Representation and the Computation of Tone Processes

Main Result: Enhancing the representation provides a tight characterization of the computationally complex tone processes noted in (Jardine, 2016)

- *Unbounded circumambient* (UC) processes, are complex tone processes in which triggers or blockers can be arbitrarily far away on either sides of any target.
- E.g: Unbounded Tone Plateauing (UTP) in Luganda (Hyman and Katamba, 2010) is a case of UC, H(igh) tones on either side of an unbounded span of toneless TBUs form a single H-toned plateau as in (1).

(1) tw - áa - láb - **w** - **a wal** ú simbi $\rightarrow$ tw - áá - láb - **w** - **á wál** ú simbi ‘We saw him, Walusimbi’

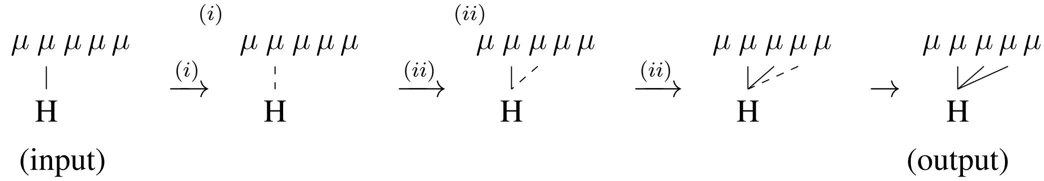
H H H → H

- Jardine argues that UC processes are not *subsequential*, a class of functions that can be computed over deterministic finite-state transducers (Mohri 1997).
- subsequentiality has been argued to form a tight bound on segmental phonology (Heinz and Lai 2013, Heinz 2018).
- We show that **extending a logical notion of subsequentiality to autosegmental representations (ARs; Goldsmith 1976) allows us to capture UC processes in tone**, thus providing a sufficiently expressive, yet restrictive characterization of tone.
- We use implicitly defined (Rogers, 1997) least-fixed point (lfp, Chandlee and Jardine 2019)-extended quantifier free (qf, Courcelle 1994) formulae.

Cilungu: (Bickmore, 1996) [unbounded H spread, Left-Subsequential]

(2) a. $\alpha'(x) \approx y \overset{\text{def}}{=} \underbrace{\alpha(x) \approx y}_{(i)} \vee (\underbrace{\alpha'(p(x)) \approx y \wedge \neg last(x)}_{(ii)})$

b.



The definition in (2a) reads as follows:

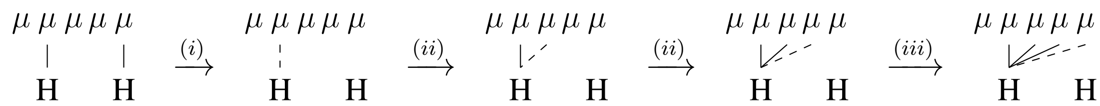
- The first conjunct $\alpha(x) \approx y$ in (i) is true when x is associated to y (α points x to y) in the *input*, and the second conjunct $\alpha'(p(x)) \approx y \wedge \neg last(x))$ in (ii) is true when the *predecessor* of x ($p(x)$) is associated to y in the *output*, as long as x is non-final ($\neg last(x)$).
- Thus, the definition states that $a'(x) \approx y$—that is, x is associated to y in the output—if and only if x and y satisfy either disjunct (i) or (ii).
- A derivation is given in (2b) to show how successive pairs are associated, converging to an output in which H spreads up to the penult.

Luganda: (Hyman and Katamba, 2010) [UTP, non-subsequential]

(3) a. $R(x,y) \stackrel{\text{def}}{=} \underbrace{(\alpha(x) \approx y \wedge first(y))}_{(i)} \vee \underbrace{(R(p(x),y) \wedge \neg(last(\alpha(x))))}_{(ii)}$

b. $\alpha'(x) \approx y \stackrel{\text{def}}{=} R(x,y) \vee \underbrace{(last(\alpha(x)) \wedge first(y))}_{(iii)}$

c.



