Capturing generalizations about exponence

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What is exponence? I

- Exponence relations within a paradigm:
  Some phonological property is present in some proper subpart of the paradigm.
  - Spanish adjective BUENO 'good':
    - 'last vowel is /a/' ⇌ FEM
    - 'last vowel is /o/' ⇌ MAS
    - 'ends in /s/' ⇌ PL

	SG	PL
mas	bueno	buenos
fem	buena	buenas

- The relevant phonological property does not always amount to containing a specific substring
  - 'does not end in /s/' ⇌ SG   'zero exponence'

What is exponence? II

- The relevant phonological property does not always amount to containing a specific substring
  - German noun MUTTER 'mother': nonfaxal alternations
    - 'nonfront vowel in first syllable' ⇌ SG
    - 'front vowel in first syllable' ⇌ PL

	SG	PL
NOM	Mutter	Mütter
ACC	Mutter	Mütter
DAT	Mutter	Müttern
GEN	Mutter	Mütter

- The relevant content is not always coherent
  - French verb FINIR 'finish': morphomic distributions

	1SG	2SG	3SG	1PL	2PL	3PL
SBJV.PRS	finis	finis	finis	finisjɔ̃	finisje	finis
IND.PRS	fini	fini	fini	finisɔ̃	finise	finis
IND.FUT	finiʁɛ	finiʁa	finiʁa	finiʁɔ̃	finiʁe	finiʁɔ̃

- 'ends in /is(j)(V)/' ⇌ IND.PRS.PL ∨ SBJV.PRS ∨ · · ·
- 'ends in /i(ʁ)(V)/' ⇌ IND.PRS.SG ∨ IND.FUT ∨ · · ·

Constructive approach to exponence

- In this talk I will pursue a constructive approach to exponence in the sense of Blevins (2006), where we express generalizations within a formal grammar that licenses wordforms on the basis of explicit abstract primitives.
- This presupposes that:
  - We have a pre-established segmentation of words into stems and affixes.
  - Stem alternants as well as affixes may have exponential value.
  - We have a pre-established statement of the exponential value of each element.
- This is definitely not the only fruitful way to reason about exponence; see remarks at the end of the talk.

Information-based morphology (IbM)

- IbM is a relatively novel formal framework for the analysis of inflection systems developed by Berthold Crysmann and myself
  (Crysmann and Bonami, 2016; Bonami and Crysmann, 2016, 2018; Crysmann and Bonami, 2017; Crysmann, 2017)
- IbM combines insights from
  - Inferential-realizational theories (Matthews, 1965; Anderson, 1992; Stump, 2001; Brown and Hippisley, 2012)
  - HPSG (Pollard and Sag, 1994), and in particular the modelling techniques for morphology introduced by Koenig (1999)
- Important design goals for IbM:
  - Nonreductionist: direct expression of generalizations.
  - Incorporate explicit insights from morphological typology
    - Deviations from the canon correspond to measurable addition of formal complexity.
  - Maintainable grammars: avoidance of rule cascades (AM, PFM) and stipulated defaults (NM)
  - Explicit interface to theories of phonology, syntax and semantics

Roadmap

1. Capturing word-level generalizations about exponence
   - Wordforms as lists of indexed morphs
   - Rules of exponence as many-to-many generalizations
   - Hierarchies of rule types (a.k.a schemas)
2. Capturing lexeme-level generalizations about exponence
   - Paradigm identifiers and rules of stem introduction
   - Inflection classes
   - Hybrid classes: overabundance and heteroclisis
3. Outlook: questioning presuppositions

Capturing word-level generalizations about exponence

I. Motivation

Variable morphotactics I

- Crysmann and Bonami (2016) documents the prevalence and theoretical importance of variable morphotactics.
  - Conditioned placement: Portuguese pronominal affixes

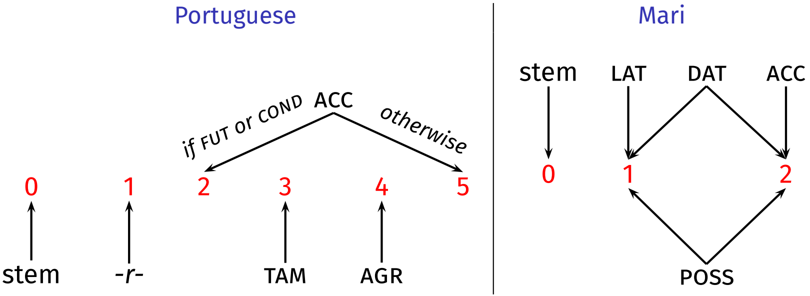
	PAST IMPERFECTIVE		CONDITIONAL	
	no praff affix	2SG.ACC affix	no praff affix	2SG.ACC affix
1SG	lav-a-va	lav-a-va-te	lav-a-r-ia	lav-a-r-te-ia
2SG	lav-a-va-s	lav-a-va-s-te	lav-a-r-ia-s	lav-a-r-te-ia-s
3SG	lav-a-va	lav-a-va-te	lav-a-r-ia	lav-a-r-te-ia
1PL	lav-á-va-mos	lav-á-va-mos-te	lav-a-r-ía-mos	lav-a-r-te-ía-mos
2PL	lav-á-ve-is	lav-á-ve-is-te	lav-a-r-íe-is	lav-a-r-te-íe-is
3PL	lav-a-va-m	lav-a-va-m-te	lav-a-r-ia-m	lav-a-r-te-ia-m

  - Free placement: Mari possessives

	ABSOLUTE	1PL POSSESSED	
		POSS ≺ CASE	CASE ≺ POSS
NOM	pört	pört-na	
ACC	pört-əm	pört-na-m	*
DAT	pört-lan	pört-na-lan	pört-lan-na
LAT	pört-eš	*	pört-eš-na

Variable morphotactics II

- Reasoning on such variable morphotactic situations is much more direct and straightforward if we recognize explicitly the notion of a morph occupying a position (Luís and Spencer, 2005).

