness patterns** are fundamentally **local**, in a computational sense, over autosegmental structures
- A theory of well-formedness using **language-specific**, **inviolable** constraints which **forbid substructures** provides a unified explanation of cross-linguistic variation in tone and meets (a)–(c)

Introduction

This talk

- Criteria for evaluating a phonological theory
  a. Captures the attested generalizations
  b. Predicted typology is restricted in a principled way
  c. Has some learning model
- A local theory compares favorably to previous approaches to tone
- Directional association and rules in derivational frameworks (e.g., Goldsmith, 1976; Archangeli and Pulleyblank, 1994)
  - satisfy (a)
  - unclear with respect to (b)
  - have no current solution for (c)

Introduction

This talk

- Criteria for evaluating a phonological theory
  a. Captures the attested generalizations
  b. Predicted typology is restricted in a principled way
  c. Has some learning model
- Optimal satisfaction of violable constraints (Meyers, 1997; Yip, 2002; Zoll, 2003)
  - satisfies (c)
  - does not satisfy (a) or (b)
- Both derivational and OT explanations invoke a **globally** evaluated notion of directionality, miss the local nature of tone patterns

Computational locality

- *blick* vs. **bnick*
- Constraint: **#bn*
- This is a **forbidden substructure constraint**

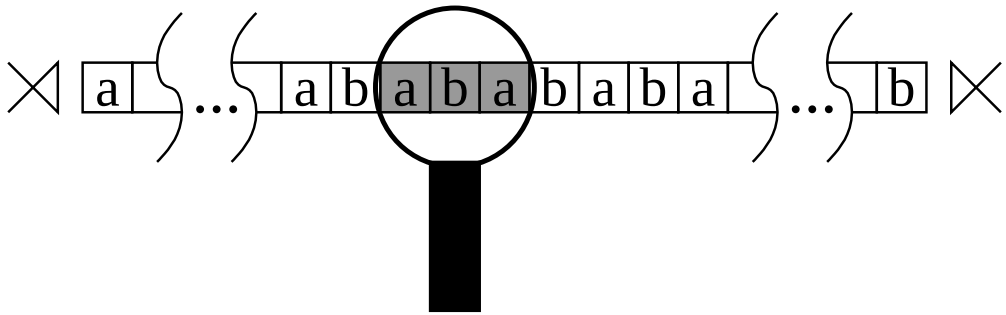
* | # | b | n |

| # | b | l | ɪ | k | # |

| **#** | **b** | **n** | ɪ | k | # |

Computational locality

- Well-formedness determined solely by well-formedness of local substructures



Rogers and Pullum (2011); Rogers et al. (2013)

- Classes of patterns thus described are extremely restrictive in their expressivity (McNaughton and Papert, 1971; Rogers and Pullum, 2011; Rogers et al., 2013; Heinz, 2010; Heinz et al., 2011)
- Such patterns can be efficiently learned (García et al., 1990; Heinz, 2010, 2011; Jardine and Heinz, accepted)

Tonal well-formedness patterns

How do we characterize the following variation?

- Attested
  - Fixed melodies realized over words of different lengths (all)
  - Contours and plateaus of tone may be restricted to left or right (Mende vs. Hausa)
  - Plateaus of a particular tone may be restricted (Kukuya)
  - Tones may appear on both edges (N. Karanga)
  - There must be exactly one of a particular tone (Hirosaki J.)
- Unattested
  - Patterns calculating over entire representation

Tonal well-formedness patterns

Mende word tone (Leben, 1973; Goldsmith, 1976)

H	a. kɔ́	H	‘war’	b. pɛ́lɛ́	HH	‘house’	c. háwámá	HHH	‘waist’
L	d. kpà	L	‘debt’	e. bɛ̀lɛ̀	LL	‘pants’	f. kpàkàlì	LLL	‘stool’
HL	g. mbû	F	‘owl’	h. ngílà	HL	‘dog’	i. félàmà	HLL	‘junction’
LH	j. mbǎ	R	‘rice’	k. nìká	LH	‘cow’	l. ndàvúlá	LHH	‘sling’
LHL	m. mbǎ̂	R-F	‘comp.’	n. nyàhâ	LF	‘woman’	o. nìkílì	LHL	‘nut’

- Words choose between 5 melodies (*HLH)
- Plateaus of tone appear at the right edge of the word
  HHH, HLL
  *LLH, *HHL
- Contours appear at the right edge of the word
  R, LF, *RL

Tonal well-formedness patterns

Hausa tone-integrating suffixes (Newman, 1986, 2000)

a. jáa	H	‘pull’	b. jíráa	HH	‘wait for’	c. béebíyáa	HHH	‘deaf mute’
c. wàa	L	‘who?’	d. màcè	LL	‘woman’	e. zàmfàrà	LLL	‘Zamfara’
f. jàakíi	LH	‘donkey’	g. jìmìnúu	HHL	‘ostriches’	h. bàbbàbbàkú	LLLH	‘roasted’
i. fáadì	HL	‘fall’	j. hántúnàa	LLH	‘noses’	k. búhúnhúnàa	HHHL	‘sacks’
l. mântá	FH	‘forget’	m. káràntá	HLH	‘read’	n. kákkáràntá	HHLH	‘reread’

- HLH allowed (LHL not depicted)
- Plateaus of tone appear at the *left* edge of the word
  LLH, HHL
  *LHH, *HLL
- Contours appear at the *left* edge of the word
  FH, *HR

Tonal well-formedness patterns

Kukuya word tone (Hyman, 1987; Zoll, 2003)

a. kâ ‘to pick’	F	b. sámà ‘conversation’	HL	c. káràgà ‘entangled’	HLL
d. sǎ ‘knot’	R	e. kàrá ‘paralytic’	LH	f. m^{w}àrə̀gí ‘brother’	LLH
g. bá ‘palms’	H	h. bágá ‘show knives’	HH	i. bálágá ‘fence’	HHH
j. bvĩ̂ falls’	R-F	k. pàlî ‘goes out’	LF	l. kàlə́gì ‘turns’	LHL

