Chapter 21

Morphology

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This chapter provides an overview of work on morphology within HPSG. Following a brief discussion how morphology relates to the issue of lexical redundancy, and in particular horizontal redundancy, I map out the historical transition from meta-level lexical rules of derivational morphology and grammatical function change towards theories that are more tighly integrated with the hierarchical lexicon (Riehemann 1998; Koenig 1999). After a discussion of fundamental issues of inflectional morphology and the kind of models these favour, the chapter summarises previous HPSG approaches to the issue and finally provides an introduction to Information-based Morphology (Crysmann & Bonami 2016), a realisational model of morphology that systematically exploits HPSG-style underspecification in terms of multiple inheritance hierarchies.

1 Introduction

Lexicalist approaches to grammar, such as HPSG, typically combine a fairly general syntactic component with a rich and articulate lexicon. While this makes for a highly principled syntactic component – e.g. the grammar fragment of English presented in Pollard & Sag (1994) contains only a handful of principles together with six rather general phrase structure schemata –, this decision places quite a burden on the lexicon, an issue known as lexical redundancy.

Lexical redundancy comes in essentially two varieties: vertical redundancy and horizontal redundancy. Vertical redundancy arises because many lexical entries share a great number of syntactic and semantic properties: e.g. in English (and many other languages) there is a huge class of strictly transitive verbs which display the same valency specifications, the same semantic roles, and the same

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linking patterns. From its outset, HPSG successfully eliminates vertical redundancy by means of multiple inheritance networks over typed feature structures (Flickinger et al. 1985).

The problem of horizontal redundancy is associated with systematic alternations in the lexicon: these include argument-structure alternations, such as resultatives or the causative-inchoative alternation, as well as classical instances of grammatical function change, such as passives, applicatives or causatives. The crucial difference with respect to vertical redundancy is that we are not confronted with what is essentially a classificational problem – assigning lexical items to a more general class and inheriting its properties –, but rather with a relation between lexical items. Morphological processes, both in word formation and inflection, crucially involve this latter type of redundancy: for example, in the case of deverbal adjectives in *-able*, we find a substantial number of derivations that show systematic changes in form, paired with equally systematic changes in grammatical category, meaning, and valency (Riehemann 1998). In inflection, change in morphosyntactic properties, e.g. case or agreement marking, is often signalled by a change in shape, which means the generalisation to be captured is about the contrast of form and morphosyntactic properties between fully inflected words.

Following Bresnan (1982b), the classical way to attack the issue of horizontal redundancy in HPSG is by means of lexical rules (Flickinger 1987). Early HPSG embraced Bresnan's original conception of lexical rules as mappings between lexical items. To a considerable extent[1], work on morphology and, in particular, derivational morphology has led to a reconceptualisation of lexical rules within HPSG: now, they are understood as partial descriptions of lexical items that are fully integrated into the hierarchical lexicon (Koenig 1999). As such, they are amenable to the same underspecification techniques that are used to generalise across classes of basic lexical items.

The chapter is structured as follows: in Section 2, I shall present the main developments towards an inheritance-based view of derivational morphology within HPSG and provide pointers to concrete work within HPSG and beyond that has grown out of these efforts. In Section 3, I shall discuss inflectional morphology, starting with an overview of the classical challenges (Section 3.1) and assess how the different types of inflectional theories – Item-and-Arrangement (IA), Item-and-Process (IP), and Word-and-Paradigm (WP) – fare with respect to these basic challenges (Section 3.2). Against this backdrop, I shall discuss pre-

[1]See also the work by Meurers (2001), providing a formal description-level formalisation of lexical rules, as standardly used in HPSG.

vious work on inflection in HPSG (Section 3.3). Section 4 will be devoted to an introduction of Information-based Morphology, a recently developed HPSG subtheory of inflectional morphology.

