Culminativity times Harmony Equals Unbounded Stress Patterns

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Culminativity $\times$ Harmony $=$ Unbounded Stress Patterns

$$\text{Harmony} = \frac{\text{Unbounded Stress Patterns}}{\text{Culminativity}}$$

What are Bounded and Unbounded Stress Patterns?

1. Bounded stress patterns are ones where the primary stress always falls within some fixed distance of the word edge.
2. Unbounded patterns are not bounded.

Unbounded Stress Patterns

Words obeying the stress pattern of Kwakiutl (Bach 1975)

Ḣ	Ĺ	H́ L	H́ H	L H́
L Ĺ	H́ L L	H́ L H	H́ H L	H́ H H
L H́ L	L H́ H	L L Ĺ	L L H́	L H́ L L
L H́ L H	H́ L L L	H́ L L H	H́ H L L	H́ H L H
L H́ H L	L H́ H H	H́ L H L	H́ L H H	H́ H H L
H́ H H H	L L H́ L	L L H́ H	L L L Ĺ	L L L H́

Unbounded Stress Patterns

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H́	Ĺ	H́ L	H́ H	L H́
L Ĺ	H́ L L	H́ L H	H́ H L	H́ H H
L H́ L	L H́ H	L L Ĺ	L L H́	L H́ L L
L H́ L H	H́ L L L	H́ L L H	H́ H L L	H́ H L H
L H́ H L	L H́ H H	H́ L H L	H́ L H H	H́ H H L
H́ H H H	L L H́ L	L L H́ H	L L L Ĺ	L L L H́

The generalization: "Stress the Leftmost Heavy otherwise the Rightmost" (LHOR)

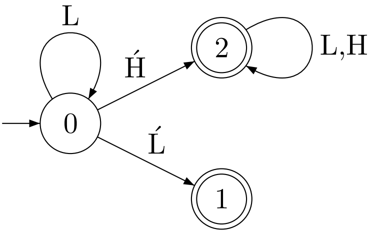
Typology of Unbounded Stress Patterns

1. LHOR (e.g. Kwakitul)
2. LHOL (e.g. Amele)
3. RHOR (e.g. Golin)
4. RHOL (e.g. Chuvash)

- More complicated unbounded patterns have been documented
- Typological studies document lexical exceptions to generalizations.
- Here the focus is on the nature of the generalizations.

(Hyman 1977, Halle and Verganud 1987, Idsardi 1992, Bailey 1995, Hayes 1995, Goedemans et al. 1996, Tesar 1998, Gordon 2002, Heinz 2007, 2009, Hulst et al. 2010)

LHOR generalization as a finite-state automaton

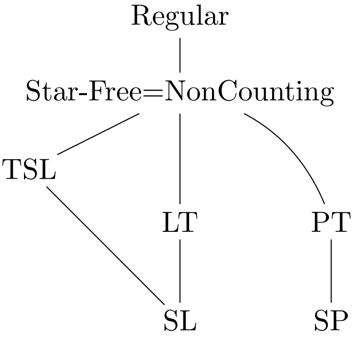


LHOR

The nature of the generalization

1. The LHOR fsa computes an infinite set:
   - every word in the set obeys the generalization
   - every word not in the set does not obey the generalization
2. SPE and OT analyses of this generalization compute the *same* infinite set (the right projection of the UR/SR relation)
3. The focus in this talk is WHAT is being computed as opposed to HOW it is computed.

Classifying regular patterns

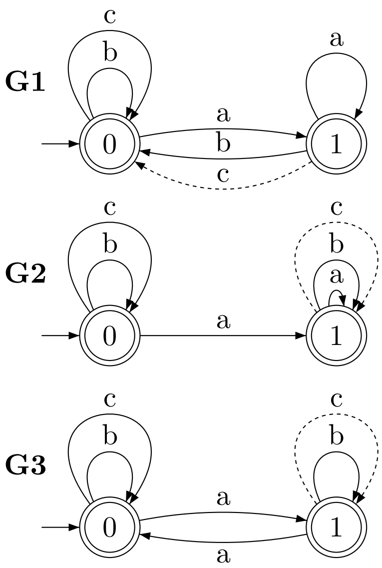


Proper inclusion relationships among language classes (indicated from top to bottom).

TSL	Tier-based Strictly Local
LT	Locally Testable
SL	Strictly Local
PT	Piecewise Testable
SP	Strictly Piecewise

(McNaughton and Papert 1971, Simons 1975, Rogers et al. 2010, Heinz et al. 2011)

3 Examples



1. G1 generates/recognizes all words except those with a forbidden string [ac]
2. G2 generates/recognizes all words except those with a forbidden subsequence [a. . . c]
3. G3 generates/recognizes all words except those with a [c] whose left context has an even number of [a]s

- G1 is Strictly 2-Local, G2 is Strictly 2-Piecewise, and G3 is Counting.

