Extending the Autosegmental Input Strictly Local Framework: Metrical Dominance and Floating Tones

Abstract

This paper extends the empirical coverage of the autosegmental input strictly local (A-ISL) framework (Chandlee and Jardine, 2019) by analyzing three tonal processes: metrical dominance effect in Shanghai Chinese, floating tone suffixation in Cantonese and a combination of metrical dominance and floating tones in Suzhou Chinese. I show both the adequacy and inadequacy of the A-ISL framework: it locally resolves some tonal processes that are otherwise non-local (Shanghai), but fails to account for other empirical data due to a lack of tonal membership specification (Suzhou). I then propose an analysis for the Suzhou data relying on a hybrid tier-based strictly local (TSL) model (Heinz et al., 2011) with autosegmental representations and morphophonological membership specification. The paper contributes to our typological knowledge of computational locality and autosegmental phonological representations.

1 Introduction

In this paper I aim to build on the autosegmental input strictly local (A-ISL) functions introduced in Chandlee and Jardine (2019), and examine some tonal processes not discussed by the previous A-ISL accounts, extending the empirical coverage of A-ISL transductions. I will assess three phonological processes involving tones: metrical dominance effect in Shanghai Chinese (Duanmu, 1999), floating tone suffixation in Cantonese (Chen, 2000; Yip, 2002), and a combination of metrical dominance and floating tones in Suzhou Chinese (my fieldwork).

I show through the examination of these three cases that the A-ISL model is well-equipped to capture most patterns involving metrical dominance (Shanghai) and floating tones (Cantonese). However, the combination of metrical dominance and floating tones (Suzhou) is not definable through quantifier-free (QF) first-order (FO) logical transductions, even if we adopt autosegmental instead of linear tone representation. That is, the tone sandhi patterns in Suzhou Chinese do not correspond to input strictly local (ISL) functions under autosegmental representations (Chandlee and Lindell, in prep). This particular insight has been discussed in Chandlee and Jardine (2019): although autosegmental phonology is claimed to be a ‘solution’ to non-local phonological processes as it makes tonal relationship local (Odden, 1994), the locality of autosegmental representations does not always hold when evaluated mathematically. I then provide an analysis for the process that is neither ISL nor A-ISL (Suzhou tone sandhi patterns): by giving the A-ISL framework access to morphophonological information, I show that the tone sandhi process in Suzhou is still strictly local on each tier.

The paper is structured as follows. In §2 I lay out some background on both autosegmental representations and A-ISL transductions. I introduce the three tonal processes and the attempts to analyze them using A-ISL transductions in §3. §4 summarizes the results and proposes an alternative analysis of Suzhou. §5 concludes this paper.

2 Background

2.1 Autosegmental Phonology

Autosegmental Phonology (Goldsmith, 1976) proposes separate autosegmental tiers and association relations between tiers as part of phonological representation to account for many long-distance/non-local phonological processes. A well-known segmental example is blocking and transparency effects of nasal harmony. In Johore Malay (Onn, 1980), vowels and approximants after a nasal consonant become nasalized, while ob-
Obstructs and liquids block this rightward nasalization process: [pəŋjəwəsən] but *[pəŋjəwəsən]. Interestingly, in Tuyuca (Barnes, 1996), obstructions are transparent to the nasal harmony: they do not carry nasality themselves, but the rightward nasal spreading can ‘skip over’ them — [mìpì]. The different transparency status with regard to nasal spreading can be easily captured by different featural specifications on the Nasality autosegmental tier:

(1) Blocking effect in Johore Malay
\[ \text{pənəwāsən} \quad \begin{array}{c} \text{[+Nasal]} \\ \text{[−Nasal]} \end{array} \]

(2) Transparency effect in Tuyuca
\[ \text{mìpì} \quad \begin{array}{c} \text{[+Nasal]} \end{array} \]

As shown, obstructions in Johore Malay are specified with a [−Nasal] feature on the nasal autosegmental tier, blocking the nasal spreading process. On the other hand, Tuyuca obstructions are transparent to spreading because they are underspecified on the nasality tier, allowing the rightward spreading to continue. Autosegmental representations allow non-local processes to be viewed locally on their respective tiers, and account for multiple blocking and non-blocking phonological processes straightforwardly.

