Misplaced Optimism

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In Idsardi 2006 I offered a reformulated and somewhat simplified proof of the computational complexity of Optimality Theory (OT), closely following earlier work by Eisner (1997, 2000). As in Eisner's original articles the proof proceeds by transforming a known NP-complete problem (finding Hamiltonian paths in a directed graph) into an OT generation problem. The reduction entails an intermediate candidate set consisting of the permutations over an alphabet, a set which cannot be perspicuously encoded. Kornai (2006) raises certain questions about how closely the assumptions behind the proof accord with actual practice within OT. Kornai's concerns are important and relevant, and I am grateful to have a chance to elucidate these issues further.

As Kornai points out, the crux of the matter is the use of self-conjoined constraints, $*\alpha^2$, which forbid two instances of α within a domain, i.e. constraints penalizing structures meeting the abstract schema $*[\ \ldots\ \alpha\ \ldots\ \alpha\ \ldots\ _{D}]$. Constraints of this type are extensively investigated in Ito and Mester 2003. Kornai correctly points out that if α and D are bounded, finite and very small, then the import of the proof is blunted. The explicit assumptions in Idsardi 2006 are that α can be an individual phoneme (i.e. a complete feature specification) and that D can be the entire prosodic word (p. 273). Kornai conjectures instead that α can be restricted to "nodes in the feature geometry" (presumably not including the root node, as this would be equivalent to allowing complete feature specifications, i.e. phonemes) and that D can be restricted to bounded phonological structures (namely syllables, feet and cola). Unfortunately, neither of these conditions hold in actual OT practice employing conjoined constraints.

As for the possible structures instantiating α, Ito and Mester (2003: 30) offer three examples: aspirated consonants (No-C^{h2} to capture Grassmann's Law effects, see also pp. 68ff), voiced obstruents (No-D^2 to capture Lyman's Law effects; this is discussed througout their book), and falling tones (No-HL^2 to capture Japanese deaccentuation facts, see also pp. 52ff). Later they also use self-conjoined constraints against particular phonemes (No-L^2 and No-R^2 to capture Latin liquid dissimilation facts, pp. 63ff) and against geminates (No-GEM² to capture Latin *lex mamilla* and Japanese loanwords, pp. 47ff). As formulated by Ito and Mester, none of these examples (except perhaps falling tones) meets Kornai's restriction to individual feature geometry nodes. For example, in Greek and Sanskrit Grassmann's Law must be restricted to aspirated stops; i.e. it must exclude /s/, even though /s/ is [+spread glottis] (Vaux 1998). The required feature specification [-continuant, +spread glottis] is not a coherent node in any feature geometry proposal. Likewise, for Ito and Mester Lyman's Law prohibits pairs of voiced obstruents, that is, the partial feature specification [-sonorant, +voiced], which is again not a coherent feature geometry node.

Many other researchers have also proposed constraints against two identical items within a domain. Since the proof relies on constraints banning identical phonemes, particularly relevant are constraints against false geminates (e.g. Baković 2005) and against long-distance geminates (e.g. Rose 2000, Frisch, Broe and Pierrehumbert 2004). Casting a wider net, Evans (1995: 734) presents a case where multiple NC clusters are prohibited within words; he also shows that this cannot be re-interpreted as prenasalized stop avoidance as the language also has prenasalized stops which are subject to different conditions. Finally, Yip 1995 proposes *Repeat(stem), which avoids identical stems in the same word, and stems are clearly an unbounded class of items.

As for the possible domains instantiating D, Ito and Mester explicitly discuss this issue (pp. 105ff) and include morpheme, stem, and prosodic word within their catalog of possible domains for self-conjunction and assign Lyman's Law and Japanese deaccentuation to the prosodic word domain. In fact they suggest that the bounded domains of syllables and feet are not possible domains for self-conjuction constraints (p. 107). Their self-conjuction domains are not inherently bounded universally. That is, there is no universal fixed upper limit on the size of morphemes, stems or, especially, words. The unbounded nature of word size has also been used in other language complexity proofs, for example Culy 1985 on the computational complexity of Bambara compound words. These two examples (Lyman's Law and Japanese deaccentuation) likewise crucially involve application of the self-conjoined constraints to compound word structures (Ito and Mester 2003: 89ff, 218ff). Even more difficult cases can be found in Bantu phrasal phonology. Synchronic versions of Meeussen's Rule (high tone dissimilation, see Kisseberth and Odden 2003: 65, Philippson and Montlahuc 2003: 481) and Dahl's Law (voiceless stop dissimilation, see Bastin 2003: 513) can operate between words, i.e. where the domain is at least the phonological phrase.

