

Disjunctive rule ordering in finite state morphology

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Finite state morphology

- Conventional finite state morphology (e.g., Beesley and Karttunen 2003)
- Finite state transducers (FSTs) for morphotactics:

<i>cant</i>	<i>are + Verb:ε</i>	<i>+1 + Sg:o</i>
<i>laud</i>		<i>+2 + Sg:as</i>
<i>am</i>		<i>+3 + Sg:at</i>
		<i>+3 + Pl:amus</i>
		<i>+2 + Pl:atis</i>
		<i>+3 + Pl:ant</i>

Finite state morphology

- FSTs for morphophonology
- Compose FSTs into a single FST mapping between lexical and surface forms

Lexical: *cantare + Verb + 1 + Sg*

Surface: *canto*

- Finite state techniques provide an efficient and well-founded framework for implementation
- Familiar 'Item and Arrangement' model of morphology

Word and Paradigm

- One well-known problem with this model is the treatment of discontinuous dependencies within words
- A solution to this and many other problems is offered by Word and Paradigm models of morphology (Robins, Matthews, Aronoff, Zwicky, Stump, et al.)
- In WP (aka *realizational* or *separationist*) models,
 - one set of rules build complete morphosyntactic representations
 - another set assigns a phonological form to a fully specified word

Word and Paradigm

- This eliminates a technical problem with FSTs
- Plenty of linguistic arguments that WP provides a more natural analysis of complex inflectional systems
- As Karttunen (2003) shows, WP finite state morphology requires only a slight change of perspective
 - Morphotactic rules construct lexical forms
 - Morphophonological rules build up the phonological realization of the given features
 - Final ‘clean-up’ transducer removes morphosyntactic features, leaving only the surface form

Word and Paradigm

- FSTs for morphotactics:

<i>cantare</i>	<i>+Verb</i>	<i>+1</i>	<i>+Sg</i>
<i>laudare</i>		<i>+2</i>	<i>+Pl</i>
<i>amare</i>		<i>+3</i>	

- Realizational rules:

If *+Verb*, delete *-are* from stem

If *+1+Sg*, add *-o* to stem

If *+2+Sg*, add *-as* to stem

Disjunctive rule ordering

- Karttunen's (2003) implementation combines realization rules via serial composition
- *Conjunctive* rule ordering: every rule applies to every form
- However, an important property of realization rules is that they are *disjunctively* ordered
 - Within each rule block, only the first (or most specific) applicable rule applies
 - Earlier (or more specific) rules *block* the application of later (more general rules)

Disjunctive rule ordering

- Disjunctively ordered realizations for English *be*

<i>is</i>	3sg pres fin
<i>am</i>	1sg pres fin
<i>are</i>	pres fin
<i>being</i>	pres part
<i>was</i>	1sg or 3sg past fin
<i>were</i>	past fin
<i>been</i>	past part
<i>be</i>	elsewhere

- DATR/KATR (Finkel and Stump 2002)

Disjunctive rule ordering

- Compiler for rule blocks
 - construct “narrower than” relation
 - topological sort
 - disjunctive composition
- Implementation in prolog, using Gertjan van Noord’s FSA Utilities
- Follow general outline of Karttunen’s implementation

Realization rules

- A realization rule is pair $\langle \sigma, \phi \rangle$, where the *structural description* σ is a recognizer and the *structural change* ϕ is a transducer
- A *rule block* is an unordered set of realization rules
- For example:

$\langle \$(pres\ fin), be:are \rangle$

$\langle \$(3sg\ pres\ fin), be:is \rangle$

$\langle \$(1sg\ pres\ fin), be:am \rangle$

$\langle \$(pres\ part), \epsilon:ing \rangle$

Realization rules

- Within a block, for any two rules either:
 - they are mutually inconsistent

Two rules $\langle \sigma_1, \phi_1 \rangle$ and $\langle \sigma_2, \phi_2 \rangle$ are *mutually inconsistent* iff $\sigma_1 \& \sigma_2 = \emptyset$

- or one must be narrower than the other

A rule $\langle \sigma_1, \phi_1 \rangle$ is *narrower than* a rule $\langle \sigma_2, \phi_2 \rangle$ iff $\sigma_1 - \sigma_2 = \emptyset$

- We check every pair of rules in a block and construct the “narrower than” partial order

Disjunctive composition

- Given the “narrower than” partial order, we perform a topological sort on the rules within a block
- The result is a list of rules such that no rule is before a rule which it is narrower than
- For example:

⟨ \$(3sg pres fin), *be:is* ⟩
⟨ \$(1sg pres fin), *be:am* ⟩
⟨ \$(pres fin), *be:are* ⟩
⟨ \$(pres part), *ε:ing* ⟩

Disjunctive composition

- Next, we modify the structural description of each rule so that it excludes words which earlier rules would apply to

$\langle \sigma_i, \phi_i \rangle$ becomes $\langle \sigma'_i, \phi_i \rangle$, where $\sigma'_i = \sigma_i - \cup_{j=1, i-1} \sigma_j$

- For example:

$\langle \$(3\text{sg pres fin}), be:is \rangle$

$\langle \$(1\text{sg pres fin}) - \$(3\text{sg pres fin}), be:am \rangle$

$\langle \$(\text{pres fin}) - \$((3\text{sg} \vee 1\text{sg}) \text{pres fin}), be:are \rangle$

$\langle \$(\text{pres part}) - \$(\text{pres fin}), \varepsilon:ing \rangle$

- Cf. Erjavac's (1994) *ordered disjunction* and Karttunen's (1998) *priority union*

Disjunctive composition

- Finally, rules are converted to transducers using a *conditional replacement* operator
- The result is a set of mutually exclusive realization rules
- These FSTs can be combined into a single FST using normal composition
- They also may be combined with conjunctively ordered rules, parallel rules, etc.
- Implementation available with FSA utilities

<http://odur.let.rug.nl/~vannoord/Fsa/>

Conclusion

- Word and Paradigm morphology with disjunctively ordered realization rules fits comfortably within a finite state model of lexical processing
- This fact is of benefit to both theoretical linguistics and language engineers
 - Finite state models provide a robust, efficient platform to allow linguists to explore the consequences of their analyses
 - Realizational morphology provides an elaborated theoretical framework for language engineers to describe complex inflectional systems