Morphological epenthesis in Serbo-Croatian noun inflection

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Introduction

• Class I:	zavod institute.NOM.SG.M	zavod-a institute.GEN.SG.M
	sel-o village.NOM.SG.N	sel-a village.GEN.SG.N
	tele calf.NOM.SG.N	tele**t**-a calf.GEN.SG.N
• Class II:	ʒen-a woman.NOM.SG.F	ʒen-e woman.GEN.SG.F
• Class III:	reʧ word.NOM.SG.F	reʧ-i word.GEN.SG.F

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morphologically conditioned consonant insertion
–
repairing vowel-final stems

Introduction

- part of a wider algorithmic process of noun inflection
  - Boolean Monadic Recursive Schemes (BMRSs)
  - analyzed as logical transductions on strings
    - stem + [Case Num] → inflected word ~ realization rules
  - hierarchical ordering of more specific and less specific blocking and licensing structures
    - ~ realization rules intrinsically ordered by Pāṇini's principle (cf. Stump 2001)
  - possibility to compose BMRSs into a complete inflectional system
    - algorithm of inflectional class assignment

Morphologically conditioned consonant insertion

- SC stems are normally C-final; those that are not are repaired via consonant insertion

  → **if another suffix follows immediately**

otherwise the word is vowel-final (bare stem) and considered well-formed (as the nom.sg. suffix is *-o*/*-e*)

	tele	‘calf.NOM.SG’
	tele*t*-a	‘calf.GEN.SG.
/tele + ji/	[teletɕi]	‘calf-like(ADJ.)’

Morphologically conditioned consonant insertion

- *t* is not the general epenthetic consonant in this language

/zaova/	[zaova]	'sister-in-law'
/violina/	[vijolina]	'violin'

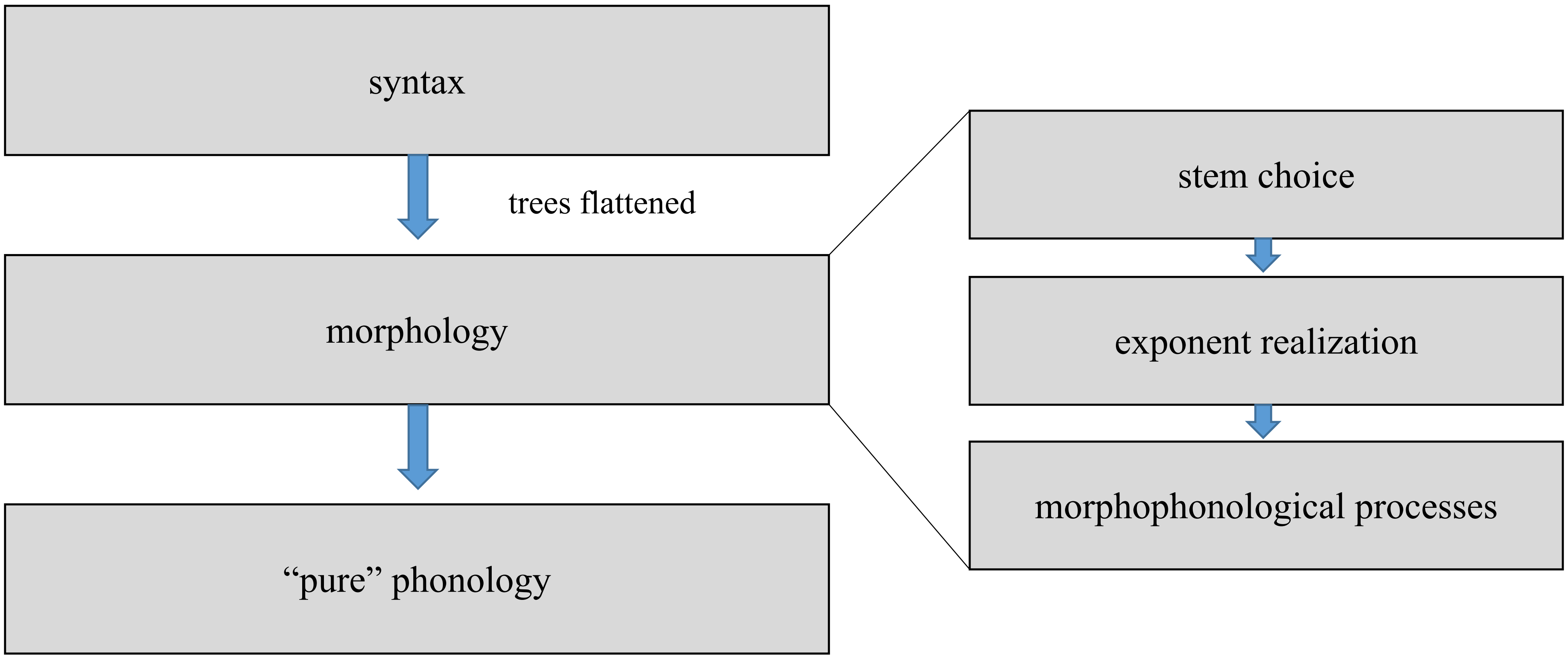
- *t* epenthesized only to repair vowel-final stems, does not depend on vowel hiatus