- Contours on right edge of word
- No plateaus of H in the presence of L

Tonal well-formedness patterns

N. Karanga Shona non-assertive tense
(Odden, 1986; Hewitt and Prince, 1989)

hàndákà-p-á	‘I didn’t give’	H
hàndákà-tór-à	‘I didn’t take’	HL
hàndákà-tór-ès-á	‘I didn’t make take’	HLH
hàndákà-tór-és-èr-á	‘I didn’t make take for’	HHLH
hàndákà-tór-és-ér-àn-á	‘I didn’t make take for e.o.’	HHHLH
hàndákà-tór-és-ér-ès-àn-á	‘I didn’t make take a lot for e.o.’	HHHLLH
hàndákà-tór-és-ér-ès-ès-àn-á	〃 〃	HHHLLLH

- Two Hs on either end, first spreads to three syllables maximally

Tonal well-formedness patterns

Hirosaki Japanese (Haraguchi, 1977)

Noun	Isolation	+NOM	Noun	Isolation
a. ‘handle’	é	e-gá	f. ‘chicken’	niwatorí
	H	LH		LLLH
b. ‘picture’	ê	é-ga	g. ‘lightening’	kaminarî
	F	HL		LLLF
c. ‘candy’	amé	ame-gá	h. ‘fruit’	kudamóno
	LH	LLH		LLHL
d.	amê	amé-ga	i. ‘trunk’	toránku
	LF	LHL		LHLL
e. ‘autumn’	áki	áki-ga	j. ‘bat’	kóomori
	HL	HLL		HLLL

- Exactly one H or F; F can only be word-final
  *L^n, *H...H, *H...F, *FL...

Tonal well-formedness patterns

Unattested generalizatons

- The number of Hs in the word must be in the Fibonacci sequence
- The number of Hs and Ls must be equal
- A single H appears as close to the center of the word as possible

Summary: Tonal well-formedness patterns

How do we characterize the following variation?

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Autosegmental representations

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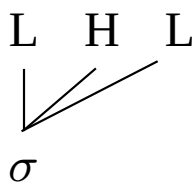

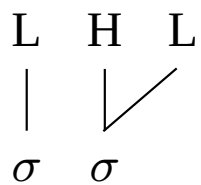

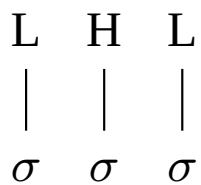

Autosegmental representations

- Tones behave independently of TBUs; Tiv (Pulleyblank, 1986):

sə́ŋ è sə́ŋ HLH ‘bird of bird’ [¯ _ ¯]

H L H
| | |
σ σ σ

sə́ŋ ꜜsə́ŋ HꜜH (same) [¯ ¯]

H L H
| |
σ σ

- Plateaus of tone behave as single units; Shona (Odden, 1980):

mbúndúdzí HHH ‘worm’ né-mbùndùdzì H-LLL ‘with worm’

H
|\
σ σ σ
mbu ndu dzi

H - L
| |\
σ - σ σ σ
ne - mbu ndu dzi

- Thus, I do not use alternatives (Cassimjee and Kisseberth, 2001; Shih and Inkelas, 2014)

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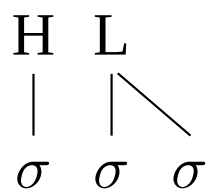
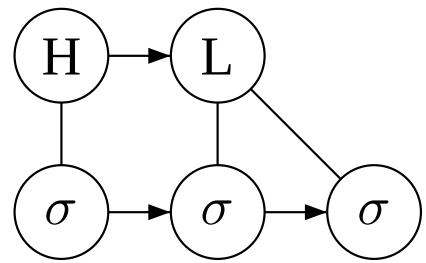
Computational locality

- What is a substructure in an autosegmental representation?
- Autosegmental representations are **graphs** (Goldsmith, 1976; Coleman and Local, 1991)

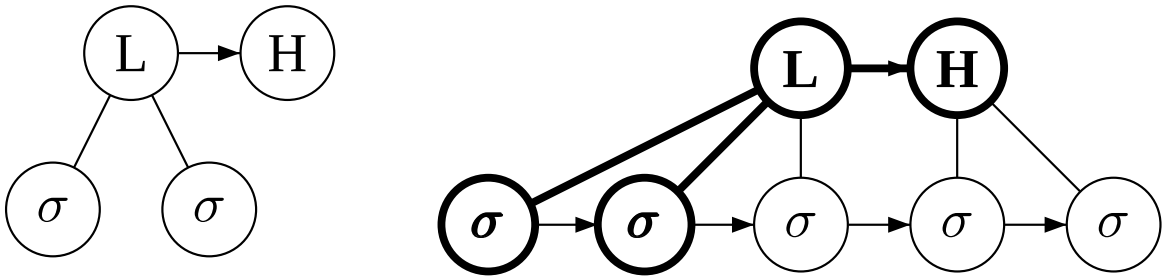
félàmà HLL ‘junction’
(Mende)