Similarly, autosegmental representations are useful tools when analyzing tonal processes, as they make non-local tonal associations local on a separate ‘tonal’ tier. Chandlee and Jardine (2019) have evaluated the computational properties of multiple spreading and deletion processes of tones, assuming autosegmental representations. In this paper, I follow their methods and explore three slightly more complex tonal processes, drawing data from Chinese languages: The first case (Shanghai) introduces a metrical dominance effect to the A-ISL model; the second case (Cantonese) discusses floating tone affixes; the third case (Suzhou) combines both metrical dominance and floating tone representations.

### 2.2 Computational preliminaries

All preliminaries come from definitions in Chandlee and Jardine (2019). For strings, I assume the following in this paper:

1. \( \Sigma \): A finite alphabet of symbols.
2. \( \Sigma^* \): Set of all strings over \( \Sigma \).
3. Strings \( w, v \) and their concatenation \( wv \); set of strings \( L \) and concatenation between strings and sets of strings \( wL \).

For models, I assume:

4. A model \( \langle D, f_1, \ldots, f_n, R_1, \ldots, R_m \rangle \) where \( D \) is a finite domain of elements, \( f_1, \ldots, f_n \) are a set of functions over the domain, and \( R_1, \ldots, R_m \) are a set of relations over the domain.
5. For our purpose of examining strings, I assume models of the signature \( \{p, s, P_{\sigma \in \Sigma}\} \).
6. \( p, s \): predecessor and successor functions. \( p(i) = i - 1, s(i) = i + 1 \), with the exceptions that the first element is its own predecessor \( (p(1) = 1) \) and the last element is its own successor \( (s(n) = n) \) for a string of length \( n \).
7. \( P_{\sigma \in \Sigma} \): A unary relation for every \( \sigma \in \Sigma \) that gives the label of each position of the string.
8. A user-defined function \( \text{first}(x) \):
   \[ \text{first}(x) \overset{\text{def}}{=} p(x) = x. \]
9. A user-defined function \( \text{second}(x) \):
   \[ \text{second}(x) \overset{\text{def}}{=} (\neg p(x) = x) \land (p(p(x)) = p(x)). \]
10. A user-defined function \( \text{last}(x) \):
    \[ \text{last}(x) \overset{\text{def}}{=} s(x) = x. \]

I follow Chandlee and Jardine (2019) in using QF logic: For all QF formulas \( \psi(x_1, \ldots, x_n) \), the variables \( x_1, \ldots, x_n \) are unbounded by quantifiers. For logical transductions, I assume:

5. An input model signature \( I \), an output model signature \( O \).
6. \( \psi(x) \): a unary predicate in the input \( I \).
7. For each function \( f \in O \), \( f(x) \overset{\text{def}}{=} \psi_f(x, y) \) for some \( \psi_f(x, y) \) in \( I \).
8. For each unary relation \( P \in O \), \( P \overset{\text{def}}{=} \psi_P(x) \) for some \( \psi_P(x) \) in \( I \).
9. For each binary relation \( R \in O \), \( R \overset{\text{def}}{=} \psi_R(x, y) \) for some \( \psi_R(x, y) \) in \( I \).
10. \( M \models \psi(x_1, \ldots, x_n) \): the model \( M \) satisfies \( \psi(x_1, \ldots, x_n) \). For each set of \( x_1, \ldots, x_n \) in
3 Metrical dominance and floating tones

3.1 Left dominance in Shanghai tone sandhi

Shanghai is a variety of Northern Wu Chinese, well known for its distinctive tone sandhi patterns. The relevant tone sandhi data for our concern is given below (data from Duanmu (1999); tones in parentheses are surface tones):

(8) a. [i] (LM) ‘fish’
   b. [i̯ o] (MH) ‘small’
   c. [wâ] (LM) ‘yellow’
   d. [ci] (HM) ‘fresh’
   e. [i̯ oŋ] (M,H) ‘small fish’
   f. [wâŋ] (LM) ‘yellow fish’
   g. [ciŋ] (H,M) ‘fresh fish’
   h. [i̯ o wâŋ] (M,H,L) ‘small yellow fish’
   i. [ci wâŋ] (H,M,L) ‘fresh yellow fish’
   j. [i̯ o ci wâŋ] (M,H,L) ‘small fresh yellow fish’

A few generalizations can be made: first, only monosyllabic words carry contour tones\(^1\); second, tonal material of the initial syllable seems to be retained (and ‘redistributed’) in polysyllabic words; lastly, the third and fourth syllables surface as L.

