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

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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: floating tone suffixation in Cantonese, metrical dominance effect in Shanghai Chinese, and a combination of floating tones and metrical dominance in Suzhou Chinese. I show both the adequacy and inadequacy of the current 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). With the addition of a morphological affiliation tier, I propose an analysis for the Suzhou data. 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: floating tone suffixation in Cantonese (Chen, 2000; Yip, 2002), metrical dominance effect in Shanghai Chinese (Duanmu, 1999), and a combination of floating tones and metrical dominance in Suzhou Chinese (Shi and Jiang 2013, my fieldwork).

I show through the examination of these three cases that the A-ISL model is well-equipped to capture most patterns involving floating tones (Cantonese) and metrical dominance (Shanghai). However, the *combination* of floating tone representation and metrical dominance (Suzhou) cannot be A-ISL: The Suzhou tone sandhi map is not definable through *quantifier-free* (QF) *first-order* (FO) logical transductions Chandlee and Lindell in prep, even if we adopt autosegmental instead of linear tonal representation. 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 also show that the Suzhou data can be accurately accounted for with a minimal addition of morphological affiliation relations (i.e. association between tones and morphemes).

The paper is structured as follows. In §2 I layout 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. Examples of two observed patterns of nasal harmony are given below.

(1) Blocking effect in Johore Malay (Onn, 1980)
/pəŋawasan/ ↦ [pəŋãw̃ãsan] (*[pəŋãw̃ãsãn])

* I would like to thank Jeffrey Heinz, Jonathan Rawski, Jane Chandlee and the anonymous reviewers for their insightful feedback. All errors are my own.

(2) Transparency effect in Tuyuca (Barnes, 1996)
/mipi/ $\mapsto$ [m̃ĩp̃ĩ] (*[m̃ĩpi])

In (1) obstruents and liquids block rightward nasalization, whereas in (2) obstruents are *transparent* to the nasal harmony. The difference between these two patterns is often captured by a (under)specified [Nasal] feature of the obstruents on the autosegmental tier: an obstruent that blocks nasalization is necessarily specified with [-Nasal], while one that allows nasality to 'pass through' is underspecified on the Nasal autosegmental tier. Autosegmental representations resolve the non-local nature of such harmony patterns by proposing that relevant features to harmony are still *local* on their respective autosegmental tiers.

For similar reasons, autosegmental representations are useful tools when analyzing tonal processes. 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 than those analyzed in Chandlee and Jardine's paper, drawing data from Chinese languages: The first case (Cantonese) discusses floating tone affixes; the second case (Shanghai) introduces a metrical dominance effect to the A-ISL model; 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:

(3) a. Σ: A finite alphabet of symbols.
b. Σ^*: Set of all strings over Σ.
c. 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. A model $\langle D | f_1, ..., f_n, R_1, ..., R_m \rangle$ where D is a finite domain of elements, $f_1, ..., f_n$ are a set of functions over the domain, and $R_1, ..., R_m$ are a set of relations over the domain.
b. For our purpose of examining strings, I assume models of the signature $\{p, s, P_{\sigma \in \Sigma}\}$.
c. 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).
d. $P_{\sigma \in \Sigma}$: a unary relation for every $\sigma \in \Sigma$ that gives the label of each position of the string.
e. A user-defined function first(x): $\texttt{first}(x) \overset{\text{def}}{=} p(x) = x$.
f. A user-defined function second(x): $\texttt{second}(x) \overset{\text{def}}{=} (\neg p(x) = x) \wedge (p(p(x)) = p(x)$.
g. A user-defined function last(x): $\texttt{last}(x) \overset{\text{def}}{=} s(x) = x$.

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

(5) a. An input model signature I, an output model signature O.
b. $\psi(x)$: a unary predicate in the input I.
c. For each function $f \in O$, $f(x) \overset{\text{def}}{=} \psi_f(x, y)$ for some $\psi_f(x, y)$ in I.
d. For each unary relation $P \in O$, $P \overset{\text{def}}{=} \psi_P(x)$ for some $\psi_P(x)$ in I.
e. For each binary relation $R \in O$, $R \overset{\text{def}}{=} \psi_R(x, y)$ for some $\psi_R(x, y)$ in I.
f. $M \models \psi(x_1, ..., x_n)$: the model M *satisfies* $\psi(x_1, ..., x_n)$. For each set of $x_1, ..., x_n$ in M the formula $\psi(x_1, ..., x_n)$ is evaluated to be true. This defines *n-ary* mappings between input and output.

