Computational Locality and Autosegmental Processes

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Introduction

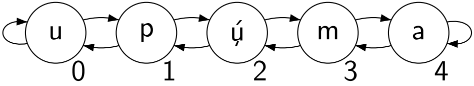
- Autosegmental representations (ARs) (Goldsmith, 1976; Clements, 1976) have been claimed to capture non-local phenomena in a local way (McCarthy, 1982; Odden, 1994).
- We apply a computational notion of locality to a selection of tone processes to get a more nuanced understanding of this ability of ARs.
- Three-way distinction:
  - Local even without ARs.
  - Local only with ARs.
  - Not local even with ARs.

Computational notion of locality

- Based on the Input Strictly Local (ISL) functions, which were originally defined in terms of formal language theory and automata theory (Chandlee, 2014).
- We'll be using the logical characterization of ISL proposed by Chandlee and Lindell (to appear).
  - ISL function = Quantifier-free First Order Graph Interpretation
- Why use logic?
  - We can directly extend a restrictive, explicit notion of locality from strings to phonological representations

FO Graph interpretations

(1) Rimi (Schadeberg, 1979; Meyers, 1997)
/u-pų́m-a/ ↦ [u-pųm-á] ‘to go away’

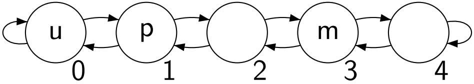


UR string model defined with:

- 5 positions, labeled with segments
- successor function: $s(0) = 1$, $s(1) = 2$, ..., s(4)=4
- predecessor function $p(4) = 3$, $p(3) = 2$, ..., p(0)=0

FO Graph interpretations

- The SR string graph is defined in terms of the UR graph using FO logic formulas (Engelfriet and Hoogeboom, 2001).



- $H(x)$ is True iff position x bears a high tone.
- $V(x)$ is True iff position x is a vowel.
- $\varphi_{\acute{V}} \stackrel{\text{def}}{=} V(x) \wedge H(p(p(x)))$
  - An output position bears a high tone iff it's a vowel and the previous vowel bears a high tone in the input graph.

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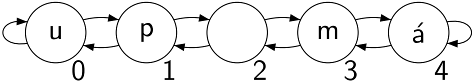

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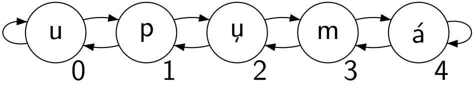

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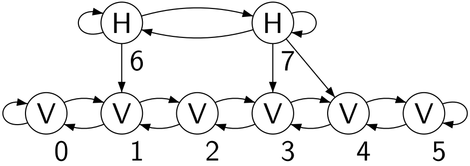
ISL = Quantifier-free FO Logic

$$\varphi_{\acute{V}} \stackrel{\text{def}}{=} V(x) \wedge H(p(p(x)))$$

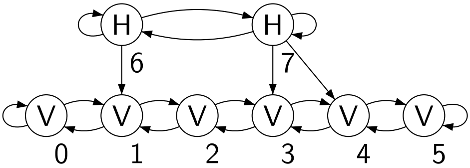
- These formulas do not use the full power of FO: they don't use quantifiers.
- The processes that can be described in this way are those for which the trigger and the target form a **contiguous substring of bounded length** in the input string.
- The boundedness means we can use the successor or predecessor function repeatedly to determine whether both the target and trigger are present.
  - No quantifier is needed.
    (e.g, no "... $\wedge$ $(\exists z)$[...]")

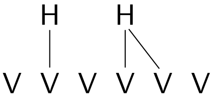
Autosegmental Representation (AR) Graphs

- Goal: extend this same notion of locality (QF FO describable) from string graphs to AR graphs (Jardine, 2016).
- Example: VV́VV́V́V



Autosegmental Representation (AR) Graphs





Method

- We designate as ISL those patterns that can be describe with QF FO using string graphs.
- We designate as AISL those patterns that can be described with QF FO using AR graphs.
- We illustrate that ISL patterns are also AISL but not vice versa
- We will also identify cases that are neither ISL nor AISL.