2 Inheritance-based approaches to derivational morphology

2.1 Krieger & Nerbonne (1993)

Probably the first attempt at a more systematic treatment of morphology is the approach by Krieger & Nerbonne (1993). They note that meta-level lexical rules, as conceived of at the time, move the description of lexical alternations, which are characteristic of morphology, outside the scope of lexical inheritance hierarchies. Consequently, they explore how morphology can be made part of the lexicon. They observe that inflection and derivation differ most crucially with respect to the finiteness of the domain: while inflection is essentially finite (modulo case stacking; Sadler & Nordlinger 2006; Malouf 2000), derivation need not be: they cite repetitive prefixation in German as the decisive example (*Silbe* 'syllable', *Vor-silbe* 'pre-syllable', *Vor-vor-silbe* 'pre-pre-syllable', etc.). Consequently, they propose modelling derivation by means of morphological rule schemata, which are underspecified descriptions of complex lexemes, and integrating them as part of the lexical hierarchy. They adopt a word-syntactic approach akin to Lieber (1992), where affixes are treated as signs that select the bases with which they combine. They propose a number of principles that govern headedness, subcategorisation, and semantic composition. What is special is that all these principles are represented as types in the lexical type hierarchy, cf. Chapter Davis & Koenig (2021), Chapter 4 of this volume. Concrete derivational rule schemata will then inherit from these supertypes. What this amounts to is that different subclasses of derivational processes may be subject to all or only a subset of these principles. They briefly discuss conversion, i.e. zero derivation, and suggest that this could be incorporated by means of unary rules.

2.2 Riehemann (1998)

The work of Riehemann (1998) takes as its starting point the previous proposal laid out in Krieger & Nerbonne (1993), treating derivational processes as partial descriptions of lexemes that are organised in an inheritance type hierarchy and that relate a derived lexeme to a morphological base. Her approach, however,

expands on the previous proposal in two important respects. First, she argues against a word-syntactic approach and suggests instead that only the morphological base, a lexeme, should be considered a sign. Affixes or modification of the base, if any, are syncategorematically introduced by rule application. In contrast to the word-syntactic approach by Krieger & Nerbonne (1993), Riehemann's conceptualisation of derivation as unary rules integrated into the hierarchical lexicon does not give any privileged status to concatenative word formation processes: as a result, it generalises more easily to modificational formations, conversion, and (subtractive) back formations (e.g. *self-destruct* < *self-destruction*).

Second, she conducts a detailed empirical study of *-bar* '-able' affixation in German and shows that besides regular *-bar* adjectives, which derive from transitive verbs and introduce both modality and a passivisation effect, there is a broader class of similar formations which adhere to some of the properties, but not others.