A logical transduction τ maps models of input structure M_I to those of output structure M_O, where:

(6) a. For each $x \in D$ there is a copy x' in the output iff $M_I \models \psi_D(x)$.
b. For some pair $x, y \in D$ and for each function $f(x') \in O$, there is a copy pair x', y' in the output such that $f(x') = y'$ iff $M_I \models \psi_f(x, y)$.
c. For some $x \in D$ and for each unary rela-

tion $P \in O$, there is a copy $x' \in P$ in the output iff $M_I \models \psi_P(x)$

d. For some pair $x, y \in D$ and for each binary relation $R \in O$, there is a copy pair $(x', y') \in R$ in the output iff $M_I \models \psi_R(x, y)$

2.3 Autosegmental models

Segmental information of strings is irrelevant for the purpose of the current paper and thus will be omitted. I will assume a Tone-Bearing-Unit (TBU) tier and a Tonal tier (containing High, Mid and Low tones) for the rest of this paper. The TBU tier and the tonal tier are treated as separate strings, connected by a binary association relation. A sufficient model signature for autosegmental representations is presented in (7):

(7) $\langle D | p, s, A, P_H, P_M, P_L, P_\sigma \rangle$

Where D is the domain, p, s are predecessor and successor functions, A is a binary association relation between tones and TBUs, P_H, P_M, P_L are unary relations for High, Mid and Low tones, and P_σ is a unary relation for TBUs (syllables). With respect to contour tones, I follow general autosegmental representations (Yip 2002 for discussion) and treat them as sequences of level tones (i.e. a high falling tone is represented as a HL sequence; see §3.2). Moreover, concatenation of autosegmental representations will simply be concatenations of strings on each autosegmental tier, preserving all association relations in A.

I will include examples for each of the cases examined in the following section. For now, I will demonstrate the tonal map process with an artificial bounded deletion example.

(8) Bounded tone deletion
/mòmó/ ↦ [mò.mo]

The process in (8) can be captured by the A-ISL model in Figure 1:

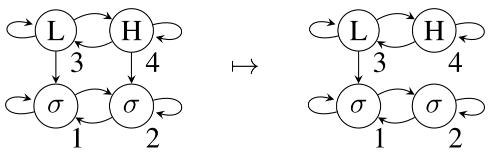


Figure 1: An example of autosegmental tonal mapping

As shown, the process of final tone deletion can be captured as the deletion of a tone-TBU association relation: the association between H (position 4) and the last syllable (position 2) — A(4,2) — is deleted on the output[1]. This hypothetical tone deletion process is definable through the following QF logical formulae, and is this A-ISL:

(9) a. $\sigma'(x) \stackrel{\text{def}}{=} \sigma(x)$
b. $T'(y) \stackrel{\text{def}}{=} T(y)$
c. $A'(y, x) \stackrel{\text{def}}{=} A(y, x) \wedge \neg \texttt{last}(y)$

(9a) states that the unary relation $\sigma'(x)$ is true if $\sigma(x)$ is true. This in turn maps all TBUs in the input (1 and 2) faithfully to the output. (9b) similarly maps all tones from the input to the output (I use T here as a short hand for all H/M/L tones). (9c) defines the crucial tonal process: the binary association $A'(y, x)$ is true if both of the following are true: (i). $A(y, x)$ is true; (ii). $\texttt{last}(y)$ is false. Put plainly, input tonal association lines are preserved in the output only if the tone is *not* the last element on the Tonal tier (in this case, 4).

In the next section, I show that the current A-ISL model (i) achieves the same empirical coverage of the ISL model in representing floating tone affixation; (ii) is able to resolve a crucial case that is non-ISL if viewed linearly (Shanghai); (iii) is unable to account for the combination case (Suzhou) due to model-external reasons.