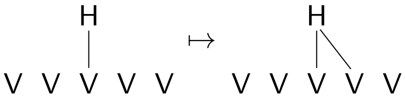
AISL Analyses

Process		ISL?	AISL?
Bounded spread	(Bemba)	✓	
Bounded shift	(Rimi)	✓	
Unbounded shift	(Zigula)	✗	
Unbounded OCP	(Arusa)	✗	
Unbounded spread	(Ndebele)	✗	
Meussen's rule	(Shona)	✗	

AISL Analyses

Bounded spread

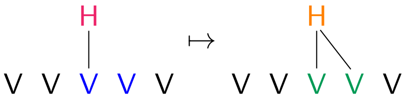
- Bemba (Bickmore and Kula, 2013)
  /bá-la-kak-a/ ↦ [bá-lá-kak-a] ‘they tie up’
  /tu-la-bá-kak-a/ ↦ [tu-la-bá-kák-a] ‘we tie them up’



AISL Analyses

Bounded spread

$$a_O(x, y) \stackrel{\text{def}}{=} a_I(x, y) \vee a_I(p(x), y)$$

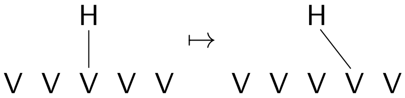


AISL Analyses

Bounded shift

- Rimi (Schadeberg, 1979; Meyers, 1997)

/u-pų́m-a/	$\mapsto$	[u-pųm-á]	‘to go away’
/rá-mu-ntu/	$\mapsto$	[ra-mú-ntu]	‘of a person’
/mu-tém-į/	$\mapsto$	[mu-tem-į́]	‘chief’



AISL Analyses

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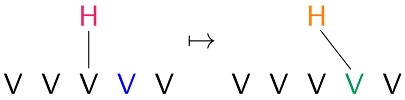

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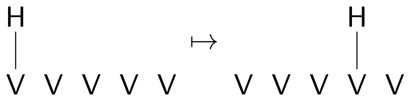
Unbounded spread	(Ndebele)	✗	
Meussen's rule	(Shona)	✗	

AISL Analyses

Unbounded shift

- Zigula (Kenstowicz and Kisseberth, 1990)

ku-gulus-a	‘to chase’
ku-lombéz-a	‘to ask’
ku-lombez-éz-a	‘to ask for’
ku-lombez-ez-án-a	‘to ask for each other’

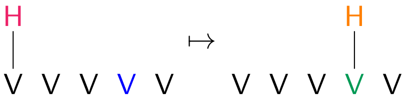


AISL Analyses

Unbounded shift

$$\texttt{lastH}(y) \stackrel{\text{def}}{=} H(y) \wedge s(y) = y$$
$$\texttt{penultV}(x) \stackrel{\text{def}}{=} V(x) \wedge (s(s(x)) = s(s(s(x)))$$

$$a_O(x, y) \stackrel{\text{def}}{=} \texttt{penultV}(x) \wedge \texttt{LastH}(y)$$

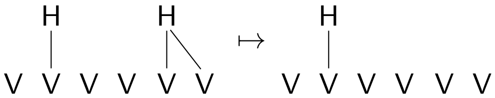


AISL Analyses

Unbounded OCP

- Arusa (Odden, 1994)

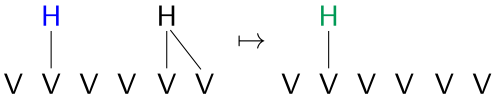
sídáy	‘good’
enkér siday	‘good ewe’
olórika siday	‘good chair’



AISL Analyses

Unbounded OCP

$$H_O(x) \stackrel{\text{def}}{=} H(x) \wedge \neg H(p(x))$$



AISL Analyses

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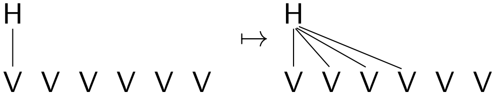
Unbounded OCP	(Arusa)	✗	✓
Unbounded spread	(Ndebele)	✗	
Meussen's rule	(Shona)	✗	

Unbounded spread

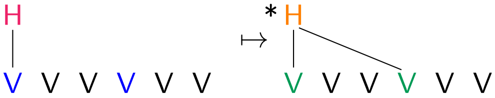
- Ndebele (Sibanda, 2004)

/ú-ku-hlek-a/	↦	[ú-kú-hlek-a]	‘to laugh’
/ú-ku-hlek-is-a/	↦	[ú-kú-hlék-is-a]	‘to amuse’
/ú-ku-hlek-is-an-a/	↦	[ú-kú-hlék-ís-an-a]	‘to amuse e. o.’