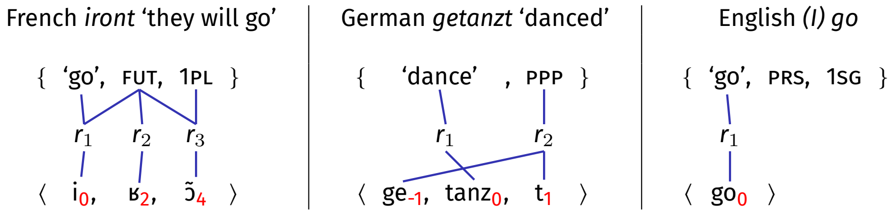


- Importantly, Anderson's 1992 arguments against morphousness do not apply to IbM.

The $m : n$ format of rules of exponence I

- Basic insight from Matthews (1972): widespread noncanonical exponence.
  - simple exponence (1 morph : 1 property) vs.
  - cumulative exponence (1 morph : n properties) vs.
  - (fully redundant) multiple exponence (m morphs : 1 property) vs.
  - overlapping exponence (m morphs : n properties)
- Most approaches to inflection take a reductionist approach to multiple exponence, by having separate rules (or morphemes) introducing overlapping (or identical) content.
- IbM adopts a much more direct approach to the typology of exponence:
  - The general format of rules of exponence is $m : n$, defining a large space of exponence types.

The *m* : *n* format of rules of exponence II



- General principles:
  - An inflected word associates a list of morphs with a property set
  - Each morph has to be licensed by a rule
  - Each property that can be expressed by a morph must be expressed
- Important notes:
  - ‘Rules’ here are declarative statements on the cooccurrence of bits of forms and bits of content, not procedural rules.
    - Standard usage in realisational morphology

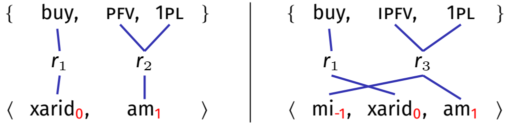
The $m:n$ format of rules of exponence III

- The framework is compatible with the formulation of grammars that introduce all exponents holistically.
  - Consider the Persian past:

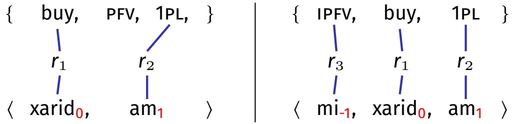
	1SG	2SG	3SG	1PL	2PL	3PL
PFV	xaridam	xaridi	xarid	xaridim	xaridid	xaridand
IPFV	mixaridam	mixaridi	mixarid	mixaridim	mixaridid	mixaridand

Past indicative forms of XARIDAN « buy »

  - The formal framework does not stop us from hypothesizing:



  - Better analysis (descriptive economy (6 vs. 11 rules), expression of generalizations):

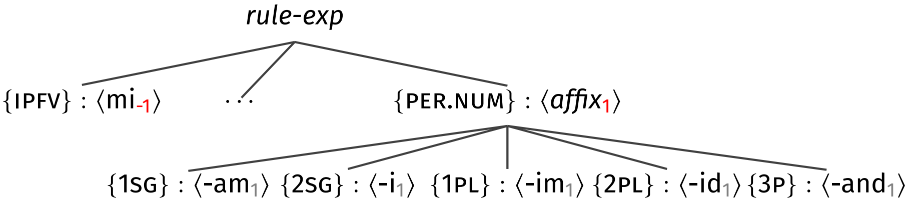


Generalizations over rules I

- Many systems exhibit important generalizations over rules of exponence.
  - Exponents of different values of the same feature share the same placement properties
  - Morphologically-conditioned allomorphs partially share the same shapes
  - Polyfunctionality: series of exponents of related feature values shared across morphosyntactic domains
  - etc.
- Important insight (Anderson, 1992; Stump, 2001): these are not linguistic universals, and hence should not be hard-coded by the theoretical framework.
- That being said, it is important for an adequate framework to have simple means of expressing such generalizations where they are empirically valid.

Generalizations over rules II

- IbM relies heavily on inheritance hierarchies of rules of exponence to that effect.
- Simple example from Persian:



Capturing word-level generalizations about exponence

A sketch of IbM

Words in IbM

- Morphological representation of a word:

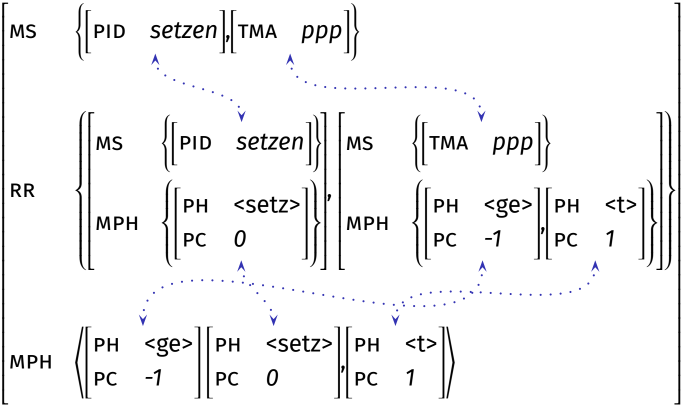
$$\begin{bmatrix} \text{MORPHOSYNTAX} & \left\{ \begin{bmatrix}\text{PID} & \textit{setzen}\end{bmatrix}, \begin{bmatrix}\text{TMA} & \textit{ppp}\end{bmatrix} \right\} \\ \text{MORPHS} & \left\langle \begin{bmatrix}\text{PH} & \langle\text{ge}\rangle \\ \text{PC} & \textit{-1}\end{bmatrix}, \begin{bmatrix}\text{PH} & \langle\text{setz}\rangle \\ \text{PC} & \textit{0}\end{bmatrix}, \begin{bmatrix}\text{PH} & \langle\text{t}\rangle \\ \text{PC} & \textit{1}\end{bmatrix} \right\rangle \\ \text{PHONOLOGY} & \langle\text{gesetzt}\rangle \end{bmatrix}$$