3 Floating tones and metrical dominance

3.1 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 (10):

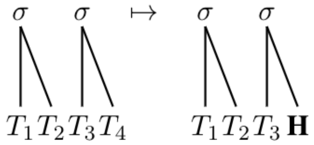
(10) a. [a](M) 'Old', a vocative prefix
b. [tsæng](HM) 'Zhang', a last name
c. [ts^{h}an] (ML) 'Chen', a last name
d. [a.tsæng] (M.HH) 'Old Zhang'
e. [a.ts^{h}an] (M.MH) 'Old Chen'

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,

[1]Tone deletion can also be captured by the deletion of tonal elements themselves. For our current purposes, I will assume that deletion of association lines achieves the same effect, as unassociated tones are not pronounceable on the surface (Yip, 2002).

2002). I will treat the process as final tone *substitution* instead of concatenation then deletion[2]:

(11) Cantonese H tone suffixation



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

(12) *Cantonese floating H suffixation is ISL.* Assume a linear transformation $T_1...T_k \mapsto T_1...T_{k-1}H$ 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, an input extension $T_k + 1...T_n$ to the two strings will result in the same output contribution: $T_k...T_{n-1}H$. The two strings have the same *tails* (see the formal definition of tails in Chandlee 2014).

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

(13) a. $\sigma'(x) \stackrel{\text{def}}{=} \sigma(x)$
b. $H'(y) \stackrel{\text{def}}{=} H(y) \vee \texttt{last}(y)$
c. $M'(y) \stackrel{\text{def}}{=} M(y) \wedge \neg\texttt{last}(y)$
d. $L'(y) \stackrel{\text{def}}{=} L(y) \wedge \neg\texttt{last}(y)$
e. $A'(x, y) \stackrel{\text{def}}{=} A(x, y)$

In the above formulae, x represents TBU elements and y tonal elements. Shown in (13), two input-output mappings are identical copies: (13a) faithfully maps input TBUs to the output, where (13e) preserves all association relations. The H tone substitution process is defined through the tonal mappings (13b)-(13d): a tone is a H tone in the output if it is H in the input *or* it is the last tone; it is a M/L in the output if it is M/L in the input *and* it is *not* the last tone. An A-ISL model demonstration of [a.ts^{h}an] (M.MH) 'Old Chen' is given below (predecessor and successor relations are omitted for readability).

Figure 2 illustrates the tonal mapping /M.ML/ ↦ [M.MH]. The unary relations for TBUs and the binary relations for tone-TBU associations are kept constant from input to output. The two M tones (in 3 and 4) are also mapped faithfully. Crucially, the tonal element in position 5 satisfies (13b) and does not satisfy (13d). As a result, a L tone in the input is substituted with a H tone in the output for 5.

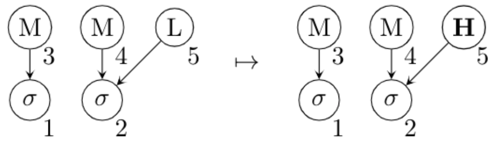


Figure 2: Cantonese H tone suffixation: A-ISL map

One fact further complicates 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 H level: /M.L/ ↦ [M.LH]. It requires a bit more effort for the tonal map to differentiate level or contour tones. However, changing the representation of L level to LL[3] correctly accounts for the transformation without altering the transduction itself.

3.2 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):

(14) a. [ŋ̍] (LM) 'fish'
b. [ɕ^{j}o] (MH) 'small'
c. [wã] (LM) 'yellow'
d. [ɕi] (HM) 'fresh'
e. [ɕ^{j}o.ŋ̍] (M.H) 'small fish'
f. [wã.ŋ̍] (L.M) 'yellow fish'
g. [ɕi.ŋ̍] (H.M) 'fresh fish'
h. [ɕ^{j}o.wã.ŋ̍] (M.H.L) 'small yellow fish'
i. [ɕi.wã.ŋ̍] (H.M.L) 'fresh yellow fish'
j. [ɕ^{j}o.ɕi.wã.ŋ̍] (M.H.L.L) 'small fresh yellow fish'

A few generalizations can be made: first, only monosyllabic words carry contour tones;[4] second, tonal material of the initial syllable seems to be re-

[2]This process can be interpreted as tonal substitution precisely due to the fact that the floating H affix is without segmental information. A process requiring tone-segment affiliations but not tone-TBU associations (i.e. floating tones *with* segments) is challenging to the current A-ISL model. See the case of Suzhou in 3.3.