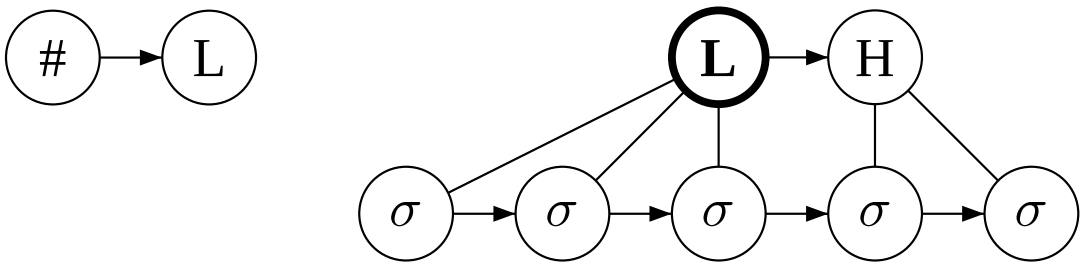


Computational locality

- Let a **subgraph** be some finite, connected piece of a graph



- Subgraphs may refer to boundaries on each tier (not depicted in full graphs)



Computational locality

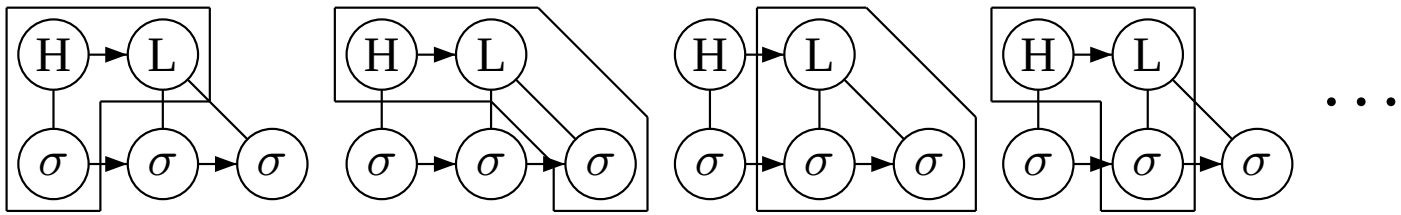
- We specify lists of **forbidden subgraph constraints** as in the following, where each ϕ_i is a subgraph:

$$\neg\phi_1 \wedge \neg\phi_2 \wedge \neg\phi_3 \wedge \ldots \wedge \neg\phi_n$$

- $\neg\phi$ means "ϕ is a forbidden substructure"
- These constraints are **inviolable** and **language-specific**

Computational locality

- Evaluation procedure now ‘crawls’ through graph



- Substructure constraints **provably** cannot specify patterns in which:
  - The number of Hs in the word must be in the Fibonacci sequence
  - The number of Hs and Ls must be equal
  - A single H appears as close to the center of the word as possible
  - ...

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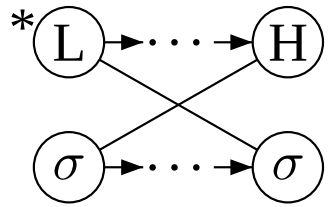
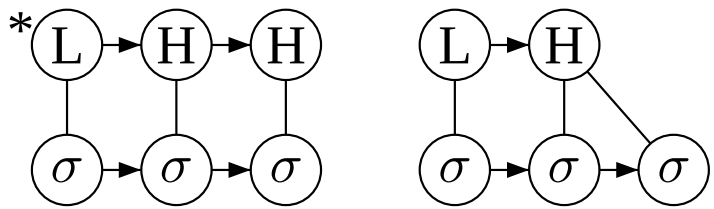
Some assumptions

- Association preserves precedence relations **(the No-Crossing Constraint (NCC))**



- Adjacent nodes on tonal tier cannot be identical **(the Obligatory Contour Principle (OCP)**

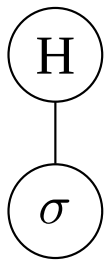


- Both of these arise as natural properties when we look at autosegmental representations as concatenation of primitives (Jardine and Heinz, 2015)

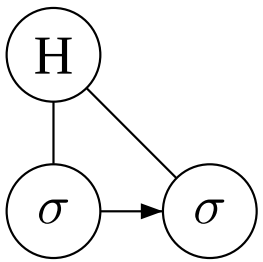
Case study: Mende

Representations

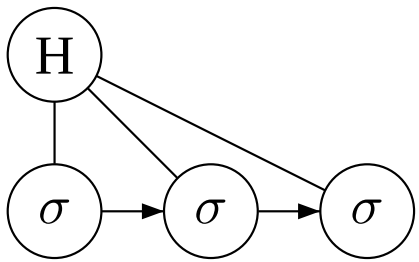
kɔ́
H
‘war’



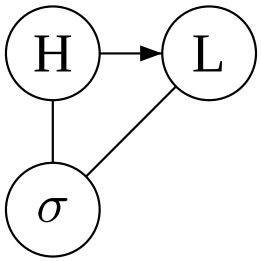
pɛ́lɛ́
HH
‘house’



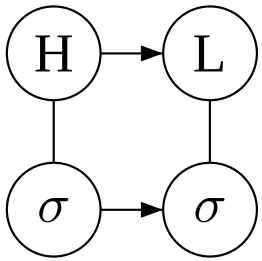
háwámá
HHH
‘waist’



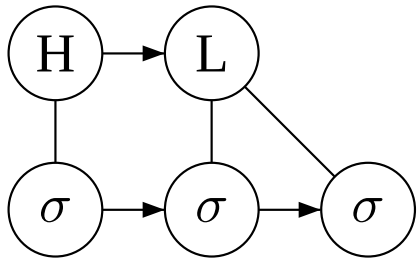
mbû
F
‘owl’



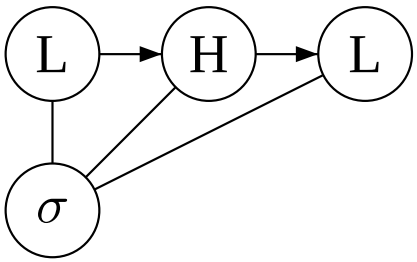
ngílà
HL
‘dog’



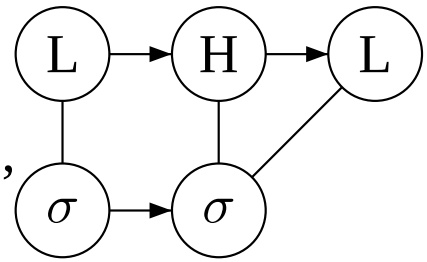
félàmà
HLL
‘junction’



mbă̂
R-F
‘comp.’

