Phonology **37** (2020). Supplementary materials

Unbounded circumambient patterns in segmental phonology

Adam G. McCollum
Rutgers University

Eric Baković
Anna Mai
Eric Meinhardt
University of California San Diego

Supplementary materials

Below we provide finite-state transducers (FSTs) for the analyses of Turkish, Degema, Copperbelt Bemba and Tutrugbu presented in §4 and §5 of the paper. In addition, we also provide an FST for the Turkana data in §6.2.2, as well as further elaboration on our claim, *contra* Jardine (2016), that Digo and Xhosa are subsequential. Appendix A presents the FSTs, and Appendix B discusses Digo and Xhosa.

Appendix A: Finite-state transducers

Since consonants do not play a role in the patterns discussed in the paper, they are ignored in the transducers which follow.

1 Turkish

The analysis of rounding harmony in Turkish is described in §4.1, where we showed that harmony propagates from left to right, targeting [+high] vowels. In the FST in Fig. 2 (cf. the tape representation in (16)), the transducer first reads the beginning of word- and root-boundary symbols. Since Turkish does not have productive prefixation, these two are adjacent. Next, the FST reads the initial-syllable vowel's [round] feature in q_2, and proceeds to q_3 if that vowel is [+round] and to q_4 if it is [−round]. Within roots, round vowels occur relatively freely, represented by the transitions between q_3 and q_4. If the root-final vowel is [+round], there are three options upon reaching the root–suffix boundary symbol. If the word does not have any suffixes, the FST reads the end-of-word symbol and transitions from q_5 to q_7, the final accepting state. If, however, [+high] suffixes are

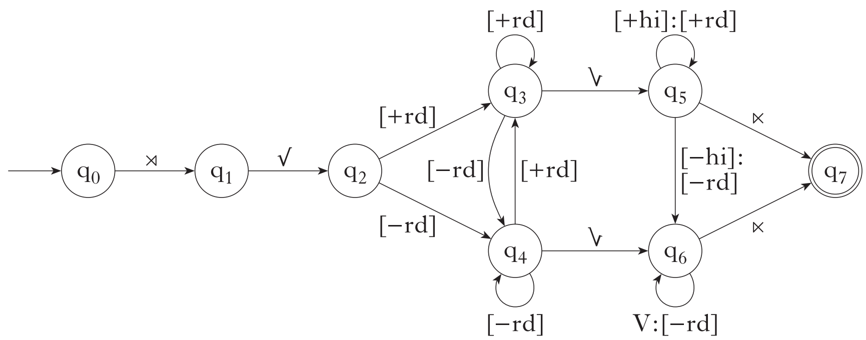

Figure 2

Left-subsequential FST for Turkish progressive rounding harmony.

present, the transducer outputs them as [+round], indicated by the loop at q_5. Finally, if a suffix vowel is [−high], then rounding harmony does not apply, and the suffix vowel is output as [−round], as indicated by the transition from q_5 to q_6. Note that since q_6 has a loop, all following suffix vowels will be output as [−round]. If, on the other hand, the final root vowel is [−round], upon reaching the root–suffix boundary only two options exist. If no suffix vowels are present, the FST reads the end-of-word symbol and transitions from q_6 to q_7. If suffixes are present, the FST outputs them as [−round], looping back to q_6 after each vowel. After all input vowels have been read, the transducer reads the end-of-word symbol, ending the mapping in q_7, the accepting state.

2 Degema

In Degema, discussed in §4.2, ATR harmony proceeds bidirectionally outward from the root. The pattern is symmetrical, and all vowels alternate for [ATR]. FSTs may only proceed in one direction, so we arbitrarily begin the analysis in the left-to-right direction, as shown in Fig. 3 (cf. (19)). The transducer first encounters prefix vowels, but since the root value for [ATR] is unknown, these vowels are output faithfully, indicated by the loop above q_1. Upon reading the prefix–root boundary symbol, the transducer moves to q_2, and, depending on the [ATR] value of the root, proceeds further to q_3 or q_4. Within roots, the FST may freely move between states q_3 and q_4, emitting vowels faithfully, to allow, at least in principle, disharmonic roots. Upon reading the root–suffix boundary symbol, the transducer proceeds to q_5 if the final root vowel was [+ATR], and to q_6 if it was [−ATR]. All suffix vowels are then output in conformity with the [ATR] value of the final root vowel, shown by the loops above q_5 and below q_6. After all suffixes (if there are any) have been mapped to their surface forms, the transducer reads the end-of-word symbol and the first pass is complete.

