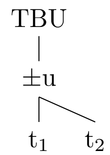
Spreading, Copying, and Notational Equivalence in Tonal Geometry

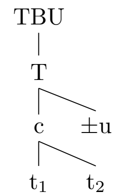
This paper pursues a computational characterization of spreading and copying mechanisms used to represent assimilatory tone sandhi patterns in Chinese dialects. We reject ‘spreadability’ as a reliable metric to distinguish competing models of tonal representation by demonstrating that, under certain crucial assumptions, spreading is formally indistinct from copying. Furthermore, we show that two feature-geometric representational models are in fact *notational variants* in that they are intertranslatable. In doing so, this paper offers new insight into questions of tonal representation.

We compare two competing feature-geometric models of tone: those proposed by Yip (1989) and Bao (1990), as in (1) (where ‘±u’ denotes a binary register feature, and ‘$t_{1/2}$’ denotes terminal tonal nodes *h* or *l*).

(1) Yip (1989):



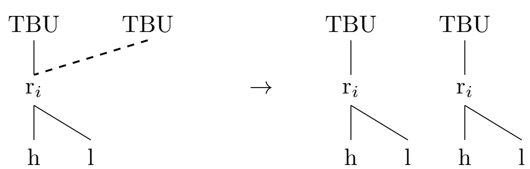
Bao (1990):



The key difference between the models is that Yip’s root node (that which associates directly to a tone-bearing unit or TBU) is specified for a register feature, whereas Bao’s root node ‘T’ is featurally unspecified and branches to separate register and contour nodes. Previous work (Chen 2000, Yip 2002) adopts Bao’s model over Yip’s given its ability to model certain assimilatory tone sandhi processes as *spreading*. As Yip’s model conflates register, contour, and root, it is incapable of capturing attested processes by which contour spreads *independently* of register (and vice versa).

Both representations, however, require an extra assumption of *tier conflation* (McCarthy 1986, Yip 1989) in which multiply-linked nodes and the structure they dominate are *copied*. A simplified example of assimilatory contour/whole tone spread in Danyang (Lü 1980) illustrates (where ‘r’ denotes a register node, regardless of featural specification):

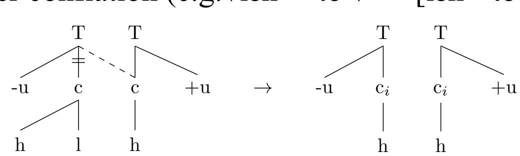
(2)



Tier conflation ensures that the resulting form is realized as [HL.HL] and not any of the logically possible (but unattested) *[H.L], *[H.HL] or *[HL.L]. Given this assumption, it is unclear that a spreading analysis of the assimilatory pattern in (2) differs from a *copying* analysis in which pieces of structure are simply copied and re-associated to yield identical surface forms.

To address this question, we adopt a model-theoretic approach (Libkin 2004) to analyze spreading and copying mechanisms over feature-geometric tonal representations. We explicitly define Bao and Yip tonal structures as sets of elements (nodes specified for features) which relate (association to a TBU, internal dominance, etc.). Assimilatory processes are formalized as *mappings* from input to output (Heinz 2018), which we define as (crucially *quantifier-free* or QF) logical formulae relating a finite number of output element copies to input structure (Courcelle 1994). A case study of contour assimilation in Zhenjiang (Zhang 1985)—traditionally analyzed as regressive spread of high contour and tier conflation (e.g. /lɛ̃n^{ML} to^{H}/ → [lɛ̃n$^{\mathbf{M}}$ to^{H}] ‘lazy’)—illustrates:

(3) /ML.H/ → [M.L]



$$c^{1,2}(x) \overset{\text{def}}{=} c(x) \wedge \texttt{last}(x)$$

$$h^{1,2}(x) \overset{\text{def}}{=} h(x) \wedge \texttt{last}(\delta(x))$$

$$l^{1,2}(x) \overset{\text{def}}{=} \texttt{False}$$

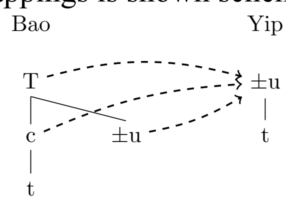
The logical formulae defined above state the following: the output structure comprises *two* copies of the rightmost (final) contour ‘c’ node and two copies of the ‘h’ node it *dominates* (denoted by δ). This definition is equivalent to *tier conflation* post-spreading in a spreading account and *copying* pieces of structure before re-association in a copying account. Other input elements with these labels—notably the falling contour on the penult—are deleted. We define output *relations* between elements in a similar way, that is, in terms of input structure. Dominance between copies is defined below.