- Rules as abstractions over words:

$$\begin{bmatrix} \text{MS} & \left\{ \begin{bmatrix}\text{TMA} & \textit{ppp}\end{bmatrix}, \ldots \right\} \\ \text{MPH} & \left\langle \begin{bmatrix}\text{PH} & \langle\text{ge}\rangle \\ \text{PC} & \textit{-1}\end{bmatrix}, \begin{bmatrix}\text{PH} & \langle\text{t}\rangle \\ \text{PC} & \textit{1}\end{bmatrix}, \ldots \right\rangle \end{bmatrix}$$

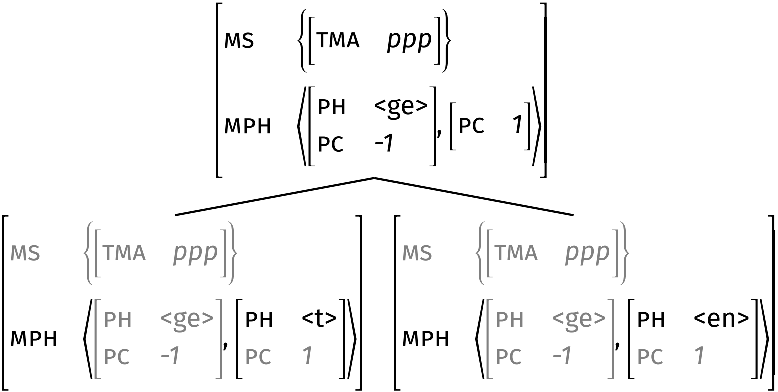
Rules in IbM

- The feature RR keeps a record of which rules license a particular wordform.



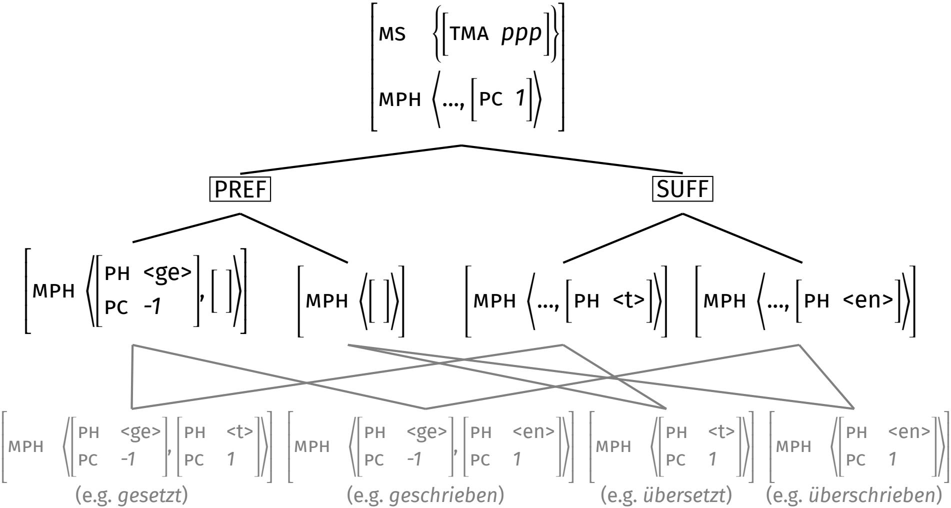
Hierarchies of rules

- Rules are descriptions of typed feature structures organized in (monotonous) multiple inheritance hierarchies.
- Monodimensional inheritance captures simple generalizations over rules:



Multiple inheritance

- Systematic co-variation is captured by multiple inheritance



Capturing word-level generalizations about exponence

Applications

Parallel exponence

- In some systems, the shape and position of affixes have separate exponential value.
- Swahili person markers (Stump, 1993)
  - Position encodes grammatical function
  - Shape encodes person/number/gender

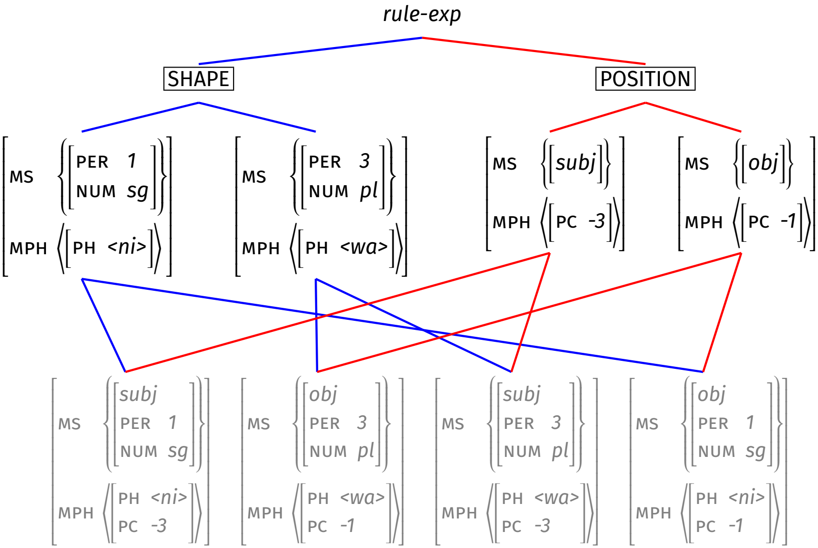
(1) a. ni-ta-wa-penda
1SG-FUT-3PL-like
'I will like them.'

b. wa-ta-ni-penda
3PL-FUT-1SG-like
'They will like me.'