/tele + ji/	[teletɕi] 'calf-like'	vs.	/koz + ji/	[kozji] 'goat-like'
/sirtɕe + ni/	[sirtɕetni] 'acetic'	vs.	/plod + ni/	[plodni] 'fertile'

The nature of morphological processes

- morphological processes are regular (Karttunen et al. 1992), most often subregular (Chandlee 2017)
- DM is a tree-based theory, but can be formalized over strings (Ermolaeva & Edmiston 2018)
  - yield function flattens trees, retaining necessary boundary symbols
- In terms of computational power, W&P morphology is equivalent to a collection of regular relations (Karttunen 2003)

Proposed model



Analysis

- *Boolean Monadic Recursive Schemes* (BMRS)
  - incorporates the observation that phonology is regular (Johnson 1972; Kaplan & Kay 1994; Heinz 2018)
  - morphology, too, is regular (Karttunen et al. 1992), most often subregular (Chandlee 2017)
  - unlike FSTs, captures linguistically significant generalizations – we can use representations that are common in linguistics
    - phonological, morphosyntactic features
    - Pāṇini's Principle (= Elsewhere condition) has no obvious finite-state implementation (Karttunen 2003), whereas it is directly captured with BMRS's 'if...then...else' syntax

Analysis

- primitives:
  - *boolean values* ⊤ and ⊥
  - *monadic predicates* $P(t)$ – take a *single* argument t, and return ⊤ or ⊥

$\mathbb{V}$ = {a, e, i, o, u}
$\mathbb{C}$ = {b, ʦ, ʧ, ʨ, d, ʤ, ʥ, f, g, h, j, k, l, ʎ, m, n, ɲ, p, r, s, ʃ, t, v, z, ʒ}
$\mathbb{M}$ = {[nom], [gen], [dat], [acc], [voc], [ins], [loc], [sg], [pl]}

$\Sigma = \mathbb{V} \cup \mathbb{C} \cup \mathbb{M}$ $\Sigma_{\bowtie} = \Sigma \cup \{\rtimes, \ltimes, +\}$

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$\mathbb{M}$ = {[nom], [gen], [dat], [acc], [voc], [ins], [loc], [sg], [pl]}

$\Sigma = \mathbb{V} \cup \mathbb{C} \cup \mathbb{M}$ $\Sigma_{\bowtie} = \Sigma \cup \{\rtimes, \ltimes, +\}$

$\mathcal{I}$ = {a(t), …, ʒ(t), [nom](t), …, [pl](t), $\rtimes(t)$, $\ltimes(t)$, $+(t)$}
$\mathcal{O}$ = {a$_o(t)$, …, ʒ$_o(t)$, [nom]$_o(t)$, …, [pl]$_o(t)$, $\rtimes_o(t)$, $\ltimes_o(t)$, $+_o(t)$}

Analysis

- no right word boundary symbol → stems are (contiguous) strings of characters occupying indices belonging to a *countably infinite* set of indices

$\mathbf{S} = \langle D; \sigma_1, \sigma_2, \ldots, p, s \rangle$

$D = \{1, 2, \ldots\}$

- the right word boundary is assigned at the end of the word only after the inflectional exponents are realized (look out for $\boldsymbol{\ltimes(x)}$ in the following slides!)
- (I do this to avoid using copy sets, which might not be a great idea.)