Duanmu’s (1999) analysis of Shanghai tone sandhi patterns proposes a metrical ‘left dominance’ effect. Simply put, footing in Shanghai is left-to-right, non-recursive and trochaic, giving phonological prominence\(^2\) to only the initial syllable in a prosodic word. According to Duanmu (1999), the initial syllable is the foot head and always retains its tonal material in tone sandhi positions. The second syllable, being the foot dependent, loses all of its tones. Additionally, tonal material from the initial syllable is shared between the first two (footed) syllables by tonal reassociations. Any unfooted syllables (third, fourth...) loses all tones and surface as toneless L (I will use italic L to represent any phonetic L tones from phonologically toneless syllables). An autosegmental demonstration of the process is given in (9):

\(^1\)Duanmu (1999) accounts for this by proposing that all syllables in Shanghai are underlyingly monomoraic, and they only get lengthened to be bimoraic when in isolation. Consequently, only syllables with two moras can carry two level tones, contributing to a contour.

\(^2\)Being in themetrical head position does not necessarily entail phonetic stress (increased intensity and duration, higher pitch). The metrical prominence here could be purely phonological in that it does not have any phonetic correlates.
(9) An autosegmental derivation of [e̋o.wä.ŋ] ‘small yellow fish’. σ⁺ stands for a footed head syllable and σ⁻ a footed dependent. The third syllable is phonologically toneless and surfaces as a phonetic L.

\[
\begin{array}{cccccc}
\sigma & + & \sigma & + & \sigma & \rightarrow (\sigma^+. \sigma^-). \sigma \\
M & H & L & M & L & M & M & H & L
\end{array}
\]

Abstracting away from the language data, the left dominant tone sandhi process can be represented as follows (toneless L are omitted):

(10)

\[
\begin{array}{cccc}
\sigma & + & \sigma^n & \rightarrow & \sigma & . & \sigma & . & \sigma^{n-1} \\
A & B & T & A & B
\end{array}
\]

In (10), A and B stand for underlying tones of the first syllable, T stands for any tones (contour or level). This tone sandhi process is not ISL: A transformation assuming strings of tones ABTⁿ → AB^n⁻¹ does not reflect the fact that tonal material of the initial syllable is redistributed between the first two (footed) syllables. This is directly caused by my representation of contour tones as subsequent level tones associated to one TBU — Contour tones can be ‘broken apart’ and shared between two syllables in Shanghai. Therefore, it is not possible to represent them as standalone units (e.g. R for Rise; see Chandlee (2018) on tone sandhi in Tianjin). Consequently, it is necessary to adopt autosegmental representations since contour tones entails many-to-one tone mapping.

However, the tone sandhi process in Shanghai is A-ISL since we can easily define it with a quantifier-free transduction using autosegmental representations.

(11) a. σ'(x) def = σ(x)  
   b. H'(y) def = H(y)  
   c. M'(y) def = M(y)  
   d. L'(y) def = L(y)

4e. A'(x, y) def = (A(x, y) \land first(x) \land first(y)) \lor (A(p(x, y) \land second(x) \land second(y))

In the above formulas, x represents TBU elements and y tonal elements. The formulas (11a)-(11d) preserves all input TBU and tones in the output.  

The formula in (11e) states the association relations in the output structure: a TBU is associated with a tone in the output if: (i) there is an association between it and the first tone in the input, and it is the first TBU; (ii) there is an association between its predecessor TBU and the second tone in the input, and it is the second TBU.