After completing the left-to-right pass, the transducer now reads the output of the first pass and rewrites the word in conformity with its surface

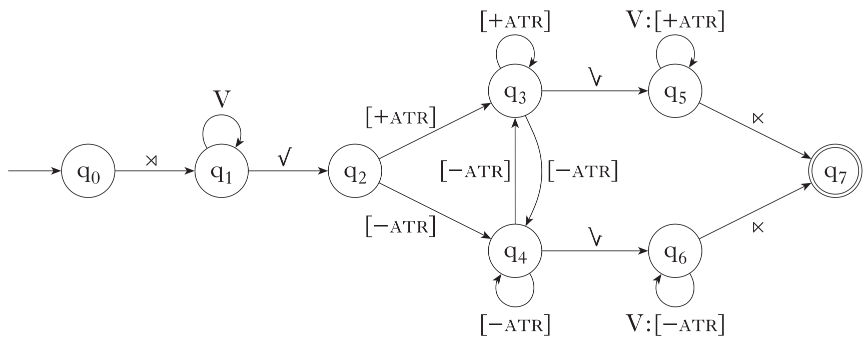

Figure 3
Left-subsequential FST for Degema bidirectional ATR harmony.

representation. The FST in Fig. 4 (cf. (20)) is effectively identical to the FST in Fig. 3, because the pattern in Degema is symmetrical – harmony produces alternations for all vowels in the language in both directions. The only difference in Fig. 4 is its direction of application, which we indicate by its orientation. During this pass, at q_1 the transducer first reads suffix vowels, which it outputs faithfully, the [ATR] value for suffixes being accounted for by the left-to-right pass. Upon encountering the root–suffix boundary symbol, the transducer moves to q_2, and outputs the [ATR] value for all root vowels faithfully, as shown for states q_3 and q_4. Upon reading the prefix–root boundary symbol, the transducer moves either to q_5 or q_6, depending on the [ATR] value for the leftmost root vowel. The transducer now outputs prefix vowels in conformity with the [ATR] value of the nearest root vowel, applying iteratively, as shown by the loops in q_5 and q_6. Finally, upon reading the beginning-of-word symbol, the transduction ends. At this point, the prefix and suffix vowels have been mapped to the [ATR] value of the nearest root vowel, in accordance with the ATR harmony pattern in the language.

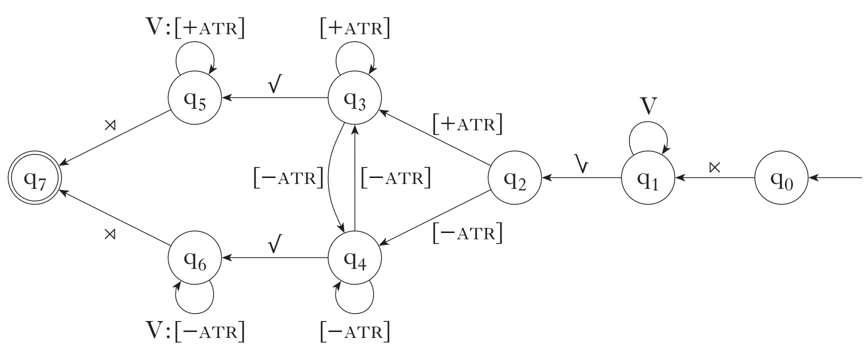

Figure 4
Right-subsequential FST for Degema bidirectional ATR harmony.

3 Copperbelt Bemba

The analysis of tone spreading in Copperbelt Bemba is described in detail in §4.3. The tape representations in (24) and (25) illustrate the operation of the FSTs shown in Figs 5 and 6.

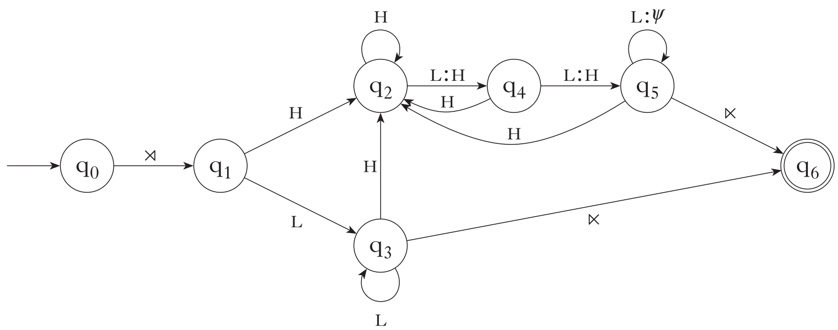

Figure 5
Left-subsequential FST for Copperbelt Bemba tone spreading.