Analysis

- In BMRS, we can refer to both input and output predicates, and define new ones

input

1	2	3	4	5	6	7	…
⋊	t	e	l	e	+	[dat sg]	…

output

	t	e	l	e	t	u	

- Examples of defining new input predicates: case/number feature combinations, syncretism, defining the class of FCs

Analysis

- necessary combinations of case and number features available for neuter nouns:

`[nom/acc/voc sg]`(x) = if `[nom/acc/voc]`(x) then `[sg]`(x) else ⊥
`[dat/loc sg]`(x) = if `[dat/loc]`(x) then `[sg]`(x) else ⊥
`[ins sg]`(x) = if `[ins]`(x) then `[sg]`(x) else ⊥
`[nom/acc/voc pl]`(x) = if `[nom/acc/voc]`(x) then `[pl]`(x) else ⊥
`[gen pl]`(x) = if `[gen]`(x) then `[pl]`(x) else ⊥
`[dat/loc pl]`(x) = if `[dat/loc]`(x) then `[pl]`(x) else ⊥
`[ins pl]`(x) = if `[ins]`(x) then `[pl]`(x) else ⊥

(one would expect 14 – 7 cases × 2 numbers – but we do not have 14 distinct phonological forms of overt suffixes)

Analysis

- (non-directional) syncretism

[dat/loc](x) = if [dat](x) then $\top$ else [loc](x)
[nom/acc/voc](x) = if [nom](x) then $\top$ else
if [acc](x) then $\top$ else [voc]
[gen/ nom/acc/voc pl](x) = if [gen](x) then $\top$
else [nom/acc/voc pl](x)
[dat/loc pl/ins pl](x) = if [dat/loc pl](x) then $\top$
else [ins pl](x)

Analysis

- effect of fronting consonants (i.e. fronting of o to e after stem-final FCs)

(FC = C[cor, -ant] + ʦ)

[FC](*x*) = if ʦ(*x*) then ⊤ else
if ʧ(*x*) then ⊤ else
if ʨ(*x*) then ⊤ else
if ʤ(*x*) then ⊤ else
if ʥ(*x*) then ⊤ else
if j(*x*) then ⊤ else
if ʎ(*x*) then ⊤ else
if ɲ(*x*) then ⊤ else
if ʃ(*x*) then ⊤ else ʒ(*x*)

Analysis

- *t*-insertion

$$\begin{aligned}\texttt{outseg}(x) = {} & \text{if } \texttt{a}_\text{o}(x) \text{ then } \top \text{ else} \\ & \text{if } \texttt{b}_\text{o}(x) \text{ then } \top \text{ else} \\ & \text{if } \texttt{c}_\text{o}(x) \text{ then } \top \text{ else} \\ & (\ldots) \\ & \text{if } \texttt{z}_\text{o}(x) \text{ then } \top \text{ else } \texttt{ʒ}_\text{o}(x)\end{aligned}$$

$$\begin{aligned}\texttt{t}_\text{o}(x) = {} & \text{if } +(x) \text{ then} \\ & \quad \text{if } \texttt{e}(p(x)) \text{ then } \texttt{outseg}(s(x)) \text{ else } \bot \\ & \text{else } \texttt{t}(x)\end{aligned}$$

Analysis

- Output predicates: (~ realization rules)