PER	GEN	SUBJECT SG	SUBJECT PL	OBJECT SG	OBJECT PL
1		ni	tu	ni	tu
2		u	*m*	ku	*wa*
3	M/WA	*a*	wa	*m*	wa
	M/MI	u	i	u	i
	KI/VI	ki	vi	ki	vi
	JI/MA	li	ya	li	ya
	N/N	i	zi	i	zi
	U	u	—	u	—
	U/N	u	zi	u	zi
	KU	ku	—	ku	—

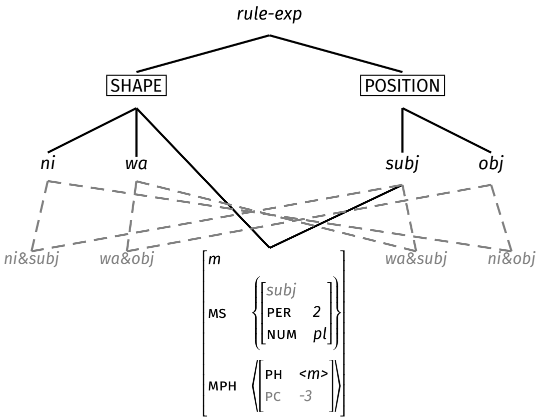
Hierarchies of rules

- Easily modeled in IbM by having separate POSITION and SHAPE dimensions describing different aspects of the same morph



Hierarchies of rules

- Shapes that are specific to one position are rigidly attached in both dimensions.



Gestalt exponence

- Some systems exhibit constructional or Gestalt exponence (Blevins, 2016).
  - Estonian first declension nouns:

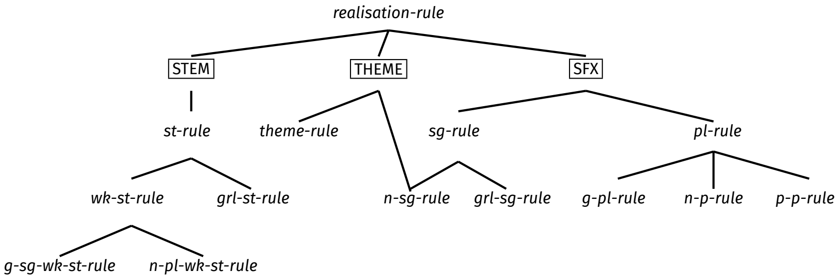
	'beak'	
	SG	PL
NOM	nokk	nok-a-d
GEN	nok-a	nokk-a-de
PART	nokk-a	nokk-a-sid

  - We want to capture holistic properties of individual words, e.g.
    - No morph in the PART.SG is specific to the PART.
    - NOM.PL contains the same morphs found in the GEN.SG, while GEN.PL contains the same morphs found in PART.SG
  - While still capturing generalizations over the paradigm, e.g.
    - Plural uses case suffixes
    - Default character of theme vowel
    - Default character or strong stem

Generalizations over combinations of exponents

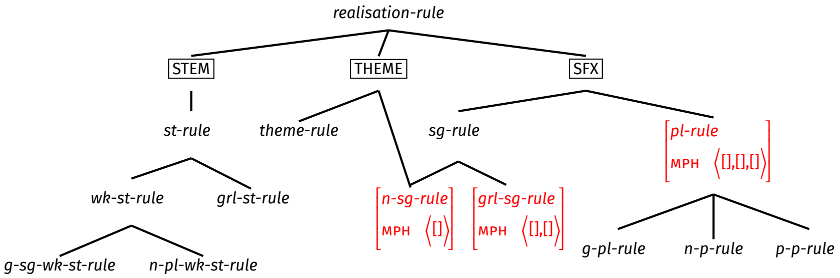
- Three dimensions controlling:

STEM	the choice of a stem alternant
THEME	the possible introduction of a theme vowel
SFX	the possible introduction of a case-number suffix



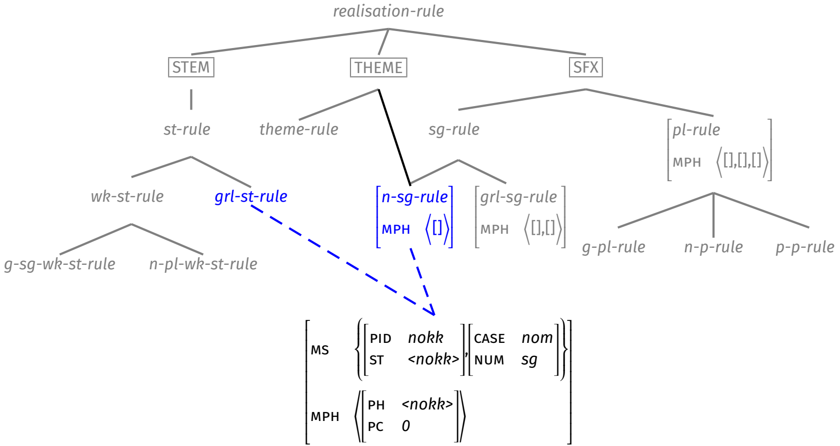
Generalizations over combinations of exponents