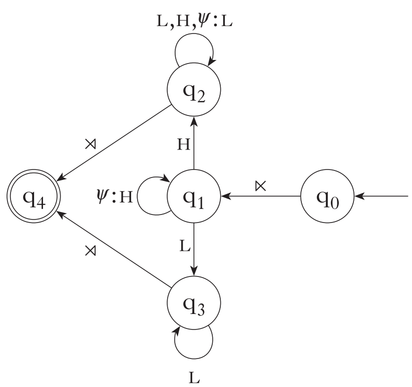

Figure 6
Right-subsequential FST for Copperbelt Bemba tone spreading.

4 Tutrugbu

The analysis of ATR harmony in Tutrugbu is detailed in §5. A single non-deterministic transducer is presented in Fig. 7.

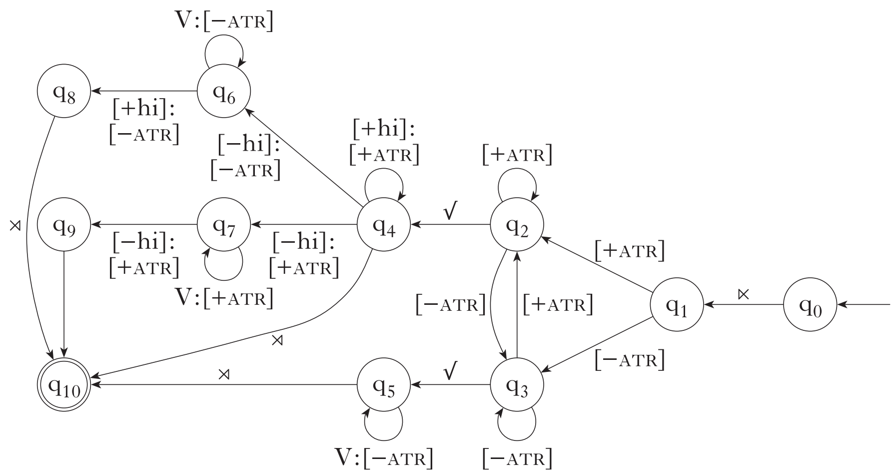

Figure 7
Non-deterministic FST for Tutrugbu ATR harmony.

The tape representations discussed in the context of (28) and (29) are exemplifications of the FSTs provided in Figs 8 and 9.

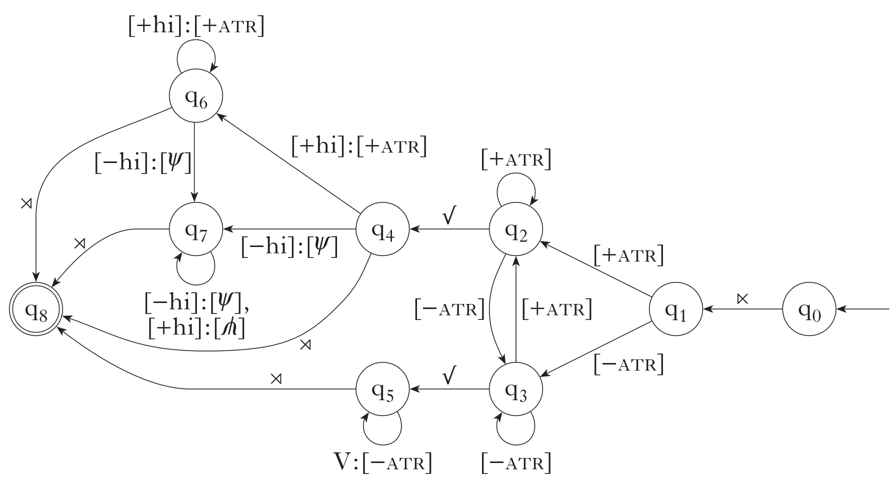

Figure 8
Right-subsequential FST for Tutrugbu ATR harmony.