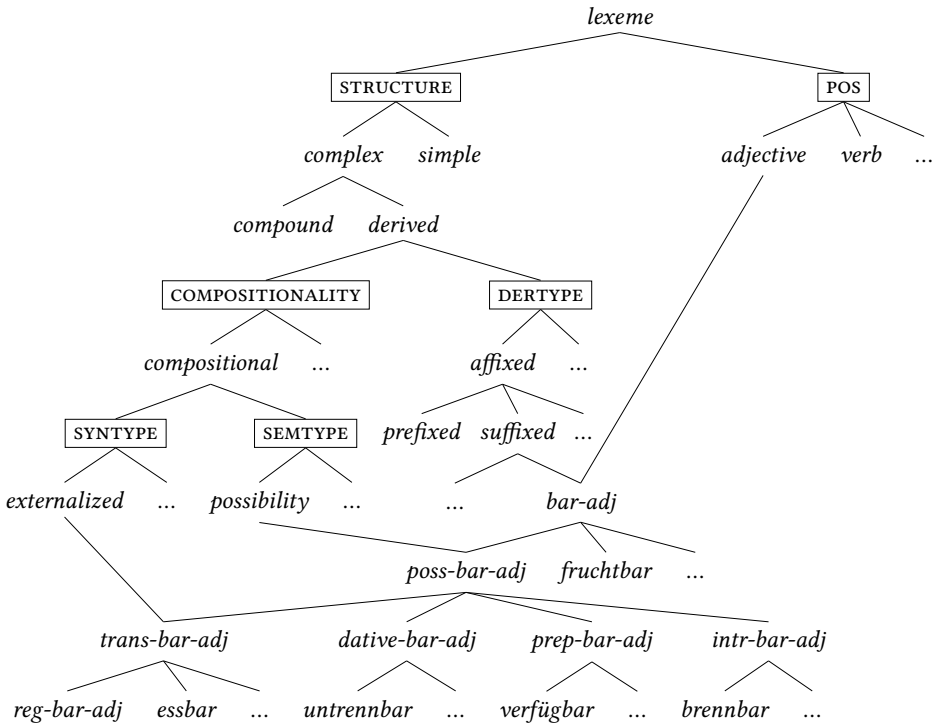


Figure 1: Type hierarchy of German *-bar* derivation according to Riehemann (1998: 64)

She concludes that multiple inheritance type hierarchies lend themselves towards capturing the variety of the full empirical pattern while at the same time providing the necessary abstraction in terms of more general supertypes from which individual subclasses may inherit.

(1)
$$\left[\begin{array}{l}\textit{reg-bar-adj}\\ \textsc{phon}\ \boxed{1}\oplus\langle\ \textit{bar}\ \rangle\\ \textsc{morph-b}\ \left\langle\left[\begin{array}{l}\textit{trans-verb}\\ \textsc{phon}\ \boxed{1}\\ \textsc{synsem}|\textsc{loc}\ \left[\begin{array}{l}\textsc{cat}|\textsc{comps}\ \left\langle \textsc{np}[\textit{acc}]{:}\boxed{2}\right\rangle\oplus\boxed{3}\\ \textsc{cont}|\textsc{nuc}\ \boxed{4}\left[\begin{array}{l}\textsc{act}\ \textit{index}\\ \textsc{und}\ \boxed{5}\end{array}\right]\end{array}\right]\end{array}\right]\right\rangle\\ \textsc{synsem}|\textsc{loc}\ \left[\begin{array}{l}\textsc{cat}\ \left[\begin{array}{l}\textsc{head}\ \textit{adj}\\ \textsc{subj}\ \left\langle \textsc{np}{:}\boxed{2}\boxed{5}\right\rangle\\ \textsc{comps}\ \boxed{3}\end{array}\right]\\ \textsc{cont}|\textsc{nuc}\ \left[\begin{array}{l}\textsc{reln}\ \diamond\\ \textsc{und}\ \boxed{5}\\ \textsc{soa-arg}\ \boxed{4}\end{array}\right]\end{array}\right]\end{array}\right]$$

Figure 1 on page 950 provides the extended hierarchy suggested by Riehemann (1998). The type for regular *-bar* adjectives given in (1) is treated as a specific subtype that inherits inter alia from more general supertypes that capture the salient properties that characterise the regular formation, e.g. *anfechtbar* 'contestable', but which also hold to some extent for subregular *-bar* adjectives, e.g. *eßbar* 'edible'.[2]

One property that is almost trivial concerns suffixation of *-bar*, and it holds for the entire class. Suffixation is no exclusive property of *-bar* adjectives, so this property can be abstracted out into the supertype *suffixed* in (2): the type *bar-adj* in Figure 1 inherits this property and specifies the concrete shape of the list appended to the morphological base.

(2)
$$\left[\begin{array}{l}\textit{suffixed}\\ \textsc{phon}\quad\boxed{1}\oplus\textit{list}\\ \textsc{morph-b}\ \left\langle\left[\textsc{phon}\ \boxed{1}\right]\right\rangle\end{array}\right]$$

[2]The feature geometry and some further details have been adapted to the conventions used in this book. For a version of Riehemann's lexical rule using the distinction between structural and lexical case (Przepiórkowski 2021, Chapter 7 of this volume) see Müller (2003).

A property which is common to most *-bar* adjectives in German is that they denote "possibility", as represented by the type constraint in (3). Exceptions include *zahlbar* 'payable', which denotes necessity instead.