- Some rule types in the THEME and SFX dimensions jointly determine the how many morphs are used:



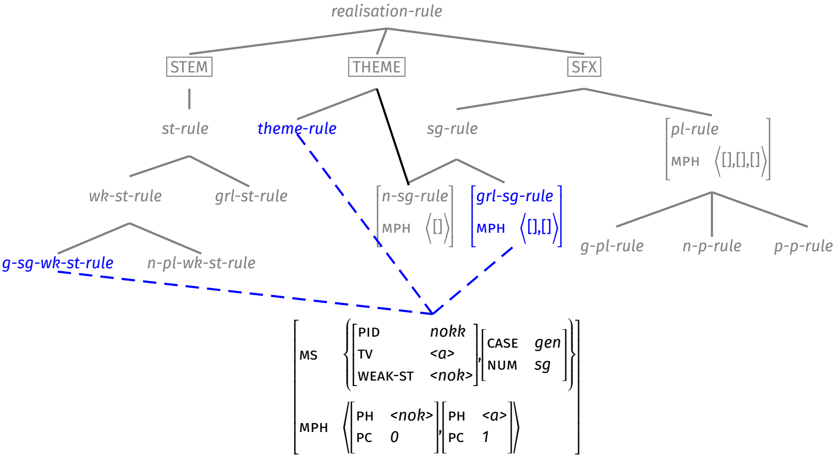
Generalizations over combinations of exponents

- In the NOM.SG, a special rule type belonging to both the THEME and SUFFIX dimension ensures that no theme vowel is used. The stem is the default, strong stem.



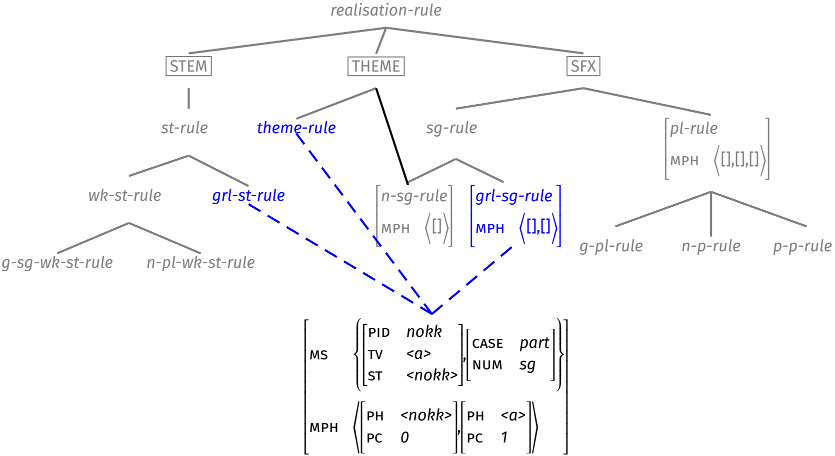
Generalizations over combinations of exponents

- In the GEN.SG, a special stem introduction rule type kicks in, making sure a weak stem is used. The other three relevant types ensure that exactly two morphs are used and introduce the theme vowel.



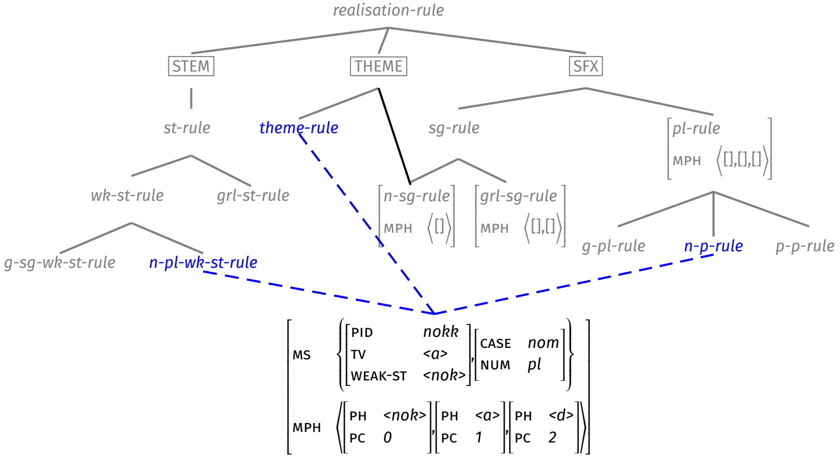
Generalizations over combinations of exponents

- The PART.SG is licensed just like the GEN.SG except that the default, strong stem is selected.



Generalizations over combinations of exponents

- Plural forms rely on a rule type requiring three morphs, and vary in the choice of stem allomorph and suffix.



IbM as constructional morphology

- IbM implements basic tenets of construction grammar in the context of inflection (see also Koenig 1994; Gurevich 2006; Booij 2010):
  - Rules of exponence may be constructional, in the sense that combinations of units of form (constructions) may contribute content unpredictable from the joint contributions of the individual units.
  - Through hierarchical organization, rules of exponence may capture generalizations about form-content relationships at any level of granularity.

Capturing lexeme-level generalizations about exponence

Paradigm identifiers I

- In IbM, every bit of form has to be licensed by some rule of exponence.
- Hence IbM makes crucial use of rules of stem introduction.
- We argue that these rules realize the paradigm identifier or PID (Bonami and Crysmann, 2018).
- The PID encapsulates all information that is specific to one paradigm:
  - Minimally, a stem shape.