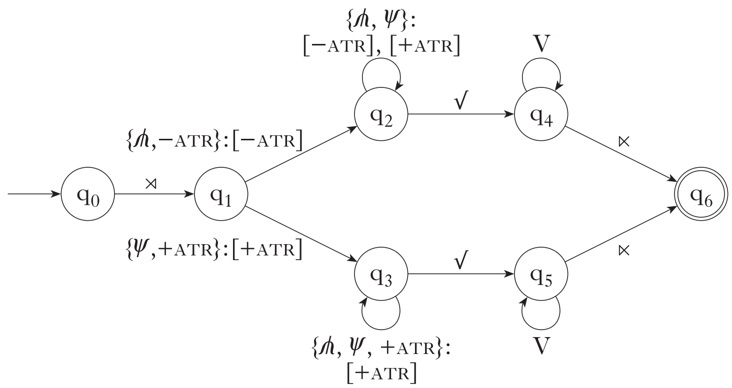

Figure 9
Left-subsequential FST for Tutrugbu ATR harmony.

5 Turkana

The ATR harmony pattern in Turkana is described in §6.2.2. To analyse it, we employ two transducers, presented in Figs 10 and 11. In Fig. 10, the first transducer reads the input string from left to right, mapping all [−ATR] vowels faithfully (states q_1 and q_2) until a [+ATR] vowel is read, which forces a transition to q_3. In state q_3, the transducer iteratively maps all [−low] vowels to their [+ATR] counterparts. However, since there is no [+low, +ATR] vowel in the language, /ɑ/ is mapped to intermediate |o|, which Baković calls 're-pairing'. The transducer loops in q_3 until the end-of-word symbol or a dominant [−ATR] suffix, which we notate $\overline{\text{ATR}}$, is read. If a dominant [−ATR] suffix is present, that vowel does not undergo assimilation to [+ATR], and the transducer moves through q_4 to q_5.

After the first pass is complete, the second, right-to-left, transducer reads the intermediate representation output of the first transducer, and rewrites the string to conform to the actual surface output in the language. This transducer, shown in Fig. 11, reads the end-of-word symbol and transitions to q_1. If the first vowel encountered is [−ATR], the transducer moves to q_2 and maps all other vowels to [−ATR]. This particular path through the transducer accounts for cases where there are no [+ATR] vowels in the word, or when there is a dominant [−ATR] suffix. If, however, there is a [+ATR] vowel in the word (in the absence of any dominant [−ATR] vowel), then this second transducer proceeds from q_1 to q_3, where all [−low] vowels are iteratively mapped to their [+ATR] counterparts. Since [+low] vowels block harmony only in the leftward direction, low vowels must behave differently in this transducer. Whereas in Fig. 10 /ɑ/ was output as |o| in a [+ATR] context, in this transducer |ɑ| is output faithfully, moving the transducer from q_3 to q_2. If no [+low] vowels blockers are present, the transducer outputs all vowels preceding the [+ATR] trigger as [+ATR].

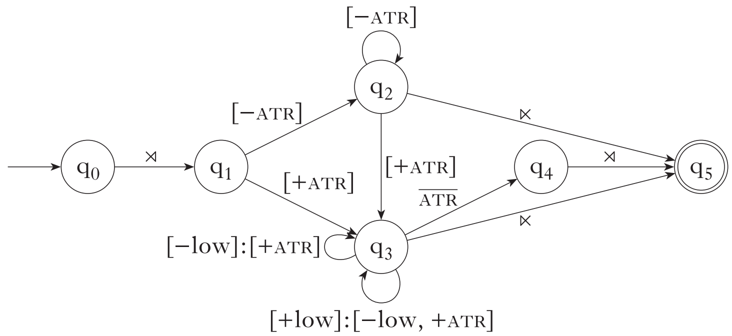

Figure 10
Left-subsequential FST for Turkana ATR harmony
(ATR = dominant [−ATR] suffix).

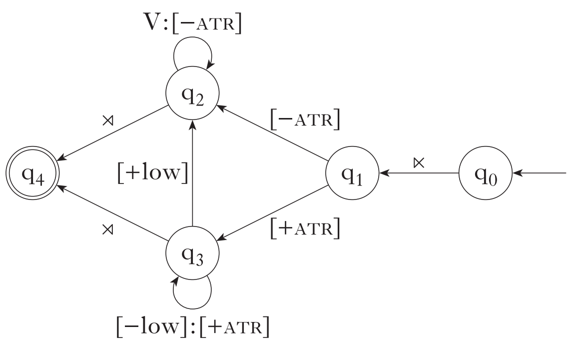

Figure 11
Right-subsequential FST for Turkana ATR harmony.