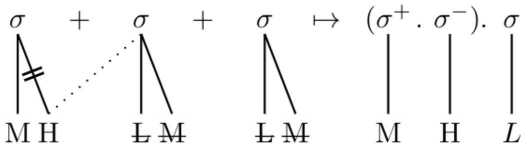
[3]This could be motivated by proposing that Cantonese is a *mora-TBU* language, and unreduced syllables in Chinese languages are usually bimoraic.

[4]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.

tained (and 'redistributed') in polysyllabic words; lastly, the third and fourth syllables surface as L.

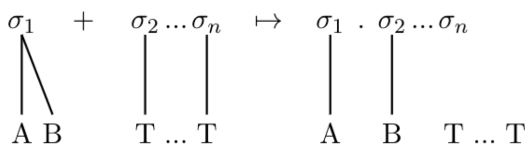
Duanmu's (1999) analysis of Shanghai tone sandhi patterns proposes a metrical 'left dominance' effect. Simply put, footing in Shanghai is left-to-right, non-recursive and trochaic, giving phonological prominence[5] to *only* the initial syllable in a prosodic word. According to Duanmu (1999), the initial 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 (15):

(15) An autosegmental derivation of [ɕʲo.wã.ŋ̍] '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.



Abstracting away from the language data, the left dominant tone sandhi process can be represented as deletion and addition of association lines while keeping all tones intact — I assume that tones without association to TBUs (i.e. floating tones) are not pronounced in the output[6]. Phonologically toneless syllables in the output are then subject to surface phonetic implementation (phonetic L in Shanghai).

(16) Left dominance in Shanghai



In (16), 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 $\mathrm{ABT}^n \rightarrow \mathrm{AB}\emptyset^{n-1}$ 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 entail many-to-one tone mapping.[7]

One reviewer has suggested that including syllable boundary symbols [.] in the alphabet could potentially resolve the non-locality of the Shanghai map: /AB.CD.EF/ $\mapsto$ [A.B.$\emptyset$]. This is indeed correct for the synchronic data of Shanghai: every lexical tone in contemporary Shanghai is a contour by historical coincidence. On the other hand, several neighboring dialects of Shanghai have complex contours (i.e. monosyllables with three tones), and it is logically possible for a syllable to have more than three tonal elements (albeit being typologically unattested). Since the existence of complex contours cannot be ruled out for theory-internal reasons, an ISL map should be able to handle tonal input of *indefinitely many tones within a syllable*. This is shown in (17)

(17) Hypothetical left-dominant mapping with complex contour input
$/\mathrm{T}_1\mathrm{T}_2...\mathrm{T}_n.\mathrm{T}_{n+1}/ \mapsto [\mathrm{T}_1.\mathrm{T}_2]$

This map is Non-ISL, because the transduction needs to 'remember' the second tone /T_2/ for an indefinite length until it encounters the first syllable boundary. 'Remembering' in ISL is achieved through a finite k-factor window (Chandlee, 2014). The current map with an indefinite memory length cannot be ISL.

However, the tone sandhi process in Shanghai is A-ISL since we can easily define it with

[5] Being in the metrical 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.

[6] A transduction with vowel deletion and reassociation would be indistinguishable from the current map in the output.

[7] Strictly speaking, Shanghai tone sandhi is non-ISL not because of any property of ISL functions, but because of the nature of *linear* phonological transformations: any current phonological framework without an autosegmental representation of contour tones will have a hard time accounting for these data.

a quantifier-free transduction using autosegmental representations.