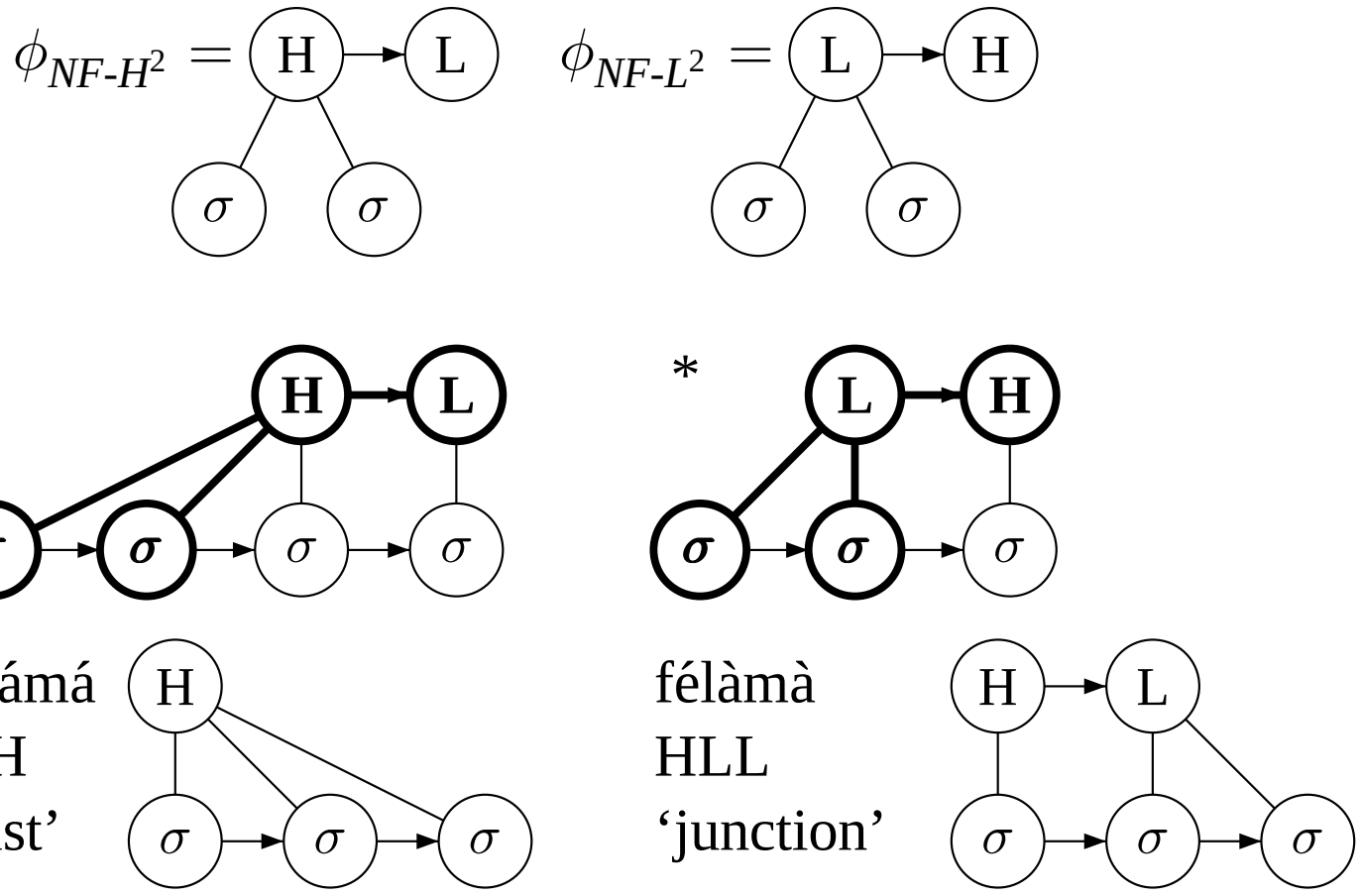


nyàhâ
LF
‘woman’