In summary, current OT practice does not support Kornai's conjectures that α and D can be restricted to bounded, finite and very small classes of items. The assumptions used in the proof (α = segment, D = prosodic word) are well-attested in the OT literature. It is true that it is generally assumed that the set of available segments in a language is a bounded set (though see Swingley 2003 and references cited there for evidence supporting a different view), but it is not true that these sets are necessarily very small. Languages like !Xóõ (Traill 1985) have upwards of 100 different phonemes, and 100! permutations is not a tractable search space.

Finally, I am somewhat puzzled by Kornai's advice, "if it ain't broke, don't fix it." In empirical sciences, everything is always broken, or as Lakatos (1970: 120) infamously observed "new theories are born refuted." So what is the "it" that isn't broken?

References

Baković, Eric. 2005. Antigemination, assimilation and the determination of identity. *Phonology* 22: 279–315.

Bastin, Yvonne. 2003. The Interlacustrine Zone (Zone J). In *The Bantu Languages*, edited by Derek Nurse and Gérard Philippson, London: Routledge, 501–528.

Culy, Christopher. 1985. The complexity of the vocabulary of Bambara. *Linguistics and Philosophy* 8: 345–353.

Eisner, Jason. 1997. Efficient generation in Primitive Optimality Theory. In *Proceedings of the 35th annual meeting of the Association for Computational Linguistics,* 313–320.

Eisner, Jason. 2000. Easy and hard constraint ranking in Optimality Theory: Algorithms and complexity. In *Finite-state phonology: Proceedings of the 5th Workshop of the ACL Special Interest Group in Computational Phonology (SIGPHON)*, edited by Jason Eisner, Lauri Karttunen, and Alain Thériault, 22–33.

Evans, Nick. 1995. Current issues in the phonology of Australian languages. In *The Handbook of Phonological Theory,* edited by John Goldsmith, Cambridge, Mass.: Blackwell, 723–761.

Frisch, Stefan A., Michael B. Broe & Janet B. Pierrehumbert. 2004. Similarity avoidance and the OCP. *Natural Language and Linguistic Theory* 22. 179–228.

Idsardi, William J. 2006. A simple proof that Optimality Theory is computationally intractable. *Linguistic Inquiry*. 37: 271–275.

Ito, Junko and Armin Mester. 2003. *Japanese Morphophonemics: Markedness and Word Structure.* Cambridge, Mass.: MIT Press.

Kisseberth, Charles and David Odden. 2003. Tone. In *The Bantu Languages*, edited by Derek Nurse and Gérard Philippson, London: Routledge, 59–70.

Kornai, András. 2006. Is OT NP-hard? Rutgers Optimality Archive (http://roa.rutgers.edu).

Lakatos, Imre. 1970. Falsification and the methodology of scientific research programmes. In *Criticism and the Growth of Knowledge,* edited by Imre Lakatos and Alan Musgrave, Cambridge: Cambridge University Press. 91–196.

Philippson, Gérard and Marie-Laure Montlahuc. 2003. Kilimanjaro Bantu (E60 and E74). In *The Bantu Languages,* edited by Derek Nurse and Gérard Philippson, London: Routledge, 475–500.

Rose, Sharon. 2000. Rethinking geminates, long-distance geminates, and the OCP. *Linguistic Inquiry*, 31: 85–122.

Swingley, Daniel. 2003. Phonetic detail in the developing lexicon. *Language and Speech,* 46, 265–294.

Traill, Anthony. 1985. *Phonetic and Phonological Studies of !Xóõ Bushman.* Hamburg: Helmut Buske Verlag.

Vaux, Bert. 1998. The laryngeal specification of fricatives. *Linguistic Inquiry*. 29: 497–511

Yip, Moira. 1995. Repetition and its avoidance: The case of Javanese. *Proceedings of South Western Optimality Theory Workshop* edited by Keiichiro Suzuki and Dirk Elzinga, Tuscon: University Of Arizona, Department of Linguistics, 238–262.

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