(18) a. $\sigma'(x) \stackrel{\text{def}}{=} \sigma(x)$
b. $H'(y) \stackrel{\text{def}}{=} H(y)$
c. $M'(y) \stackrel{\text{def}}{=} M(y)$
d. $L'(y) \stackrel{\text{def}}{=} L(y)$
e. $A'(y,x) \stackrel{\text{def}}{=} (A(y,x) \wedge \texttt{first}(x) \wedge \texttt{first}(y)) \vee (A(y,p(x)) \wedge \texttt{second}(x) \wedge \texttt{second}(y))$[8]

The formulae (18a)-(18d) preserve *all* input TBUs and tones in the output. The formula in (18e) 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. I demonstrate the A-ISL map using the example [ɕi.ŋ̩] (H.M) 'fresh fish'.

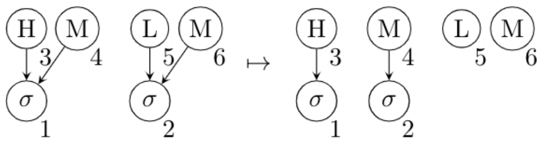


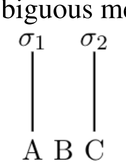
Figure 3: Shanghai left-dominant sandhi: A-ISL map

In Figure 3, all TBUs and tones (1 through 6) are preserved in the output. The autosegmental relation $A(3,1)$ satisfies the left disjunct of (18e) (first tone to first TBU), and is mapped faithfully to the output. The right disjunct of (18e) is satisfied when x is 2 and y is 4 (predecessor TBU is associated with the second tone), therefore a new autosegmental association $A'(4,2)$ is established in the output. As discussed above, left-over tones without association lines (5 and 6) are not pronounced in the output.

Interestingly, this transduction handles situations where the initial syllable only has one tone correctly as well: /H/ + /ML/ ↦ [H.*L*]. As there is not a pair of value that satisfies the right disjunct of (18e), the second syllable will not be associated with any tones in the output and becomes toneless. The same is true with situations where the initial syllable has *indefinitely many tones*: the second tone will be displaced, whereas all left-over tones remain floating.

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 affiliation status. This is demonstrated in (19):

(19) An autosegmental representation with ambiguous membership status



The current autosegmental model has no way of expressing morphological affiliation of floating tones: we know σ_1 precedes σ_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 σ_1 or σ_2 underlyingly. This poses a problem when we encounter languages utilizing *both* metrical dominance and floating tones (see §3.3).

3.3 Floating tones and left dominance in Suzhou tone sandhi

The tone sandhi data of Suzhou Chinese comes from (Shi and Jiang, 2013) and my fieldwork (Zhu, in prep). Here, I present two pairs of alternation that motivate *both* floating tone representation and left dominance:

(20) a. [sʲæ] (HL) 'small'
b. [mã] (LH) 'blind'
c. [nɪn] (LH) 'person'
d. [sʲæ.nɪn] (HL.*L*) 'child'
e. [mã.nɪn] (L.H) 'blind person'

Left dominance is still present in Suzhou: tones from initial syllables are always preserved in polysyllabic words, while tones from non-initial syllables are all deleted. Crucially, tonal redistribution does not always take place in Suzhou: in (20d), an underlying /HL/ falling tone stays in the initial syllable, where as in (20e) the underlying /LH/ evenly

[8] One reviewer has expressed concerns with the user-defined function `second`(x): why are there only `first` and `second`, but not `third` and more? This echoes with the insightful observation made by (Kenstowicz, 1994): 'linguistic rules do not count beyond two'. Here, the binary tone pattern in Shanghai is accounted for using a non-iterative binary foot (Duanmu, 1999). Including larger prosodic constituents (e.g. feet, prosodic words) is perfectly in line with principles of Autosegmental Phonology and the current A-ISL model. As such, a metrical foot level is not yet incorporated purely due to space constraints rather than model-internal limitations.

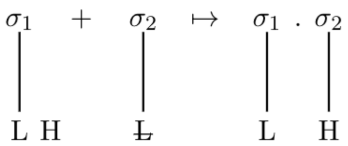
distributes itself over two syllables. Such pattern is inherent to the two lexical tones and is systematic across different morphemes.