Case study: Mende

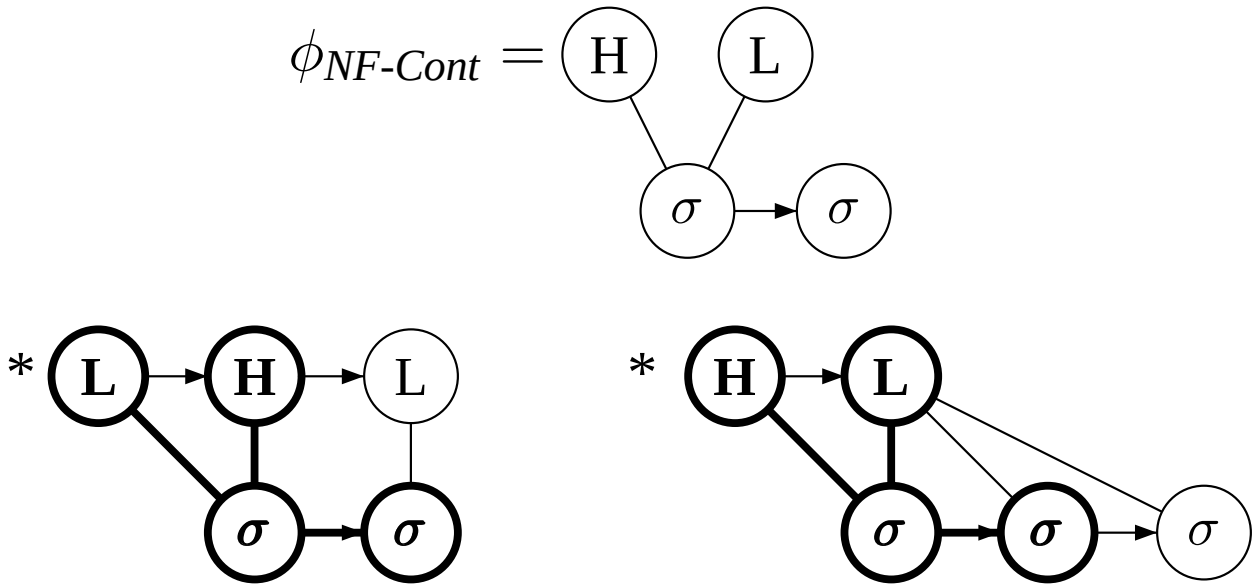
Plateaus



- Kukuya will use $\phi_{NF\text{-}H^2}$ but not $\phi_{NF\text{-}L^2}$

Case study: Mende

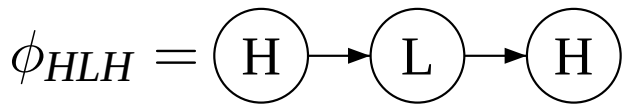
Contours

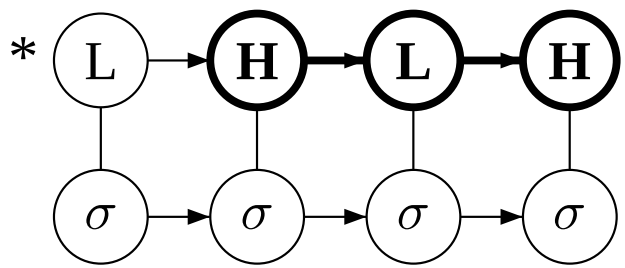


- c.f. Zhang (2000)

Case study: Mende

Melody constraint





Case study: Mende

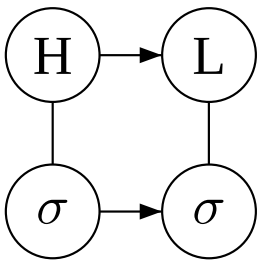
- Mende summary:

$$\neg\phi_{HLH} \wedge \neg\phi_{NF\text{-}Cont} \wedge \neg\phi_{NF\text{-}H^2} \wedge \neg\phi_{NF\text{-}L^2}$$

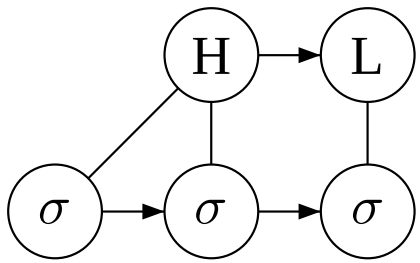
Case study: Hausa

Representations

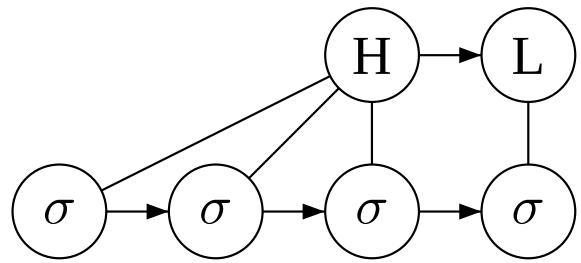
fáadì HL ‘fall’



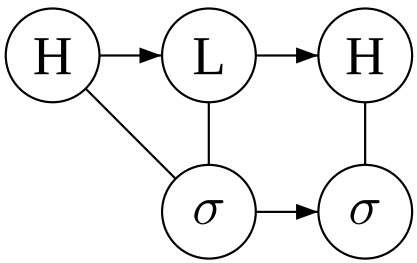
hántúnàa HHL ‘noses’



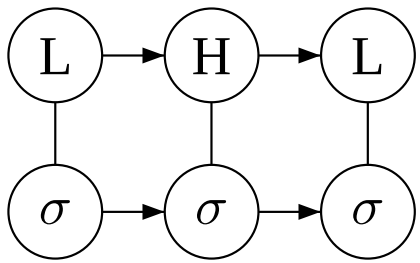
búhúnhúnàa HHHL ‘sacks’



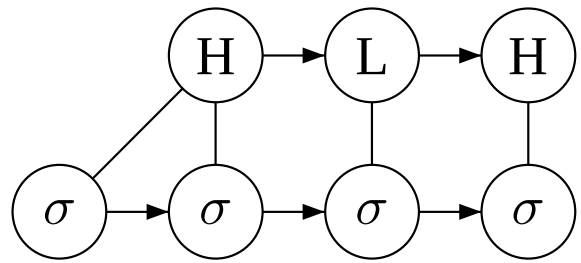
mântá FH ‘forget’



káràntá HLH ‘read’