The English lexeme BOOK
(partial lexical entry)

$$\begin{bmatrix} \textit{lexeme} & \\ \text{SS}|\text{CAT}|\text{HD} & \begin{bmatrix} \textit{noun} & \\ \text{LID} & \textit{book-rel} \end{bmatrix} \\ \text{PID} & \begin{bmatrix} \textit{pid} & \\ \text{STEM} & \text{<bʊk>} \end{bmatrix} \end{bmatrix}$$

A basic rule of stem introduction

$$\begin{bmatrix} \text{MS} & \left\{ \begin{bmatrix} \textit{pid} & \\ \text{STEM} & \boxed{1} \end{bmatrix} \right\} \\ \text{MPH} & \left\langle \begin{bmatrix} \text{PH} & \boxed{1} \end{bmatrix} \right\rangle \end{bmatrix}$$

Paradigm identifiers II

- Where needed:
  - Separate stem and thematic elements (Bonami and Lacroix, 2011; Crysmann and Bonami, 2017)
  - Stem space (Bonami and Boyé, 2002) encoded as an ordered list of stems (Bonami and Boyé, 2006)
  - Grammatical gender
- PIDs are organized in an inheritance hierarchy.
  - PID types implement irreducible inflection class distinctions
  - Allows for highly structured encoding of inflection class systems.
- We illustrate this by looking at Czech declension (Bonami and Crysmann, 2018).

Czech declension: basic facts

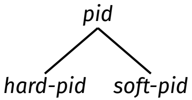
- Partial paradigms of main declension types for masculine inanimate and neuter nouns:

		MASCULINE		NEUTER	
		hard	soft	hard	soft
SG	NOM	most	pokoj	měst-o	moř-e
	GEN	most-u	pokoj-e	měst-a	moř-e
	DAT	most-u	pokoj-i	měst-u	moř-i
	ACC	most	pokoj	měst-o	moř-e
PL	NOM	most-y	pokoj-e	měst-a	moř-e
	GEN	most-ů	pokoj-ů	měst	moř-í
	DAT	most-ům	pokoj-ům	měst-ům	moř-ím
	ACC	most-y	pokoj-e	měst-a	moř-e
		'bridge'	'room'	'town'	'sea'

- Existence of generalizations based on gender or hard vs. soft declension type.
- Hard vs. soft only partially predictable from the quality of the stem-final consonant.

Cross-classifying lexemes I

- Hard vs. soft as a distinction of type of PID value.



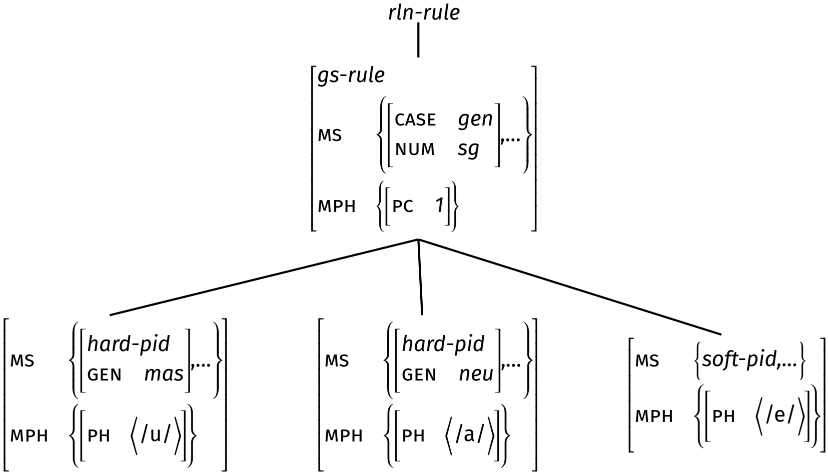
- Individual lexemes pick a specific gender and PID type

$$\begin{bmatrix} \textit{lexeme} & \\ \text{SS|CAT|HD} & \begin{bmatrix}\textit{noun} & \\ \text{LID} & \textit{bridge-rel}\end{bmatrix} \\ \text{PID} & \begin{bmatrix}\textit{hard-pid} & \\ \text{GEN} & \textit{mas} \\ \text{STEM} & \langle\text{most}\rangle\end{bmatrix}\end{bmatrix} \quad \begin{bmatrix} \textit{lexeme} & \\ \text{SS|CAT|HD} & \begin{bmatrix}\textit{noun} & \\ \text{LID} & \textit{room-rel}\end{bmatrix} \\ \text{PID} & \begin{bmatrix}\textit{soft-pid} & \\ \text{GEN} & \textit{mas} \\ \text{STEM} & \langle\text{pokoj}\rangle\end{bmatrix}\end{bmatrix}$$

$$\begin{bmatrix} \textit{lexeme} & \\ \text{SS|CAT|HD} & \begin{bmatrix}\textit{noun} & \\ \text{LID} & \textit{town-rel}\end{bmatrix} \\ \text{PID} & \begin{bmatrix}\textit{hard-pid} & \\ \text{GEN} & \textit{neu} \\ \text{STEM} & \langle\text{měst}\rangle\end{bmatrix}\end{bmatrix} \quad \begin{bmatrix} \textit{lexeme} & \\ \text{SS|CAT|HD} & \begin{bmatrix}\textit{noun} & \\ \text{LID} & \textit{sea-rel}\end{bmatrix} \\ \text{PID} & \begin{bmatrix}\textit{soft-pid} & \\ \text{GEN} & \textit{neu} \\ \text{SSTEM} & \langle\text{moř}\rangle\end{bmatrix}\end{bmatrix}$$

Cross-classifying lexemes II

- Particular rules of exponence may select underspecified PID values



(e.g. *most-u*) (e.g. *měst-a*) (e.g. *pokoj-e*, *moř-e*)