To account for the different movability nature of the two lexical tones, I propose a tonal representation contrast between (20a) and (20b): Both H and L are associated in (20a), while (20b) has both tones floating underlyingly. The autosegmental representations are given in (21):

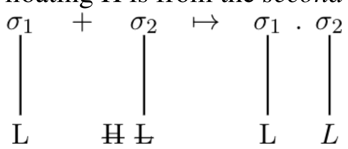
(21) a. 'small' b. 'blind'

The tone sandhi process in Suzhou differs from that of Shanghai in that associated tones cannot be redistributed to other TBUs (due to a general restriction on deleting association lines). Only floating tones from the initial syllable can be freely associated to other footed syllables in sandhi position. This process is not ISL for the same reason given in 3.2: one linear string of tones cannot express many-to-one tonal association relations. Moreover, this process is also Non-A-ISL. Since floating tones have no way to express their morphological affiliation status under the current autosegmental representations (recall (19)), 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 (22) and (23):

(22) A LH.L disyllabic sequence where the floating H is from the *initial* syllable.



(23) A L.HL disyllabic sequence where the floating H is from the *second* syllable.



In (22), the sequence contains an initial LH syllable with a floating H and a second L syllable. The floating H tone is redistributed to the second syllable in the output. In contrast, (23) 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 (22) and (23), 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.[9] 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. This is a roadblock to traditional linear-based phonology and is the motivation for Autosegmental Phonology in the first place.

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 (and also ISL) because floating tones in said case are tones without segmental content. However, in Suzhou, floating tones are elements associated with specific morphemes[10] without the TBU-tone association relations. This morpheme-tone association plays a crucial role in the application of tone sandhi, but cannot be expressed under the current model.

4.2 A reanalysis 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 representations in Suzhou. For the Suzhou tone sandhi data, the task is to account for the different tonal redistribution status for /HL/ (no redistribution) and /LH/ (even redistribution across two syllables). My floating tone analysis requires the model to recognize tone-morpheme association relations (i.e. which syllable a specific floating tone belongs to underlyingly). One solution is to simply include the tone-

[9](Chandlee and Jardine, 2019) claims that Bounded Meussen's Rule in Luganda corresponds to the forth possibility — ISL but not A-ISL.

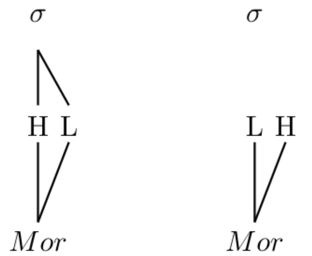
[10]A dominant majority of morphemes in Modern Chinese are monosyllabic. Polysyllabic morphemes are mostly transliterated loanwords. See Lin 2007.

Process	ISL	A-ISL
Cantonese floating H affixation	Yes	Yes
Shanghai left dominant tone sandhi	No	Yes
Suzhou left dominant tone sandhi with floating tones	No	No

Table 1: Summary of analyses

morpheme association information on a separate tier (see a similar treatment with morphological indexes in Trommer and Zimmermann 2014). A refined representational model would look like (24):

(24) a. ‘small’ b. ‘blind’



Shown above are the representations of the two lexical tones in (21). With an additional Mor (morpheme) tier, the representation includes morphological affiliation status of tones by the tone-morpheme association. For instance, both tones in (24b) are floating due to their non-association on the tonal tier. However, the two floating tones are inherent ‘members’ of the morpheme ‘blind’ due to their association with Mor on the morpheme tier.

With the added morphological information, the transduction becomes very similar to that of Shanghai. I give the revised model signature and transduction in (25) and (26)

(25) $\langle D|p, s, A, R_{Mor}, P_{Mor}, P_H, P_M, P_L, P_\sigma \rangle$

(26) a. $\sigma'(x) \stackrel{\text{def}}{=} \sigma(x)$

b. $H'(y) \stackrel{\text{def}}{=} H(y)$

c. $M'(y) \stackrel{\text{def}}{=} M(y)$

d. $L'(y) \stackrel{\text{def}}{=} L(y)$

e. $Mor'(z) \stackrel{\text{def}}{=} Mor(z)$[11]

f. $A'(x, y) \stackrel{\text{def}}{=} (A(x, y) \wedge \texttt{first}(x)) \vee (\texttt{first}(x) \wedge \texttt{first}(y)) \vee (\neg A(p(x), y) \wedge R_{Mor}(y, z) \wedge \texttt{first}(z) \wedge \texttt{second}(x) \wedge \texttt{second}(y))$