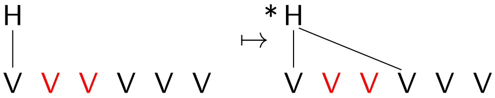
Unbounded spread

$$a_O(x, y) \overset{\text{def}}{=} a_I(x, y) \vee \left(\texttt{antepenultV}(x) \wedge H_I(y)\right)$$



Unbounded spread

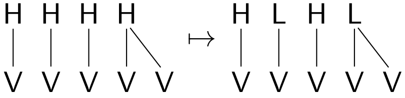
- No QF statement can identify all intermediate vowels



Meussen's Rule

- Shona Odden (1986); Meyers (1987, 1997)

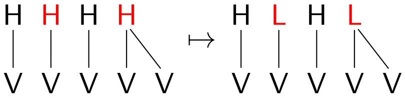
/né-hóvé/	↦	[né-hòvè]
/né-é-hóvé/	↦	[né-è-hóvé]
/né-é-é-hóvé/	↦	[né-è-é-hòvè]



Meussen's Rule

- Need to pick out the set of `even` H's—this is well-known to be not definable even with (first-order) quantification (Thomas, 1982)

$$L_O \stackrel{\text{def}}{=} H_I(x) \wedge \texttt{even}(x)$$



Summary

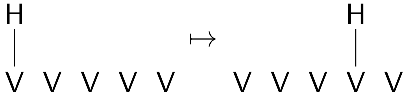
Process		ISL?	AISL?
Bounded spread	(Bemba)	✓	✓
Bounded shift	(Rimi)	✓	✓
Unbounded shift	(Zigula)	✗	✓
Unbounded OCP	(Arusa)	✗	✓
Unbounded spread	(Ndebele)	✗	✗
Meussen's rule	(Shona)	✗	✗

Discussion

- Tone patterns include both ISL and non-ISL patterns
  Unbounded shift:

  $$\mathrm{V\ \acute{V}\ V\ V\ V\ V} \mapsto \mathrm{V\ V\ V\ V\ \acute{V}\ V}$$

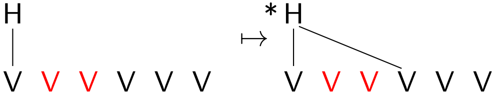
- With AISL, we can capture some non-ISL patterns



- Thus, ARs make *some* non-local patterns local

Discussion

Unbounded spread:



- One option for non-ISL/AISL processes is to **further enrich** the representations
- We might consider AR models with $<$ instead of p (generalization of Strictly Piecewise (Heinz, 2010; Rogers et al., 2010))

Discussion

- Another option is to consider **output-based** locality

(2) Johore Malay (Onn, 1980)
/pəŋawasan/ ↦ [pəŋãw̃ãsan] 'supervision'

- **Output SL** functions have been characterized for strings in terms of formal language and automata theory (Chandlee et al., 2015)
- A logical characterization of OSL remains for future work.

Why do logical characterizations matter?

- Enable a rigorous, restrictive, and learnable (Chandlee and Heinz, 2018) definition of what it means to be “local” and “non-local”.
- Directly extend these notions from strings to ARs.
- Logics are tightly connected to the complexity of functions (Filiot and Reynier, 2016).
- Computational complexity classes have been shown to capture the typology of spreading (Heinz and Lai, 2013).

Conclusion

- We *directly compared* different representations to better under how ARs can render non-local processes local.
- Given an **input-based** notion of locality, ARs capture some, but not all, patterns that are non-local over strings.
- In future, an **output-based** notion of locality may accommodate additional processes that are not AISL.

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