Interestingly, through this transduction, all other tones not belonging to the initial syllable are still present in the output, but they are not associated. This essentially renders all footed (i.e. neither first nor second) syllables toneless, and subject to surface phonetic implementation. In Shanghai, all toneless syllables simply surfaces as L. A related observation is that tones in Shanghai show their ‘membership’ status through the association relations: the first two tones ‘belong’ to the initial syllable, because they are associated with the initial syllable. If morphemes in the language contain floating tones, our current model is not able to determine its membership status. This is demonstrated in (12):

(12) An autosegmental representation with ambiguous membership status

\[
\begin{array}{ccc}
\sigma_1 & \sigma_2 \\
A & B & C
\end{array}
\]

The current autosegmental model has no way of expressing membership of floating tones: we know \( \sigma_1 \) precedes \( \sigma_2 \), and tone B is in between tones A and C. However, there is no way to determine if the floating tone B comes from \( \sigma_1 \) or \( \sigma_2 \) underlyingly. This poses a problem when we encounter

\^[4]An A-ISL transduction where all unassociated tones are deleted/replaced by L is also viable. For simplicity of the model, I assume that all unassociated tones will not have any impact on the output.

\^[5]On a side note, this transduction handles situations where the initial syllable only has one tone correctly as well: [ci][H] + [fo][H] = [ci][fo][H,L]. As there is not a second tone associated with the first syllable, the second syllable will not be associated with any tones on the output and becomes toneless. Same is true with situations where the initial syllable has three or more tones (unattested in Shanghai, but generalizable to other left-dominant dialects).
languages utilizing both metrical dominance and floating tones (see §3.3).

3.2 Floating tone suffixation in Cantonese

Both Chen (2000) and Yip (2002) present a case of the ‘familiar vocative’ affix in Cantonese as a demonstration of floating tone suffixation. The relevant data is presented in (13):

(13) a. [a] (M) ‘Old’, a vocative prefix
    b. [tsaeng] (HM) ‘Zhang’, a last name
    c. [tsa] (ML) ‘Chen’, a last name
    d. [a,tsaeng] (M.HM) ‘Old Zhang’
    e. [a,tsa] (M.MH) ‘Old Chen’

The process is rather straightforward: a floating H morpheme is attached to the right edge of the familiar vocative term, overwriting the rightmost tone of the rightmost syllable (Chen, 2000; Yip, 2002). The process can be represented as follows:

\[
\begin{align*}
\sigma^n + \sigma & \rightarrow \sigma^n . \sigma \\
T & A B H T A H
\end{align*}
\]

Interestingly, this process is both ISL and A-ISL.

(15) Cantonese floating H suffixation is ISL.

Assume a linear transformation \( T_1...T_k + H \rightarrow T_1...T_{k-1}H \) for any \( k \), two input strings \( T_1...T_k \) and \( T_0T_1...T_k \) have the same \( k \)-suffix (\( T_1...T_k \)). Moreover, adding any input extension to the two strings will result in the same output contribution: \( (T_0)T_1...T_k...T_n + H \rightarrow (T_0)T_1...T_k...T_{n-1}H \). The two strings have the same tails (see the formal definition of tails in Chandeeli (2014)).

This process is A-ISL as it is QF-definable by the following transduction:

(16) a. \( \sigma'(x) \equiv \sigma(x) \)
    b. \( H'(y) \equiv H(y) \)
    c. \( M'(y) \equiv M(y) \)
    d. \( L'(y) \equiv L(y) \)
    e. \( A'(x, y) \equiv (A(x, y) \land \neg \text{last}(x)) \lor \text{last}(x) \land (A(x, y) \land A(x, s(y))) \lor (\text{last}(y) \land \text{last}(x))) \)

Similar to (11), (16a)-(16d) maps every input TBU and tone to the output (including the floating H).

The formula (16e) determines the output association relations between the two tiers: (i) preserve all association relations that do not involve the last syllable; (ii) associate the first tone of the last syllable in the input to the last syllable; (iii) associate the last tone (floating H) in the input to the last syllable.

There is also an interesting twist to the Cantonese data: if the rightmost syllable has a level tone, the floating H affixation process will create a contour tone instead of overwriting the rightmost level: \( M.L + H \rightarrow M.LH \). It requires a bit more effort to differentiate cases where the rightmost tone is a level or a contour in the logical transduction. However, changing the representation of L level to LL\(^6\) correctly accounts for the transformation without altering the transduction itself.