Harmony

Samala Chumash regressive sibilant harmony (Applegate 1972)

Alveolar		
/s-api-t͡ʃʰo-us/	[sapit͡sʰolus]	‘he has a stroke of good luck’
/s-iʃ-tiʃi-jep-us/	[sistisijepus]	‘they (2) show him’
Post-alveolar		
/s-api-t͡ʃʰo-us-waʃ/	[ʃapit͡ʃʰoluʃwaʃ]	‘he had a stroke of good luck’
/ha-s-xintila-waʃ/	[haʃxintilawaʃ]	‘his former Indian name’

Consonantal harmony patterns are Strictly 2-Piecewise

Strictly 2-Piecewise are those which describe patterns in terms of *permissible* and *forbidden subsequences* of length 2.

Example

Phonotactic pattern derived from Samala Chumash

[sapit͡sʰolus sistisijepus ʃapit͡ʃʰoluʃwaʃ haʃxintilawaʃ]

Notation:

s	[+strident,+anterior]	T	[-syllabic,-strident]
ʃ	[+strident,-anterior]	V	[+syllabic]

Forbidden sʃ, ʃs

Permissible sT, sV, ʃT, ʃV, Ts, Tʃ, TV, TT, Vs, Vʃ, VT, VV (everything else)

(Heinz 2010)

FSA representation of this infinite set

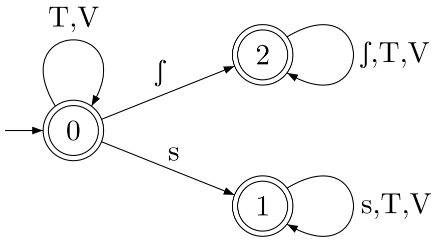


Figure: An automaton which recognizes the sibilant harmony pattern in Samala Chumash.

s	[+strident,+anterior]	T	[-syllabic,-strident]
ʃ	[+strident,-anterior]	V	[+syllabic]

(Rogers et al. 2010)

Are unbounded stress patterns Strictly 2-Piecewise?

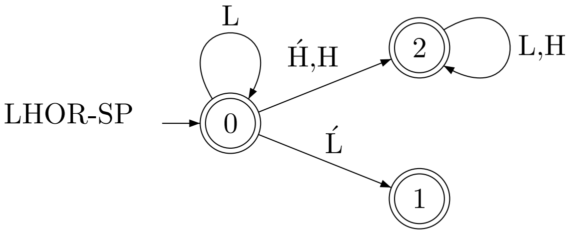
1. We can answer this by identifying the *permissible* and *forbidden* subsequences in LHOR.

The permissible and forbidden subsequences of LHOR

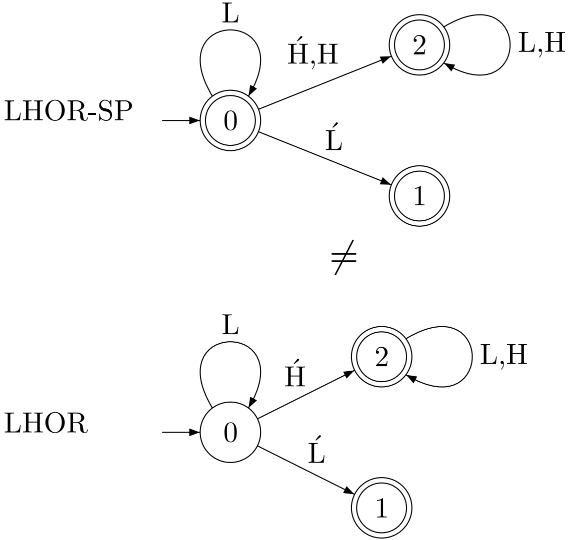
H́	Ĺ	H́ L	H́ H	L H́
L Ĺ	H́ L L	H́ L H	H́ H L	H́ H H
L H́ L	L H́ H	L L Ĺ	L L H́	L H́ L L
L H́ L H	H́ L L L	H́ L L H	H́ H L L	H́ H L H
L H́ H L	L H́ H H	H́ L H L	H́ L H H	H́ H H L
H́ H H H	L L H́ L	L L H́ H	L L L Ĺ	L L L H́

permissible		forbidden	
L L	H H	H H́	Ĺ L
L Ĺ	H L	H Ĺ	Ĺ Ĺ
L H	H́ H	H́ H́	Ĺ H
L H́	H́ L	H́ Ĺ	Ĺ H́

FSA representations

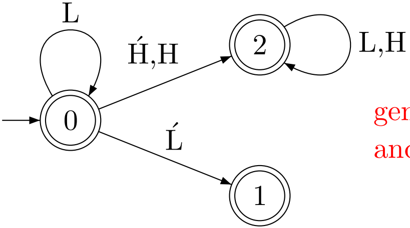


FSA representations



FSA representations

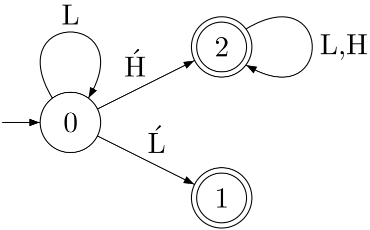
LHOR-SP



generates L L L L
and L H L etc.

≠

LHOR



but LHOR does not!