(4) $\delta^{1,1}(x) \approx y \overset{\text{def}}{=} \delta(x) \approx y \qquad \delta^{2,1}(x) \approx y \overset{\text{def}}{=} \delta(x) \approx p(y)$

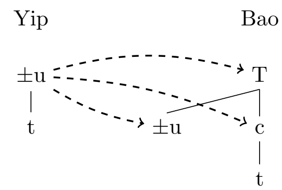
The first formula in (4) preserves input dominance between the first copy of the final 'c' node and the 'T' node that dominates it. The second formula relates the second copy of 'c' to its input *predecessor* (denoted *p*). This definition of relations is analogous to a regressive *spreading* mechanism before tier conflation in a spreading analysis and *re-association* post-copying in a copying analysis. Copying and spreading mechanisms therefore realize the *same map*, and are thus formally indistinguishable. On these grounds, we reject spreadability as a reliable metric to distinguish competing models of tonal representation such as those proposed by Bao (1990) and Yip (1989). Logical formulae as in (3) and (4) can be employed in the same fashion to define an identical mapping over Yip's representation.

Furthermore, and using the same formalism, we show that these models are notationally equivalent in that they are intertranslatable. We define a *mapping* from any tonal structure in Bao's representation to an equivalent structure in Yip's representation and vice versa. The intuition behind these mappings is shown schematically in (5).

(5) a.



b.



A mapping from Bao's model to Yip's (5a) represents a *fusion* of Bao's 'T' root, 'c' contour, and register nodes into a single Yip register node. By contrast, the inverse mapping (5b) *expands* Yip's register (root) node into separate 'T' root, 'c' contour, and featurally-specified register nodes in Bao's representation. These translation mappings, as was also the case with the assimilatory tone sandhi mappings, are definable using QF logical formulae.

A computational approach is well-suited to the questions broached by this study. Focusing on the *mappings* assimilatory tone sandhi processes realize abstracts away from assumptions specific to any one grammatical formalism (e.g. crucially-ordered rules in a derivational framework or constraints which target a spreading or copying mechanism specifically in an OT framework) to analyze their formal properties directly. QF-definability of process mappings underlies the important observation that assimilatory tone sandhi processes in Chinese dialects are fundamentally *local* (Chandlee and Lindell, forthcoming). QF also provides a restrictive and computationally simple complexity bound on translation mappings to explore model equivalence in a rigorous way. Our result also addresses an issue raised by Zhang (2014), who argues that the discussion of tonal representation is essentially at a standstill. We offer a new approach by asking whether the current hypothesis space is indeed populated by *distinct* theories, and evaluating the mechanisms which purport to distinguish them. We reason over both aspects of this question in the same formal language. Future work can apply this methodology to other competing models of tone.

Selected references: ● Bao, Z. (1990). On the nature of tone. PhD thesis, MIT. ● Chandlee, J. and Lindell, S. (forthcoming). A logical characterization of strictly local functions. In Heinz, J., ed. *Doing Computational Phonology*. OUP. ● Courcelle, B. (1994). Monadic second-order definable graph transductions: a survey. *Theoretical Computer Science* 126. ● Heinz, J. (2018). The computational nature of phonological generalizations. In Hyman, L. and Plank F., eds. *Phonological Typology*, p. 126-195. ● Libkin, L. (2004). *Elements of Finite Model Theory*. Berlin: Springer-Verlag. Yip, M. (1989). Contour tones. *Phonology* 6. ● Zhang, J. (2014). Tones, tonal phonology, and tone sandhi. In Yen-hui, A., Simpson, A. and Huang, J., eds. *The Handbook of Chinese Linguistics*, p. 443-464.