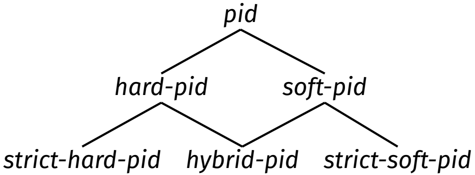
Hybrid classes

- This corner of the Czech declension system exhibits two types of hybridization between hard and soft declensions.
  - Lexically-conditioned overabundance in the masculine
  - Heteroclisis in the neuter

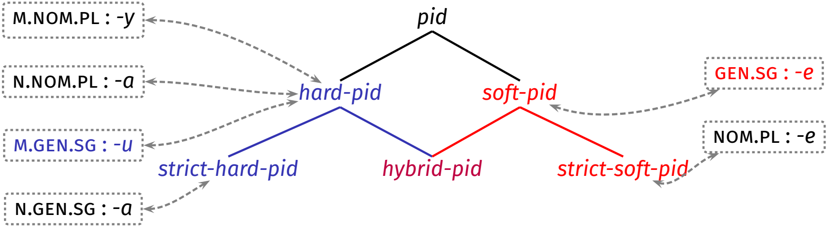
		MASCULINE			NEUTER		
		hard	hybrid	soft	hard	hybrid	soft
SG	NOM	most	pramen	pokoj	měst-o	kuř-e	moř-e
	GEN	most-u	pramen-u~pramen-e	pokoj-e	měst-a	kuř-et-e	moř-e
	DAT	most-u	pramen-u~pramen-i	pokoj-i	měst-u	kuř-et-i	moř-i
	ACC	most	pramen	pokoj	měst-o	kuř-e	moř-e
PL	NOM	most-y	pramen-y	pokoj-e	měst-a	kuř-at-a	moř-e
	GEN	most-ů	pramen-ů	pokoj-ů	měst	kuř-at	moř-í
	DAT	most-ům	pramen-ům	pokoj-ům	měst-ům	kuř-at-ům	moř-ím
	ACC	most-y	pramen-y	pokoj-e	měst-a	kuř-at-a	moř-e
		‘bridge’	‘spring’	‘room’	‘town’	‘chicken’	‘sea’

Hybrid classes in the PID hierarchy

- Hybrid classes have multiple supertypes in the PID hierarchy:

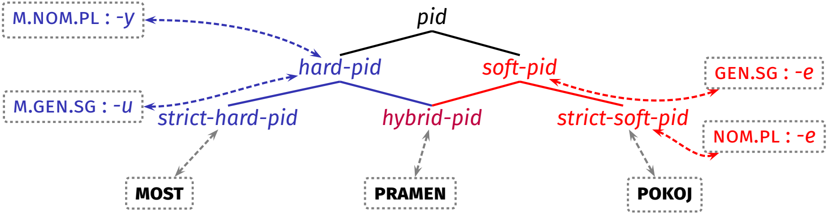


  - Both overabundant and heteroclite lexemes belong the the *mixed-pid* type.
  - Rules of exponence may pick out a leaf type or a supertype.

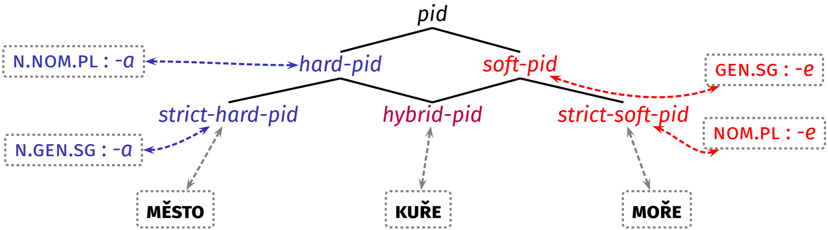


Overabundance and the PID hierarchy

- Overabundance occurs where two rules expressing the same features pick out distinct supertypes of a lexeme's PID.

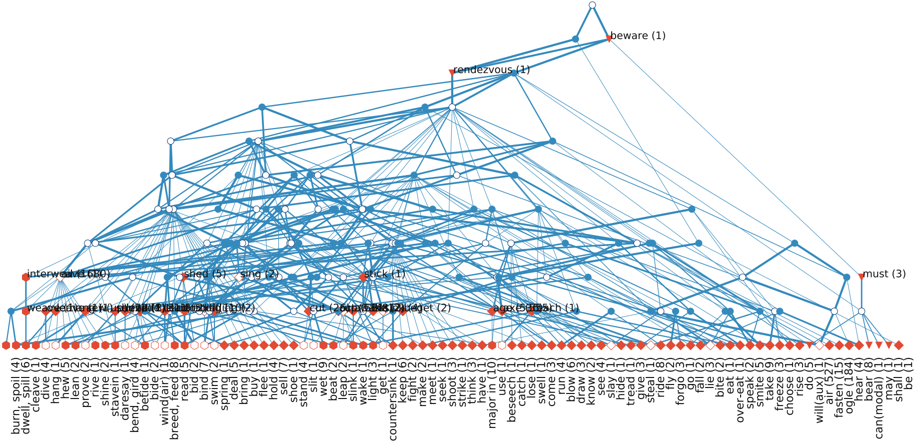


- Heteroclisis occurs where the PID type is mixed, but no pair of rules expressing the same features pick out different supertypes.



Supporting evidence: inductive classification

- Beniamine (forthcoming) infers hierarchies of classes from raw inflectional data.
- Densely populated class lattices, with a high prevalence of hybrid classes.



