A Computational Model of Tonal Variation

Chilin Shih
University of Illinois at Urbana-Champaign
cls@uiuc.edu

Abstract

Many phonological processes originated as phonetic reduction phenomena. A way to understand these processes and the related issue of the phonology/phonetics interface is to build a computational model that simulates these processes. This paper with a tone1. investigates production data of Mandarin tone2 sandhi rule and presents a computational simulation model that accounts for the data.

Introduction

Many phonological processes originated as phonetic reduction phenomena. A good way to understand these processes and the related issue of the phonology/phonetics interface is to build a phonetic implementation model that simulates these processes. simulation. This paper investigates production data of Mandarin tone2 in an environment that may induce Mandarin **2** tone2 sandhi, and shows that the sandhi rule is a phonetic reduction phenomenon occurring in prosodically weak positions, which can be modeled following the proposal of (Kochanski and Shih, 2003;

collected as the control.

Mandarin tone2 sandhi refers to a process whereby an underlying tone2 (a rising tone) sur

faces, or appears to surface as a tone1 (a high level tone) when it occurs in a weak syllable following a tone that ends in a high target. For example, it was cited in Chao (Chao, 1968) that words such as *dong1 nan2 feng1* “southeast wind” may optionally surface as *dong1 nan1 feng1*. Figure 1 is a schematic picture of this process, where a trisyllabic tone1 tone2-tone1 sequence depicted in solid line changes to tone1-tone1-tone1. The arrow indicates the di rection of change and the dashed line indicates the end result. Previous accounts of this phenomenon, starting with Chao (Chao, 1968) and including most recently the account in Chen (Chen, 2000), have uniformly treated this phenomenon as a phonological process. Details aside, what all of these accounts have in common is that they treat the process as a *categorical* replacement of the underlying tone2

Already, there are details of this process that are problematic for the phonological view. For example, the rule is apparently sensitive to style and speaking rate. Previous accounts primarily deal with ways of building metrical structure over words, and have difficulty incorporating style and duration into the rule formulation. Furthermore, untrained speakers are unaware of Tone 2 sandhi, which leads to a significant amount of disagreement on what the facts are, let alone the analysis. This paper investigates these issues with production experiments and model

The Experiment

The experiment investigated tone2 variations in the environment that may facilitate Mandarin tone2 sandhi. Tone1's in the same environment were also

The keywords included Mandarin three and four syllable words with the tone patterns: 1-1-1 (tone1

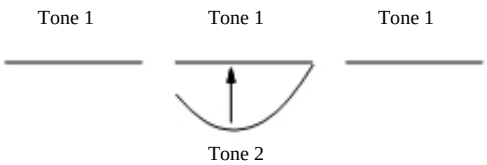

Figure 1: *Schematic representation of Mandarin tone2 sandhi showing a 1-2-1 tonal sequence chang ing to 1-1-1.*

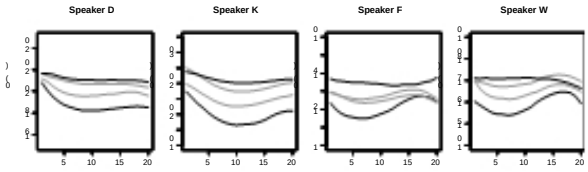

Figure 2: *Tone2 on the medial syllable of a three syl lable word becomes increasingly more like a tone1. Isolation (black solid line), foreground in a sentence frame (solid grey line), background in a sentence frame (dashed grey line), and conversation (dashed black line).*

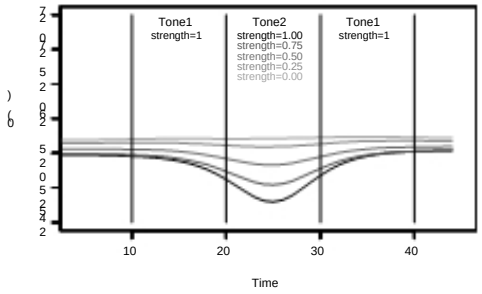

Figure 3: *Model simulation of Mandarin tone2 sandhi as a phonetic reduction process.*

tone1-tone1), 1-2-1, 1-1-1-1, 1-2-1-1 and 1-1-2-1. The keywords were elicited in four speaking styles covering a range from careful to casual speech, in cluding three reading tasks and conversation. Isola tion (I): the keywords were read in isolation. Fore ground in frame (F): the keywords were read in a sentence frame, conveying foreground information. Background in frame (B): the keywords were read in a sentence frame, conveying background informa tion. Conversation (C): free form conversation be tween the experimenter and the subject. All words produced by the subject with the targeted tone pat terns were collected for analysis.

3 Results

Figure 2 presents averaged f0 trajectories of tone2, including data from the medial syllable of three syl lable words. There is a general trend that tone 2 loses more of its distinctive shape and becomes in creasingly more similar to tone1 as speaking styles change from careful to casual.

4 Phonetic Implementation Model

Following work on the prosody modeling platform *Soft Template Markup Language* (Kochanski and Shih, 2003; Kochanski et al., 2003), we show that there is a principled way to link lexical tones with their respective surface variations. The phenomenon of Mandarin tone2 sandhi can be seen as a con sequence of tone shapes interacting via articula tory constraints. Lexical contrast may be lost when the tonal trajectory of a weak tone is contradictory to the trajectory defined by strong neighbors. In those cases the weak tone accommodates the shapes of neighboring strong tones. The resulting f0 is smoother than what is required of the tones, reflect ing less articulatory effort.

Figure 3 shows a simulation of this model at work. We used average tonal contour obtained from a database as the tonal templates, specified global pa rameters that represent speaker characteristics such as pitch range, muscle speed, and the speed for pitch to return to the rest position, and simulated f 0 generation on the tonal sequence tone1-tone2-tone1. The black line shows the model-generated f0 where all syllables were assigned the weight 1. In this case, the middle syllable had equal strength as its neighbors, and it maintained the rising shape. As the weight on this syllable became smaller (lighter shades of grey), the generated f0 contour lost more of its rising shape and gradually became indistin guishable from a tone1.

By adjusting the prosodic strength of the middle syllable, we generated gradient surface variations of Mandarin tone2 sandhi without changing lexical tone templates.

References

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