3.3 Left dominance and floating tones in Suzhou tone sandhi

The tone sandhi data of Suzhou Chinese mainly comes from my fieldwork. Here, I present two pairs of alternation that motivates both left dominant sandhi and floating tones:

(17) a. \( [s\text{\`a}] \) (HL) ‘small’
    b. \( [s\text{\`a}] \) (HL) ‘laughter’\(^7\)
    c. \( [\text{\`i}] \) (LH) ‘story’
    d. \( [s\text{\`a},\text{\`i}] \) (HL.L) ‘small story’
    e. \( [s\text{\`a},\text{\`i}] \) (L.H) ‘funny story; joke’

Suzhou resembles Shanghai as it also has left-dominant tone sandhi patterns: tones from initial syllables are always preserved in polysyllabic words, while tones from non-initial syllables are all deleted. \( [\text{\`i}] \) (‘story’) carries a LH contour tone in isolation, but always neutralizes to L when it is the second syllable in a prosodic word. Crucially, Suzhou presents an opaque sandhi process, where two morphemes/syllables sharing the same surface isolation tones (17a)(17b) behave differently in sandhi positions (17d)(17e). My analysis is to posit an tonal representation contrast between (17a) and (17b): Both H and L are associated in (17a), while (17b) has an associated H and an floating L underlingly. The autosegmental representations are given in (18):

\(^{6}\)This could be motivated by proposing that Cantonese is a mora-TBU language, and unreduced syllables in Chinese languages are usually bimoraic.

\(^{7}\)A more conservative variety of Suzhou pronounces (17b) as having a HLH complex contour. The contrast between HL and HLH tones is lost among younger speakers.
Suzhou tone sandhi process differs from that of Shanghai in that associated tones cannot be redistributed to other TBUs (corresponding to constraints in the OT literature such as $\text{MAX-LINK} - \mu[S\text{EG}]$; see Mören (1999)). Only floating tones from the initial syllable can be freely associated to other footed syllables in sandhi position.

The tone sandhi process in Suzhou is not ISL for the same reason given in 3.1: one linear string of tones cannot express many-to-one tonal association relations. Moreover, this process is also not A-ISL. Since floating tones have no way to express their membership status under the current autosegmental representations (recall (12)), the model cannot determine if a floating tone belongs to the initial syllable or not — left dominance cannot function on floating tones under the current framework. Consider a more concrete pair of examples in (19) and (20):

\begin{align*}
(19) & \hspace{1cm} & (20) & \hspace{1cm} \\
\sigma_1 & + & \sigma_2 & \rightarrow & \sigma_1 & , & \sigma_2 & \hspace{1cm} & \sigma_1 & + & \sigma_2 & \rightarrow & \sigma_1 & , & \sigma_2 \\
L & H & & & L & H & & & L & L & & & L & H & & & L & L
\end{align*}

In (19), the sequence contains an initial LH syllable with a floating H and a second L syllable. Since the H tone is floating and belongs to the initial syllable, it is retained and reassigned to the second syllable in tone sandhi positions. In contrast, (20) contains an initial L syllable and a second HL syllable with a floating H. Both tones in the second syllable are deleted in tone sandhi, and the surface form would be $[L.L]$ instead of $[L.H]$. Our current framework cannot differentiate (19) and (20), since there is no way to express membership of floating tones.

4 Discussion

4.1 Evaluation of analyses

In 3 I have illustrated three tonal processes in Chinese and their ISL/A-ISL status. The result is summarized in Table 1 below.

I have shown three out of four different logical possibilities of ISL and A-ISL transductions: (i) both ISL and A-ISL; (ii) not ISL but A-ISL; (iii) neither ISL nor A-ISL. Considering the analyses of Shanghai and Suzhou as a whole, the metrical dominance effect is non-ISL mainly because of the many-to-one tonal mapping. An ISL model treating tones as linear strings cannot represent contour tones as sequences of levels without some modification (e.g. including syllable boundaries in the tonal string).

On the other hand, having floating tones in the representation does not necessarily make the transformation non-A-ISL. The Cantonese affixation case is A-ISL because the process is purely linear on the tonal level. Floating tones in the Cantonese case only stand for tones without segmental content. However, in Suzhou, floating tones are members of specific syllables/morphemes. This membership plays a crucial role in application of tone sandhi, but cannot be expressed under an A-ISL model.