Appendix B: Digo and Xhosa

Jardine (2016) contends that Digo and Xhosa exhibit unbounded circumambient tone spreading. In §6.2.6, however, we suggested a simpler, left-subsequential analysis of these patterns. We further elaborate on our claim here. We follow Kisseberth's (1984) description of Digo, as does Jardine (2016), as involving two distinct patterns: tone shifting and tone spreading. A single high tone shifts to the penult, while tone spreading occurs only in the presence of two underlying high tones. At first glance, this description seems consistent with other patterns in Jardine (2016), like unbounded tone plateauing. Crucially, though, only the second high tone in Digo initiates spreading, and spreading always terminates in a fixed position, the penult. As a result, it is possible to analyse Digo tone spreading with a less complex, left-subsequential function.

In the Digo data in (39), a single underlying H shifts to the penult (39b). Note that the final two syllables in (b) are realised as a rising–falling sequence. Below we treat them as a HL sequence. In a word containing two underlying H tones, the first H shifts to the penult and the second H initiates spreading up to the penult (39c). (Underlying H tones are underlined.)

(39) *Digo tonal spreading*

a. ni-na+tsukur-a ‘I am taking’
b. ni-na+a̲-tsukǔr-â ‘I am taking them’
c. a̲-na+á̲-tsúkúr-â ‘s/he is taking them’

Jardine (2016: §2.2.2) claims that the tonal pattern in Digo is unbounded circumambient. However, the pattern is analysable as left-subsequential, as we show in Fig. 12. The transducer reads the input tape from left to right, and spreads H from the second input H until the penultimate syllable. The analysis only requires ‘waiting’ two symbols upon reading an input H to ensure that the target for tone shifting (if only a single H occurs), or the final target for tone spreading (if two H tones occur) is the penult. One reviewer suggests that, when viewed as two separate patterns, tonal plateauing is still unbounded circumambient. As we have noted, the issue is that the computational approach that guides both our work and Jardine’s addresses the total input–output mapping, without assigning any formal status to individual patterns like tone shifting or tone plateauing. As a whole, the mapping is left-subsequential.

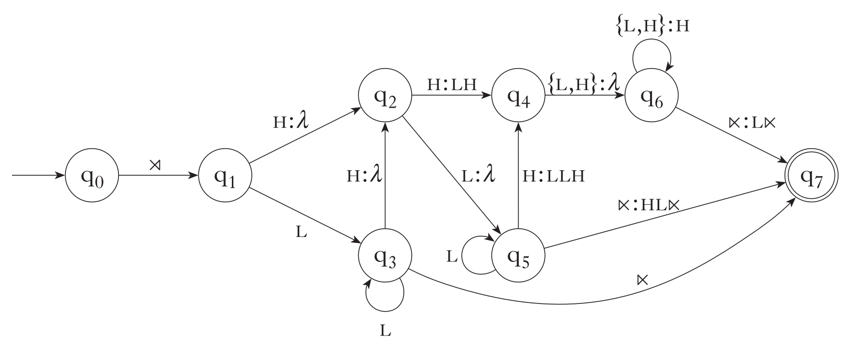

Figure 12

Left-subsequential FST for Digo tone shifting and tone spreading (assuming that the rise–fall sequence on the final two TBUs is a HL sequence).

Moreover, we see no convincing evidence that the pattern in Xhosa is unbounded circumambient either. In Xhosa, Kisseberth & Odden (2003: 67–68) note that a single H shifts to the antepenult. In words (or perhaps phrases) with more than one H, H spreads from the second underlying H to the antepenult, the destination for leftmost tone shifting. Just like Digo, a left-subsequential transducer can trigger spreading from the second H encountered up to the antepenult with only bounded look-ahead, almost exactly like the Digo analysis just sketched.

ADDITIONAL REFERENCES

Kisseberth, Charles W. (1984). Digo tonology. In G. N. Clements & John A. Goldsmith (eds.) *Autosegmental studies in Bantu tone*. Dordrecht: Foris. 105–182.

Kisseberth, Charles W. & David Odden (2003). Tone. In Derek Nurse & Gérard Philippson (eds.) *The Bantu languages*. London & New York: Routledge. 59–70.