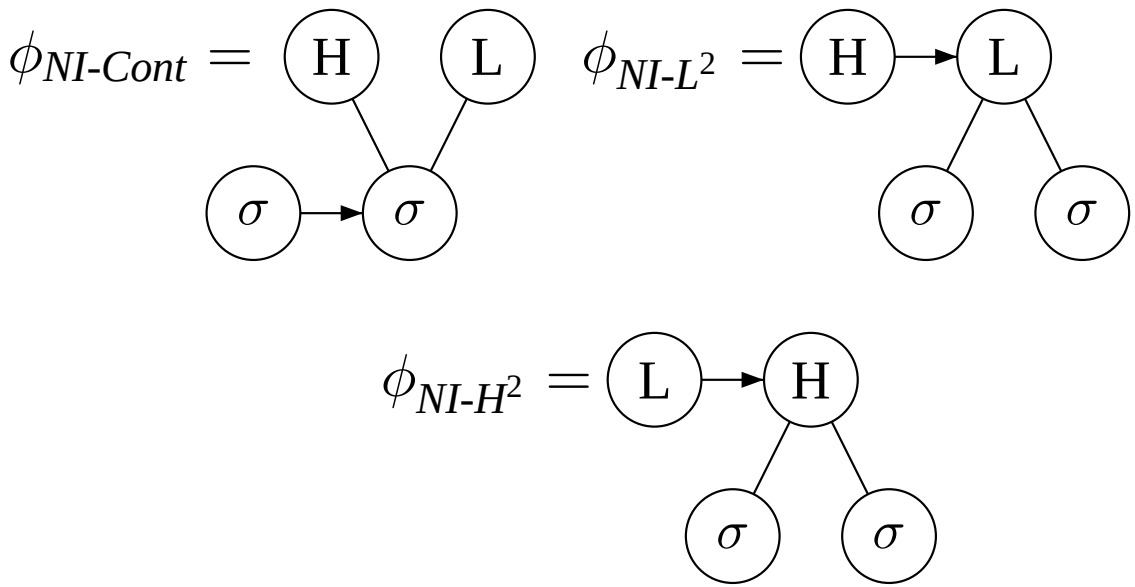


kákkáràntá HHLH ‘reread’



Case study: Hausa

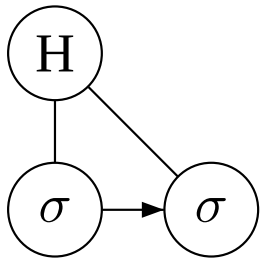
Constraints



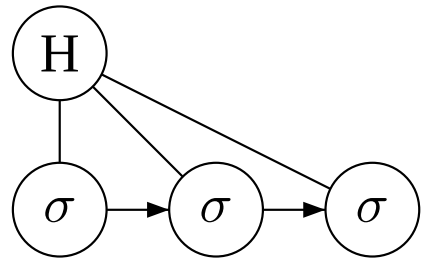
Case study: Kukuya

Representations

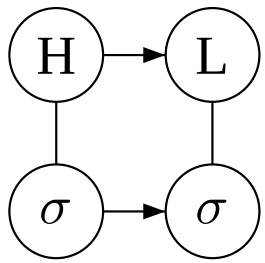
bágá
HH
‘show knives’



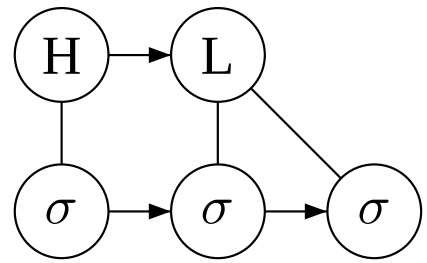
bálágá
HHH
‘fence’



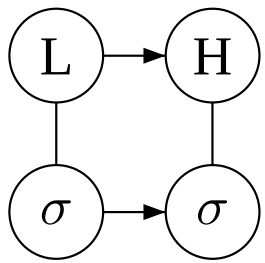
sámà
HL
‘conversation’



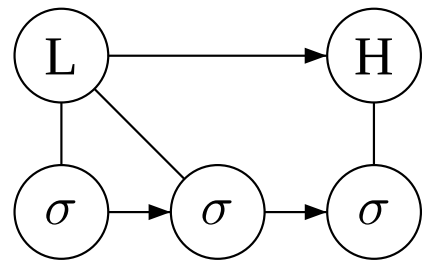
káràgà
HLL
‘entangled’



kàrá
LH
‘paralytic’

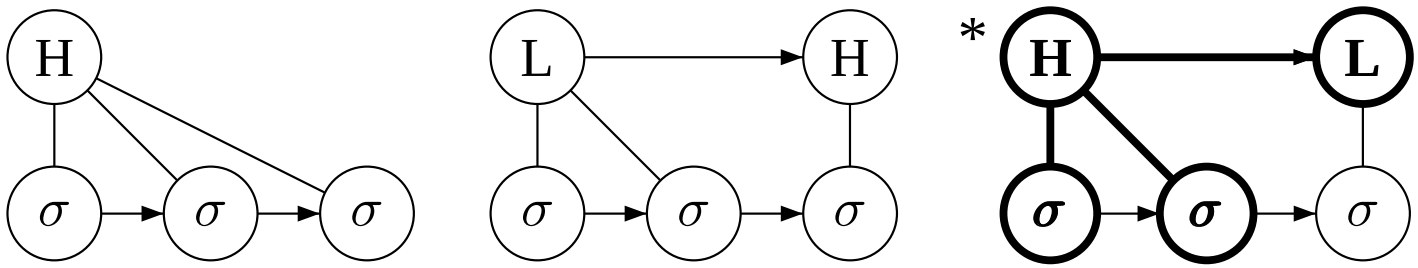


m^{w}àrə̀gí
LLH
‘brother’