Interim Summary

- SP generalizations can express “At most one stress.” (e.g. Ĥ Ĥ is a forbidden subsequence)
- SP generalizations cannot express “At least one stress” or “exactly one stress.”

Culminativity

- Culminativity is the principle that each word has exactly one prosodic peak.
- It has long been recognized as a central principle in virtually every theory of stress.

(Hyman 1977, Prince 1983, Halle and Verganud 1987, Idsardi 1992, Hayes95, Hulst et al. 2010)

Culminativity as an infinite set

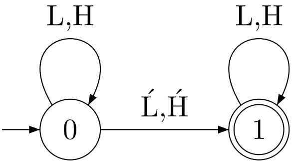


Figure: A finite-state acceptor describing Culminativity.

All ingredients but one

1. The infinite set of LHOR
2. The infinite set of LHOR-SP
3. The infinite set of Culminativity
4. …need some way to combine Culminativity with LHOR-SP to yield LHOR

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Set intersection

Set intersection

1. Set intersection yields a set including only those elements common to both.
2. Automata product computes set intersection for regular sets.

For automata A, B, C:

if

$$A \times B = C$$

then

$$L(A) \cap L(B) = L(C)$$

(Sipser 1997, Hopcroft et al. 2001)

Specific claims in this talk

Language-theoretic version

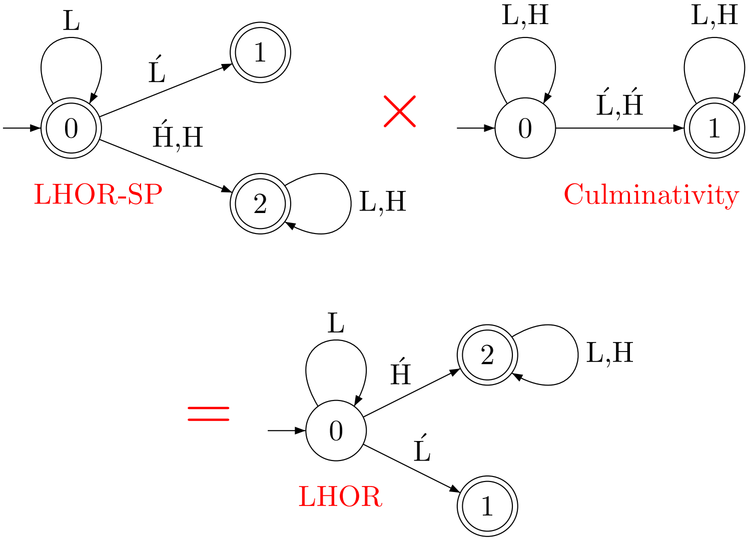
1. L(LHOR-SP) $\cap$ L(Culminativity) $=$ L(LHOR)
2. L(LHOL-SP) $\cap$ L(Culminativity) $=$ L(LHOL)
3. L(RHOL-SP) $\cap$ L(Culminativity) $=$ L(RHOL)
4. L(RHOR-SP) $\cap$ L(Culminativity) $=$ L(RHOR)

Specific claims in this talk

Automata-theoretic version

1. A(LHOR-SP) $\times$ A(Culminativity) = A(LHOR)
2. A(LHOL-SP) $\times$ A(Culminativity) = A(LHOL)
3. A(RHOL-SP) $\times$ A(Culminativity) = A(RHOL)
4. A(RHOR-SP) $\times$ A(Culminativity) = A(RHOR)

All of these claims are easily verified.



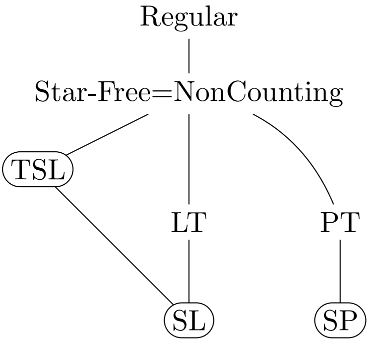
Harmony $\times$ Culminativity = Unbounded Stress Patterns

$$\text{Harmony} = \frac{\text{Unbounded Stress Patterns}}{\text{Culminativity}}$$

Conclusion

1. This analysis unifies long-disance phenomenon in unbounded harmony systems and simple segmental harmony systems: they are Strictly Piecewise modulo Culminativity.
2. It will be interesting to see how far this result can be pushed when more complicated unbounded stress patterns and segmental harmony patterns are considered.
3. There is also a learnability consequence since SP_2 patterns can be learned from positive data (Heinz 2010a,b) and Culminativity has been argued to be a principle of UG.

Conclusion



4. More generally, these classes allow one to constrain theories of phonology computationally.

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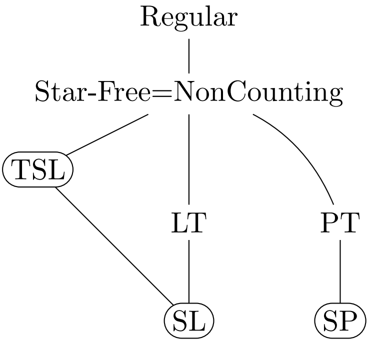

4. More generally, these classes allow one to constrain theories of phonology computationally.

Thank you