(3) $\begin{bmatrix} \textit{possibility} \\ \textsc{synsem|loc|cont|nuc|reln} \diamond \end{bmatrix}$

Clearly more specific, albeit fairly general still, is the passivisation effect observed with transitive bases, as it does not apply in the same way to verbal bases taking dative (*entrinnbar* 'escapable') or prepositional complements (*verfügbar* 'available/disposable') instead of an accusative, and it does not apply at all to intransitive bases (*brennbar* 'combustible').

(4) $\begin{bmatrix} \textit{externalised} \\ \textsc{synsem} \quad \left[\textsc{loc|cat|subj} \left\langle \text{NP}:\boxed{1} \right\rangle\right] \\ \textsc{morph-b} \left\langle \left[\textsc{synsem|loc|cat|comps} \left\langle \text{NP}[\textit{acc}]:\boxed{1}, \ldots \right\rangle\right] \right\rangle \end{bmatrix}$

Regular *-bar* adjectives (1) inherit from all these supertypes, which accounts for most of their properties, while at the same time the overall hierarchy of *-bar* constructions captures the relatedness of regular *-bar* adjective to subregular formations.

2.3 Koenig (1999)

Koenig's work on lexical relations has made several important contributions to our understanding of morphological processes within the HPSG lexicon. Based on joint work with Dan Jurafsky (Koenig & Jurafsky 1995), he uses Online Type Construction to turn the hierarchical lexicon, which is actually a static system into a dynamic, generative device. This enables him in particular to make a systematic distinction between open types for regular, productive formations, and closed types for subregular and irregular ones.

Koenig (1999) takes issue with the early conception of lexical rules as meta-level rules either deriving an expanded lexicon from a base lexicon (generative lexical rules), or else establishing relations between items within the lexicon (redundancy rules). He argues on the basis of grammatical function change, such as the English passive, that systematic alternations are amenable to underspecification in the hierarchical lexicon, once cross-classification between types can be performed dynamically.

Online Type Construction depends on a hierarchical lexicon that is organised into an AND/OR network of conjunctive dimensions (represented in boxed capitals) and disjunctive types (in italics). While in a standard type hierarchy any two

types that do not have a common subtype are understood as incompatible, Online Type Construction derives new subtypes by intersection of leaf types from different dimensions. Leaf types within the same dimension are still considered disjoint. Thus, dimensions define the range of inferrable cross-classifications between types, without having to statically list these types in the first place.

In Koenig's conception of the lexicon as a type underspecified hierarchical lexicon (TUHL), the unexpanded lexicon is just a system of types. Concrete lexical items, i.e. instances, are inferred from these by means of Online Type Construction.

Let us briefly consider a simple example for the active/passive alternation: the minimal lexical type hierarchy in Figure 2 is organised into two dimensions, one representing specific lexemes, the other specifying active voice and passive voice linking patterns for lexemes. Concrete lexical items are now derived by cross-classifying exactly one leaf type from one dimension with exactly one leaf type from the other.