In (25), a unary relation P_{Mor} for morphemes and a binary relation R_{Mor} for tone-morpheme associations are added. In (26), x stands for TBU positions, y for tones and z for morphemes. (26a)-(26e) map all TBUs, tones and morphemes faithfully to the output. (26f) is the revised transduction for the output tone-TBU association relations. A TBU is associated with a tone on the surface in the following three conditions: (i). If the TBU is the first syllable and the tone is associated to itself in the input; (ii). The first tone is by default associated to the first syllable in the output, regardless of its floating status; (iii). If the TBU 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 ((20d), [HL.L]), while a second floating tones of the first syllable can redistribute to the second syllable ((20e), [L.H]). I demonstrate the A-ISL maps for both cases below.

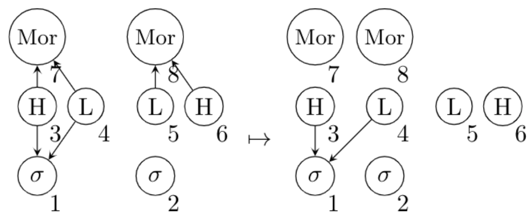


Figure 4: Suzhou A-ISL map — [HL.L]

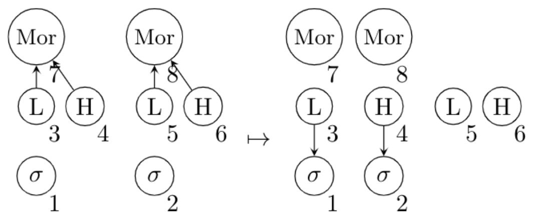


Figure 5: Suzhou A-ISL map — [L.H]

In Figure 4, two tone-TBU association relations $A(3, 1)A(4, 1)$ satisfy the first disjunct of (26f): they are both tone-TBU associations with the first syllable. Morphological information is irrelevant in this case. This gives us the correct out-

[11] I remain agnostic regarding the status of morpheme-tone associations (R'_{Mor}) in the output. It is possible that tone-morpheme reassociations also take place through the tone sandhi map. As far as I know, there is no additional post-sandhi phonological process that requires information regarding the morphological association of tones *before* sandhi.

put [HL.L]. In Figure 5, however, the latter two disjuncts of (26f) apply: Firstly, the first tone in 3 is associated with the first syllable in 1 in the output; Secondly, the third disjunct of (26f) is satisfied when x is 2, y is 4 and z is 7 — The second tone (position 4) of the first morpheme (position 7) is not associated with the first syllable (position $p(2)$).The output is [L.H], with both tones of the initial morpheme evenly distributed.

5 Conclusion

In this paper, I have examined three distinct tonal processes among Chinese languages assuming an A-ISL framework. I have shown that floating tone suffixation in Cantonese is both ISL and A-ISL, and pure metrical dominance in Shanghai is A-ISL but not ISL. A combination of floating tone representations and metrical dominance in Suzhou tone sandhi is neither ISL nor A-ISL. This is precisely because 'floating tone' has different entailment in the two cases: in Cantonese, a floating tone suffix is simply a tonal element without segmental information; in Suzhou, however, a floating tone is not associated to the TBU underlyingly, but is also part of the lexical representation of specific morphemes. I propose a modified A-ISL model with an additional morpheme tier, and provide a reanalysis of Suzhou by allowing tone-morpheme associations. Crucially, the Suzhou case is problematic for the current A-ISL model *not* due to any model-internal reasons: regardless of the formalism, a working phonological analysis of such pattern has to motivate morphological affiliation independently (Zhu, in prep).

The analyses so far have informed the typology of computational locality and possible Input Strictly Local maps. The three cases I have presented are all definable through Quantifier-Free transductions, and are thus A-ISL. In future work I would like to focus on more cases of linearly ISL but Non-A-ISL tonal maps (as discussed in Chandlee and Jardine 2019), and to see if floating tone representations indeed lead to problems unsolvable under the A-ISL model.

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