4.2 A morphophonological analysis of Suzhou

As I have shown in §3.3, the current A-ISL framework cannot account for the combination effect of left dominance and floating tone realizations in Suzhou. For the Suzhou tone sandhi data, the task is to posit distinct representations for the two [HL] surface tones, and account for their different realizations in sandhi positions. My floating tone analysis requires the analytical model to recognize membership of tones (i.e. which syllable a specific floating tone belongs to underlyingly), which the A-ISL framework is incapable of doing. One solution is to adopt a hybrid Tier-based strictly local (TSL, Heinz et al. (2011)) and A-ISL model. An TSL grammar can ignore certain elements in a string, while projecting everything relevant to the tier adjacent to each other. The membership problem can be solved if we stipulate a morphophonol-
ogy tier and project the binary association relations between morphemes (often as syllables in Chinese languages) and tones. A refined representational model would look like (21):

\[
\begin{array}{c}
\sigma_1 \\
\sigma_2 \\
H L \\
H L \\
Mor_1 \\
Mor_2
\end{array}
\]

Shown above are the refined representations of the minimal tonal pair in (18). With an additional Mor (morpheme) tier, the framework recognizes membership of tones by their association to specific morphemes. For instance, the second H in (21a) is floating due to its non-association on the tonal tier, but it clearly belongs to the first morpheme due to its association to Mor1.

With the added morphophonology tier information, the transduction becomes very similar to that of Shanghai. I give the revised model signature and transduction in (22) and (23)

\[
\begin{align*}
&\text{(22)} & D[p,s,A,R_{Mor},P_H,P_M,P_L,P_\sigma] \\
&\text{(23)} & a. \quad \sigma'(x) \overset{\text{def}}{=} \sigma(x) \\
& & b. \quad H'(y) \overset{\text{def}}{=} H(y) \\
& & c. \quad M'(y) \overset{\text{def}}{=} M(y) \\
& & d. \quad L'(y) \overset{\text{def}}{=} L(y) \\
& & e. \quad Mor'(z) \overset{\text{def}}{=} Mor(z)^8 \\
& & f. \quad A'(x,y) \overset{\text{def}}{=} (A(x,y) \land \text{first}(x)) \lor \\
& & \quad (\neg A(p(x),y) \land Mor(y,z) \land \\
& & \quad \text{first}(z) \land \text{second}(x) \land \text{second}(y))
\end{align*}
\]

In (22), a binary morphophonological relation \(R_{Mor}\) is added, associating tones with their corresponding morphemes. In (23), \(x\) stands for TBU positions, \(y\) for tones and \(z\) for morphemes. (23a)-(23e) map all string information (TBUs, tones, morphemes) to the output. (23f) is the revised transduction for the output tonal association relations. A TBU is associated with a tone in the output if: (i), it is the first syllable and the tone is associated to itself in the input, or (ii) it is the second syllable, and the second tone belonging to the first morpheme (by \(R_{Mor}\)) is not associated to the first syllable (by \(A\)). This transduction ensures that all tonal associations to the first syllable are preserved in the output ((17d), [H,L]), while a second floating tones of the first syllable can redistribute to the second syllable ((17e), [H,L]).

A cautionary note to this alternative analysis is that the model could become too powerful (i.e. overgenerating): by adding a morphophonology tier and assuming that autosegmental representations have access to morphological information, the framework becomes less restrictive in that it allows more possibilities in autosegmental representations, some of which might not have been attested in natural languages. The nature of floating tones and left dominance in Suzhou invites more in-depth discussion, which would benefit both theories of autosegmental representations and ones of computational locality.

5 Conclusion

In this paper, I have examined three distinct tonal processes among Chinese languages assuming an A-ISL framework. I have shown that pure metrical dominance in Shanghai is A-ISL but not ISL, floating tone suffixation in Cantonese is both ISL and A-ISL. However, a combination of metrical dominance and floating tones in Suzhou tone sandhi is neither ISL nor A-ISL. I propose a modified A-ISL model with a morphophonological tier, which resolves the tonal membership problem by tone-morpheme association and renders the tone sandhi process A-ISL again. The analyses contribute to our typological knowledge of computational locality and autosegmental phonology.
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