The labeled disjuncts work as follows:

- (i) states that x and y are associated if x is associated to the first y in the input; or if the predecessor of x on the timing tier is associated to y and it is not the case that the position to which x is associated is last (ii).
- (iii) associates the TBU associated to the final tone ($last(\alpha(x))$) to the first tone ($first(y)$).
- (3c) shows a step-by-step derivation of (3a-b). (We omit the deletion of the second H, but this is also QFLFP-definable).

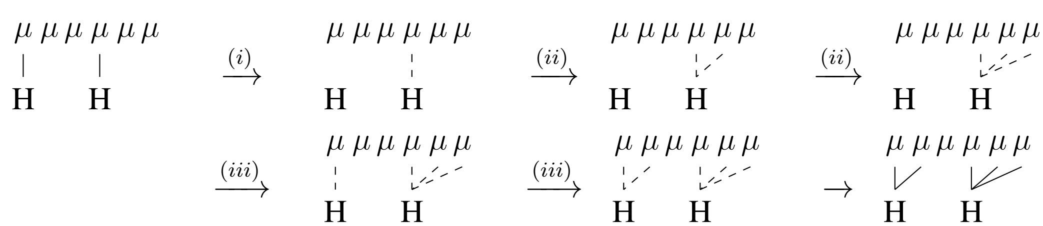
(4)

Copperbelt Bemba (Bickmore and Kula, 2015) [bounded and unbounded H spread, non-subsequential]

(5) a. $R(x,y) \stackrel{\text{def}}{=} \underbrace{(\alpha(x) \approx y \wedge last(y))}_{(i)} \vee \underbrace{(R(p(x),y))}_{(ii)}$

b.
$\alpha'(x) \approx y \stackrel{\text{def}}{=} R(x,y) \vee ((\underbrace{\alpha(x) \approx y \vee \alpha(p(x)) \approx y \vee \alpha(p(p(x))) \approx y}_{(iii)}) \wedge \underbrace{\neg s(x) \approx s(y)}_{(iv)})$

(6)



The formulae work as follows:

- Disjunct (i) first considers the pair that are associated in the input *only if* y is the last tone. The disjunct in (ii) then recursively associates subsequent TBUs, analogous to unbounded spreading in (2).
- The fact that this recursion only begins in (i) with the last tone captures the generalization in Bemba that only the last tone spreads unboundedly.
- The definition in (5b) then captures the bounded case: (iii) states that x is associated to y if they are associated in the input, *or* if $p(x)$ is associated to y in the input (binary spreading), *or* $p(p(x))$ is associated to y in the input (ternary spreading).

– (iii) is subject to the conjunction in (iv) (the OCP condition): x and y can only associate when there is no following input association (here, $s(x)$ indicates the immediate *successor* of x).

References

Bickmore, L. S. (1996). Bantu Tone spreading and displacement as alignment and minimal misalignment. ROA #161-1196.

Bickmore, L. S. and Kula, N. C. (2015). Phrasal phonology in Copperbelt Bemba. *Phonology*, 32:147–176.

Chandlee, J. and Jardine, A. (2019). Quantifier-free least fixed point functions for phonology. In *Proceedings of the 16th Meeting on the Mathematics of Language*, pages 50–62.

Courcelle, B. (1994). Monadic second-order definable graph transductions: a survey. *Theoretical Computer Science*, 126:53–75.

Goldsmith, J. (1976). *Autosegmental Phonology*. PhD thesis, Massachussets Institute of Technology.

Heinz, J. (2018). The computational nature of phonological generalizations. In Hyman, L. and Plank, F., editors, *Phonological Typology*.

Hyman, L. and Katamba, F. X. (2010). Tone, syntax and prosodic domains in Luganda. In Downing, L., Rialland, A., Beltzung, J.-M., Manus, S., Patin, C., and Riedel, K., editors, *Papers from the Workshop on Bantu Relative Clauses*, volume 53 of *ZAS Papers in Linguistics*, pages 69–98. ZAS Berlin.

Jardine, A. (2016). Computationally, tone is different. *Phonology*, 33:247–283.

Rogers, J. (1997). Strict lt2 : Regular :: Local : Recognizable. In Retoré, C., editor, *Logical Aspects of Computational Linguistics: First International Conference, LACL '96 Nancy, France, September 23–25, 1996 Selected Papers*, pages 366–385.