Biophonology is not Finite State

This paper illustrates and elaborates on the discussion of the computational complexity of morphophonology in Chapter 5 of Barton et al. (1987). Those authors discuss systems that are built upon Finite State Transducers (Fsts), and it is this aspect that we focus on. Finite State (FS) methods have proven very useful for the engineering applications of Computational Phonology, but we will argue that issues raised by Barton et al., as well as our elaborations, demonstrate that the phonological component of the human language faculty is not FS in complexity.

Our first issue relates to the fact that most of the literature on FS methods in phonology is based on either orthographic representations or IPA-like phonetic representations. Several related problems arise if we wish to take seriously the idea that phonological segments are actually composites of features, rather than primitives. Fsts are built on regular relations (Karttunen 1993) — mappings from an input tape to an output tape. Using orthographic or phonetic transcriptions yields an unsavory duplication problem. A simple devoicing rule has to be expressed with multiple arcs (1). This transducer clearly fails to capture the Structural Change of a phonological obstruent devoicing rule $[-\text{son}, +\text{voi}] \rightarrow [-\text{voi}]$ based on features. We could extend the model and postulate something like (2). However, the transition itself now requires additional computational power: we are no longer consuming an input from a formal alphabet and writing a new symbol on the corresponding output tape. Simple FS phonological models fail to represent natural classes and have to enumerate sets of segments or sets of arcs, as in (2).

Chomsky’s (1957) demonstration of the insufficiency of FS models for natural language is based on their failure to capture long-distance dependencies like subject-verb agreement or the matching of elements in either . . . or both . . . and constructions. Barton et al. mention the potential difficulty with modeling reduplication and vowel harmony using FS methods, but do not go into detail. We present the long-distance dependency across transparent vowels, for example in Finnish (3) which can be modeled with FS methods, but not in a perspicacious manner.

Another long-distance phenomenon occurs in the Identity and Non-Identity conditions discussed by McCarthy, Yip, Odden and Reiss in the context of the OCP. Sherwood (1983) motivates a rule in Maliseet-Passamaquoddy which deletes the short vowels /ɔ/ and /ɒ/ in doubly open syllables when flanking consonants are identical. While a FS solution is possible, basically by enumerating all cases, it will fail to capture the intuition that it is identity between non-adjacent segments that is being computed. In addition to the representational issues that arise when only partial identity is computed (as in conditions of homorganicity on consonants flanking a vowel) such a system obviously requires some kind of memory, which is not available to a simple FS system. Finally we consider cases where elements in a phonological relation can be arbitrarily far apart, as in Chumash sibilant harmony (Poser 1982).

Our conclusions are the following. As in syntax, the strings of any finite corpus, and also some infinite ones, can be generated using FS methods, but we may not want to do so. FS systems represent the lowest step of the Chomsky Hierarchy and are easily implementable, but there is another dimension that must be considered—the representation system. If representations are featural, then a FS model of phonology that depends crucially on atomic segment symbols (orthography or phonetic alphabet), as in the majority of published work, is of no use for biophonology. It looks like we need representations of considerable complexity. If we adopt plausible representations and have to give up on FS methods, why should we be bothered—we already know that syntax is not FS? We will try to demonstrate that the long-distance phenomena we present are all amenable to an analysis at the next level of the Chomsky Hierarchy, that of Context Free Grammars.
(3) Finnish backness harmony

a. tyhmä  
   ‘stupid’

b. tyhmä-stä  [tyhmästä]  
   ‘stupid’ (elative)

c. tuhma  
   ‘naughty’

d. tuhma-stä  [tuhmasta]  
   ‘naughty (elative)

e. väräniä  
   ‘spinning wheel’

f. väräntä-lii-ni-kan  [väräntällänihan]  
   ‘with spinning wheel, as you know’

g. palttina  
   ‘linen cloth’

h. palttina-lii-ni-kan  [palttinallänihan]  
   ‘with linen cloth, as you know’

References