$\mathtt{u}_{\mathrm{o}}(x)$ = if $\mathtt{[dat/loc\ sg]}(x)$ then $\top$ else $\mathtt{u}(x)$
$\mathtt{a}_{\mathrm{o}}(x)$ = if $\mathtt{[gen/\ nom/acc/voc\ pl]}(x)$ then $\top$ else
if $\mathtt{[gen\ pl]}(p(x))$ then $\top$ else
if $\mathtt{[ins\ pl]}(p(p(x)))$ then $\top$ else $\mathtt{a}(x)$
$\mathtt{o}_{\mathrm{o}}(x)$ = if $\mathtt{[nom/acc/voc\ sg]}(x)$ then $\top$ else
if $\mathtt{[ins\ sg]}(x)$ then $\top$ else $\mathtt{o}(x)$
$\mathtt{m}_{\mathrm{o}}(x)$ = if $\mathtt{[ins]}(p(x)))$ then $\top$ else $\mathtt{m}(x)$
$\mathtt{i}_{\mathrm{o}}(x)$ = if $\mathtt{[ins\ pl]}(x)$ then $\top$ else $\mathtt{i}(x)$
$\mathtt{e}_{\mathrm{o}}(x)$ = if $\mathtt{o}_{\mathrm{o}}(x)$ then
if $+(p(x))$ then $\mathtt{[pal]}(p(p(x)))$ else $\bot$
else $\mathtt{e}(x)$

$\mathtt{l}_{\mathrm{o}}(x) = \mathtt{l}(x)$
$\mathtt{b}_{\mathrm{o}}(x) = \mathtt{b}(x)$
(etc., for {ʦ, ʧ, ʨ, d, ʤ, ʥ, f, ɡ, h, j, k, l, ʎ, n, ɲ, p, r, s, ʃ, v, z, ʒ})

Analysis

	1	2	3	4	5	6	7	8	9
input	⋊	t	e	l	e	+	[ins sg]		…
output		t	e	l	e	t	o	m	

- Output predicates:

$$
\begin{aligned}
\mathtt{u}_o(x) &= \text{if } \mathtt{[dat/loc\ sg]}(x) \text{ then } \top \text{ else } \mathtt{u}(x)\\
\mathtt{a}_o(x) &= \text{if } \mathtt{[gen/\ nom/acc/voc\ pl]}(x) \text{ then } \top \text{ else}\\
&\quad\ \text{if } \mathtt{[gen\ pl]}(p(x)) \text{ then } \top \text{ else}\\
&\quad\ \text{if } \mathtt{[ins\ pl]}(p(p(x))) \text{ then } \top \text{ else } \mathtt{a}(x)\\
\mathtt{o}_o(x) &= \text{if } \mathtt{[nom/acc/voc\ sg]}(x) \text{ then } \top \text{ else}\\
&\quad\ \text{if } \mathtt{[ins\ sg]}(x) \text{ then } \top \text{ else } \mathtt{o}(x)\\
\mathtt{m}_o(x) &= \text{if } \mathtt{[ins]}(p(x))) \text{ then } \top \text{ else } \mathtt{m}(x)\\
\mathtt{i}_o(x) &= \text{if } \mathtt{[ins\ pl]}(x) \text{ then } \top \text{ else } \mathtt{i}(x)\\
\mathtt{e}_o(x) &= \text{if } \mathtt{o}_o(x) \text{ then}\\
&\qquad\quad \text{if } +(p(x)) \text{ then } \mathtt{[pal]}(p(p(x))) \text{ else } \bot\\
&\quad\ \text{else } \mathtt{e}(x)
\end{aligned}
$$

$$
\begin{aligned}
\mathtt{l}_o(x) &= \mathtt{l}(x)\\
\mathtt{b}_o(x) &= \mathtt{b}(x)
\end{aligned}
$$

(etc., for {ʦ, ʧ, ʨ, d, ʤ, ʥ, f, g, h, j, k, l, ʎ, n, ɲ, p, r, s, ʃ, v, z, ʒ})

Analysis

$\ltimes(x)$ = if $\texttt{[nom sg]}(x)$ then $\texttt{e}(p(x))$ else
if $\texttt{[nom/acc/voc sg]}(p(x))$ then $\top$ else
if $\texttt{[dat/loc sg]}(p(x))$ then $\top$ else
if $\texttt{[gen/ nom/acc/voc pl]}(x)$ then $\top$ else
if $\texttt{[ins sg]}(p(p(x)))$ then $\top$ else
if $\texttt{[dat/loc pl/ins pl]}(p(p(p(x))))$ then $\top$ else $\bot$

out(x) = if $\texttt{+}(x)$ then $\texttt{t}_{\texttt{o}}(x)$ else
if $\rtimes(x)$ then $\bot$ else
if $\ltimes(x)$ then $\bot$ else $\top$