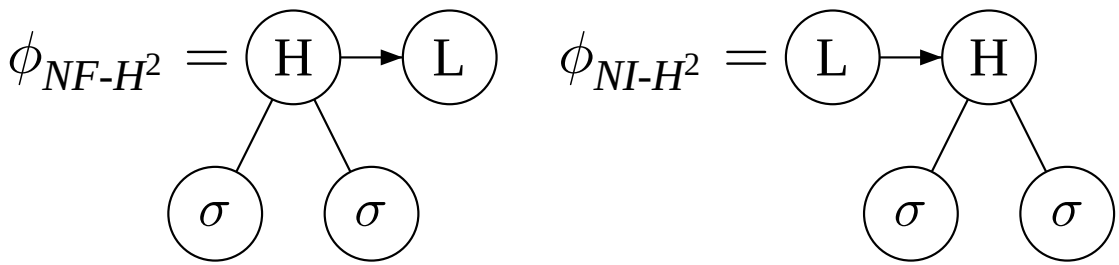


Case study: Kukuya

- H cannot spread in the presence of another tone

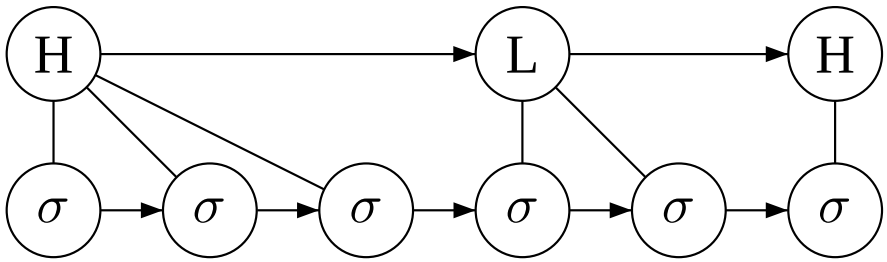


- In terms of forbidden subgraphs, this is just conjunction of $\neg\phi_{NF\text{-}H^2}$ (Mende) and $\neg\phi_{NI\text{-}H^2}$ (Hausa)



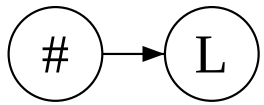
Case study: N. Karanga

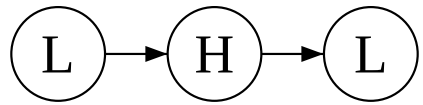
- H on both edges; first spreads maximally to three syllables

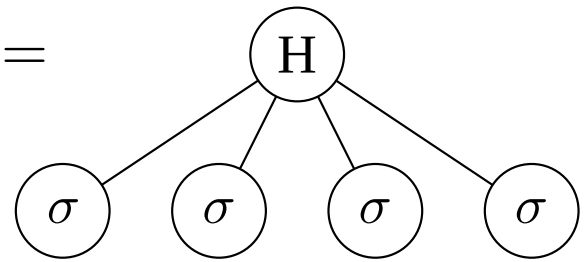


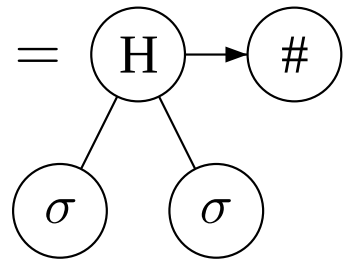
hàndákà-tór-és-ér-ès-àn-á HHHLLH

'I didn't make take a lot for e.o.'

$\phi_{IL} =$ 

$\phi_{LHL} =$ 

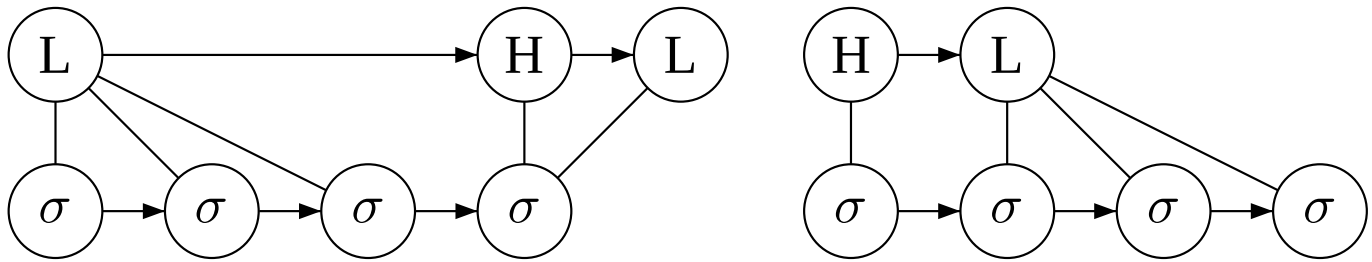
$\phi_{H^4} =$ 

$\phi_{F\text{-}H^2} =$ 

Case study: Hirosaki Japanese

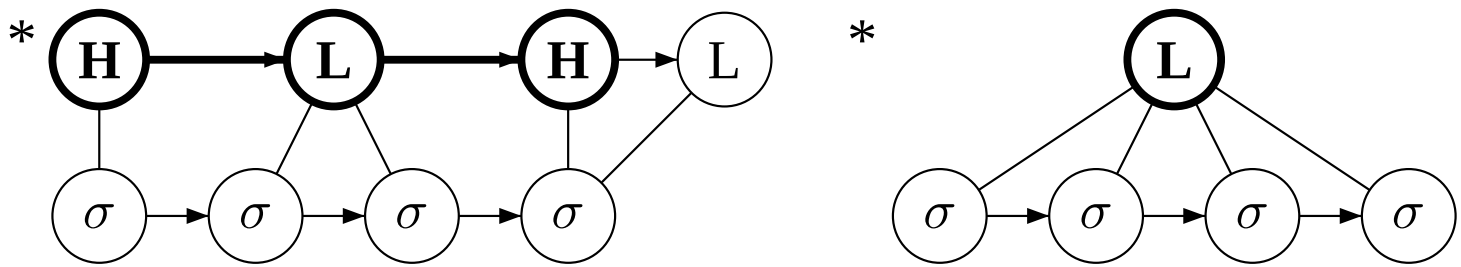
- Exactly one H or F:

  kaminarî LLLF ‘lightening’ kóomori HLLL ‘bat’