Supporting evidence from analogical similarity

- Guzman Naranjo (2019):
  - In general, phonological similarity of stems predicts similarity of inflectional behavior.
    - Naturally captured in IbM as constraints on PID.
  - In overabundant hybridization, the stems of hybrid classes have phonological properties intermediate between those of the two non-overabundant classes.
    - Predicted by the present analysis of hybridization.
    - Although Guzman Naranjo does not discuss it, we predict that the same will hold for heteroclite hybridization.

Outlook: questioning presuppositions

Outstanding issues

- At the beginning of the talk I made explicit three presuppositions:
  - I assume a pre-established segmentation of words into stems and affixes.
  - I assume that stem alternants as well as affixes may have exponential value.
  - I assume a pre-established statement of the exponential value of each element.
- These presuppositions would be unproblematic if we had well-established, undisputed ways of meeting these asumptions.
- But we don't (Spencer, 2012).

Questioning presuppositions: allomorphy

- Consider the following patterns of stem alternation in French:

	1SG	2SG	3SG	1PL	2PL	3PL
DÉMENER	demɛn	demɛn	demɛn	demənɔ̃	deməne	demɛn
DÉCÉDER	desɛd	desɛd	desɛd	desedɔ̃	desede	desɛd
DÉJEUNER	dejœn	dejœn	dejœn	dejənɔ̃	dejəne	dejœn

- Analytic customs suggest to not treat alternating vowels as exponents, because they are not taken to be distinct morphs.
- Yet these alternating vowels, rather than the global shape of the stems, have exponential value, in the sense that they constitute a phonological property of the word with contrastive value.
- In general then, we need to consider how each (sub)segmental property of a word contributes to exponence.
- Beniamine and Bonami (2019): steps towards an automated, inductive segmentation strategy grounded in the contrastive value of individual phonological properties of words.

Questioning presuppositions: exponents of what?

- Consider the distribution of -ɔ̃ in French conjugation.

	1SG	2SG	3SG	1PL	2PL	3PL
PRS	lav	lav	lav	lavɔ̃	lave	lav
PST.IPFV	lavɛ	lavɛ	lavɛ	lavjɔ̃	lavje	lavɛ
PST.PFV	lavɛ	lava	lava	lava**m**	lavat	lavɛʁ
FUT	lavəʁɛ	lavəʁa	lavəʁa	lavəʁɔ̃	lavəʁe	lavəʁɔ̃

- -ɔ̃ has a quirky distribution: $($1PL $\wedge\ \neg$PST.PFV$)\ \vee\ ($3PL $\wedge$ FUT$)$
- Our analytic habit is to try as much as possible to reduce such distributions by appealing to homonymy and Panini's Principle
  - -$ɔ̃_1$: 1PL, -*m*: IND.PST.PFV.1PL, -$ɔ̃_2$: FUT.3PL
- This is definitely worth questioning: Saying that -ɔ̃ is the exponent of 1PL does not do full justice to the information that is provided to the speaker by the fact that the word ends in -ɔ̃.
- Way forward: exponence as probability of content given form.

Questioning presuppositions: exponence types

- Theories of exponence are still largely based on Matthews's 1972 typology of distributions.
- Yet this is far from complete (Harris, 2017).
- In particular, basic definitions do not exhaust the types that present themselves (Carroll, 2019).

	SG	PL
1		*x*
2		*x*
3	*y*	*xy*

Simple exponence

	SG	PL
1		*x*
2		*x*
3		*xy*

Multiple exponence

	SG	PL
1	*x*	*x*
2	*x*	
3	*xy*	*y*

???

- Way forward (current collaboration with Matthew Carroll):
  - Explicit model-theoretic formalization of distribution types
  - Large-scale empirical exploration of the prevalence of different types

Conclusions

- I have presented a general formal framework for inflectional morphology that crucially uses:
  - Many-to-many rules of exponence
  - Inheritance hierarchies of rules of exponence
  - Inheritance hierarchies of paradigm types
- I have highlighted how this provides for direct expression of various types of generalizations over exponence:
  - Variable morphotactics
  - Parallel exponence
  - Gestalt exponence
  - Hybrid exponence strategies, in the form of both overabundance and heteroclisis
- Much conceptual and empirical work remains to be done on the nature and typology of exponence.
- IbM provides a rich formal scaffolding to build on.

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Why morphousness is not a problem

- Classical arguments against morphousness (Anderson, 1992) do not apply to IbM:
  - No ‘zero morphemes’: absence of expression is the absence of a morph, not the presence of an empty element.
  - The constraint-based lexicalist architecture is sufficient to ensure that syntax cannot manipulate morphs.
  - Because IbM is declarative, rules do not feed other rules, and hence there is no sense in which one rule could be sensitive to the structure build by another.
  - Non-concatenative morphology is not an obstacle to morphousness within a model-theoretic model, and can be addressed by combining underspecified descriptions of the same string.

Lexical entry of RING:

$$\begin{bmatrix} \textit{apo-vb-pid} & \\ \text{STEM} & \langle r\rangle + \langle \textit{vowel} \rangle + \langle ng\rangle \end{bmatrix}$$

Exponence of past:

$$\begin{bmatrix} \text{MS} & \left\{ \begin{bmatrix}\textit{apo-vb-pid} & \\ \text{STEM} & \boxed{1}\end{bmatrix}, \begin{bmatrix}\text{TMA} & \textit{pst}\end{bmatrix} \right\} \\ \text{MPH} & \left\langle \begin{bmatrix} \text{PH} & \boxed{1}\ \textit{list(seg)}+:\langle a\rangle+\textit{list(cons)}\end{bmatrix}\right\rangle \end{bmatrix}$$