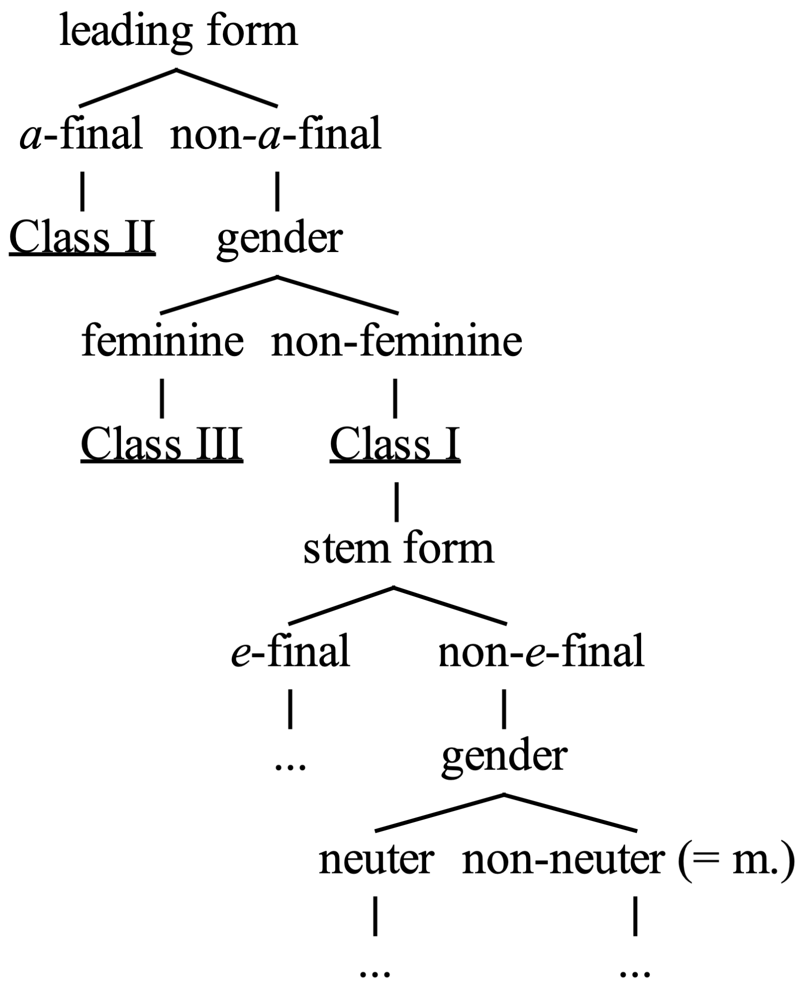
Analysis

- no copy sets = no epenthesis/insertion of material longer that 1 symbol ☹
- is there a smart way to do this (+ more → non-concatenative morphology) without copy sets? The non-computationally minded often find them counterintuitive

Class membership assignment in SC

- Class membership assignment in SC can be modeled as a predictable process if we take into account a *leading form*/*base* (Wurzel 1990, McCarthy 2005, Albright 2008)
- This I argue to be the nominative singular: it is the most frequent form (subject case), and it ranks highest in the Case Hierarchy (Blake 2001).
- loanwords do not (necessarily) have an oblique form – they are incorporated into the declension system on the basis of their input form (which is borrowed as nominative singular)
- so, lexical entry = {stem, leading form, morphosyntactic info}, but the algorithm should work with a deficient lexical entry too

Class membership assignment in SC



Conclusions

- Inserting *t* repairs aberrant, V-final stems (whenever an overt suffix is attached)
- This happens regardless of whether that suffix is vowel- or consonant-initial
- A means to avoid stipulating listed stems – assuming unpredictable stem allomorphs would basically reduce the phenomenon to an accident
- Assuming morphological epenthesis enables us to express the generalizations explicitly and overtly

Conclusions

- BMRSs can directly capture morphological and phonological generalizations, retaining the computationally restrictive nature of such processes
- Intuitive, easily implementable, extendable to a wider range of phenomena
- Future work: noun class membership assignment base on ‘if…then…else’ syntax; class membership does not have to be listed information

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