- Unattested: *HLLF, *LLLL

$\phi_{HLH} =$ H → L → H $\qquad \phi_{\#L\#} =$ # → L → #



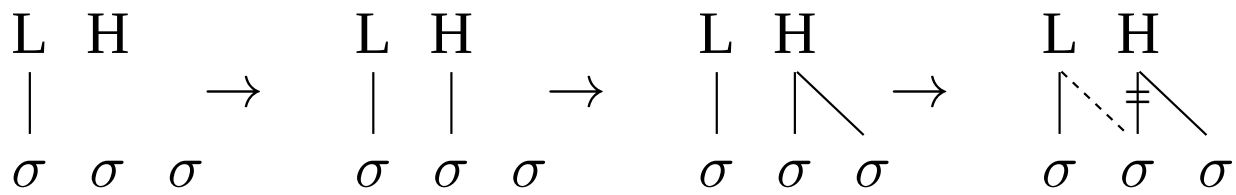
Discussion

- We have characterized the following variation in tone patterns with **local** constraints:
  - Fixed melodies realized over words of different lengths (all)
  - Contours and plateaus of tone may be restricted to left or right (Mende vs. Hausa)
  - Plateaus of a particular tone may be restricted (Kukuya)
  - Tones may appear on both edges (N. Karanga)
  - There must be exactly one of a particular tone (Hirosaki J.)

Discussion: theory comparison

- Rule-based employ a plethora of association paradigms (Goldsmith, 1976; Leben, 1978; Yip, 1988; Hewitt and Prince, 1989, inter alia) and language-specific rules (e.g., Hyman, 1987)

Kukuya:



- They capture the attested patterns
- No clear constraints on what a possible rule/association paradigm
- It is unclear what typology is, or how association paradigms/rules can be learned

Discussion: theory comparison

- Zoll (2003) employs violable constraints in OT; *CLASH for Kukuya, ALIGN for directionality
- Clear picture of typology (Prince and Smolensky, 1993, 2004) and learnability (Tesar and Smolensky, 1998; Tesar, 2013)
- ALIGN constraints cannot capture N. Karanga Shona (as Zoll 2003 points out)

Discussion: theory comparison

- ALIGN constraints can generate ‘H closest to center’ pattern (Eisner, 1997)

		ALIGN(σ,R,H,R)							
	$\sigma\sigma\sigma\sigma\sigma\sigma\sigma$+H	σ_1	σ_2	σ_3	σ_4	σ_5	σ_6	σ_7	(total)
	a. $\acute{\sigma}\sigma\sigma\sigma\sigma\sigma\sigma$	0	*	**	***	****	*****	******	21
	b. $\sigma\acute{\sigma}\sigma\sigma\sigma\sigma\sigma$	*	0	*	**	***	****	*****	16
	c. $\sigma\sigma\acute{\sigma}\sigma\sigma\sigma\sigma$	**	*	0	*	**	***	****	13
☞	d. $\sigma\sigma\sigma\acute{\sigma}\sigma\sigma\sigma$	***	**	*	0	*	**	***	12
	e. $\sigma\sigma\sigma\sigma\acute{\sigma}\sigma\sigma$	****	***	**	*	0	*	**	13
	f. $\sigma\sigma\sigma\sigma\sigma\acute{\sigma}\sigma$	*****	****	***	**	*	0	*	16
	g. $\sigma\sigma\sigma\sigma\sigma\sigma\acute{\sigma}$	******	*****	****	***	**	*	0	22

- Optimization gets complex patterns with simple constraints (Gerdemann and Hulden, 2012)

Discussion: theory comparison

- *Both* derivational and optimization-based approaches miss generalization that well-formedness is local, which is a central feature of the current proposal

Discussion: learning

- Language-specific forbidden substructure constraints are learnable
- The main idea: learner only pays attention to substructures of a particular size (García et al., 1990; Heinz, 2010, 2011; Jardine and Heinz, accepted)
- This idea can be extended straightforwardly to local autosegmental grammars (Jardine and Heinz, LSA)
- With some assumptions, autosegmental constraints can be learned directly from strings (Jardine and Heinz, 2015)

Conclusions

- The character of tonal well-formedness is fundamentally **local** over autosegmental structures
- **Forbidden substructure constraints** over autosegmental representations are an attractive theory of tonal well-formedness
- These constraints are inviolable, language-specific, and local
- They capture the full range of patterns, while not overgenerating in the same way as previous theories
- We know how they can be learned

Future work

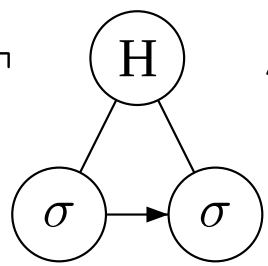
- So far, only considered *computational* restrictions
- We can incorporate other (e.g., perceptual, articulatory) information explicitly in graph and consider restrictions on *type* of subgraphs we can ban
- How can this be applied to **segmental** representations? The question of complex segments versus clusters (Jardine et al., 2015)?
- How does representation relate to the idea that tone is different from segmental phonology (Hyman, 2011; Jardine, to appear)?

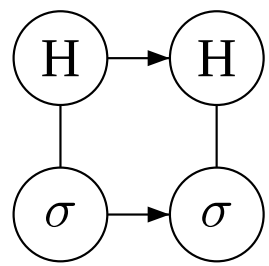
Future work

- The locality of the generalizations discussed in this talk is a fact. Incorporating it into **transformations** is an interesting, yet approachable problem
- Chandlee (2014) shows how this can be done for strings
- For autosegmental representations, we can encode URs and correspondence in graph (Jardine, dissertation; Potts and Pullum, 2002)

Future work

- By varying logical grammars and representation, we get a space of **constraint definition languages** (de Lacy, 2011) whose relative expressive power is well-defined
- This space is not yet well understood!
- We can use this to study both the nature of MARKEDNESS and FAITHFULNESS

*CLASH= ¬ 

∧¬ 

ALIGN(σ,R,H,R)= ✘

- We can explicitly study and compare other theories of representation (Browman and Goldstein, 1986; Cassimjee and Kisseberth, 2001; Rose and Walker, 2004; Shih and Inkelas, 2014)

Acknowledgements

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