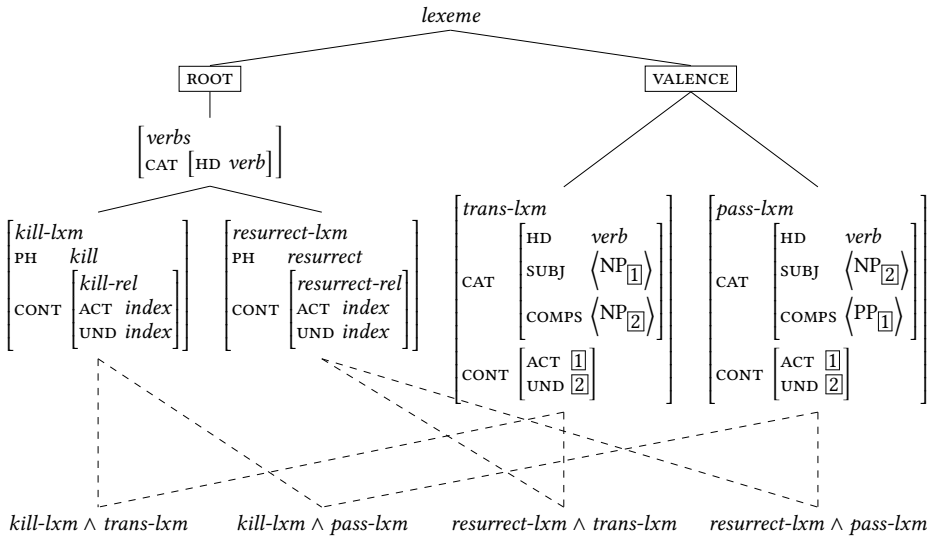


Figure 2: Online type construction

An important aspect of this integration of alternations into the hierarchical lexicon is that it becomes quite straightforward to deal with lexical exceptions in a systematic way. The key to this is pre-typing, as illustrated in Figure 3: in English, for instance, some transitive verbs, like possessive *have* fail to undergo passivisation. Rather than marking these verbs diacritically with exception fea-

tures, pre-typing to the active pattern precludes their cross-classification with the passive pattern, because leaf types within a dimension are disjoint and pre-typing makes this type already a type in both dimensions.

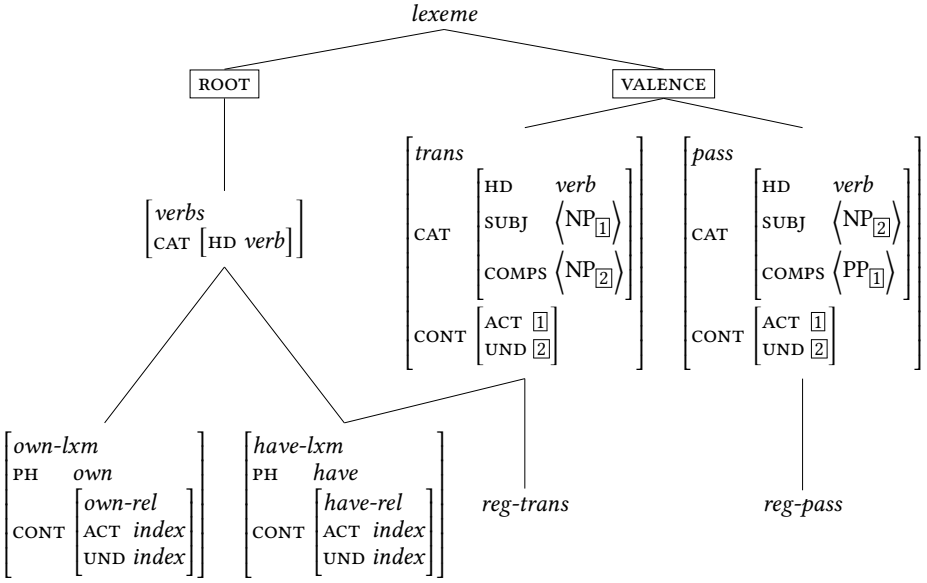


Figure 3: Exceptions via pre-typing

Online Type Construction successfully integrates systematic alternations into type hierarchies. A crucial limitation is, however, that Online Type Construction is confined to finite domains: by itself, it is suitable for inflection and possibly quasi-inflectional, non-recursive processes as grammatical function change, while a full treatment of derivational processes will still require recursive rule types, which remain a possibility in Koenig's general approach to derivational morphology.[3]

The works of Riehemann (1998) and Koenig 1999 had considerable impact on subsequent work on word formation, both within the framework of HPSG and beyond. Within HPSG, several studies of French derivation and compounding

[3]Blevins (2003) discusses the interaction between passives and impersonals in Baltic and Slavic languages and its relevance to some of the issues I just discussed. See Avgustinova et al. (1999) for an account along these lines. Müller (2013: 925–927) and Müller & Wechsler (2014: Section 8.1) take a highly sceptical stance, arguing that interactions in grammatical function change depend on the possibility for one lexical rule to apply to the output of another, or, as in the case of Turkish causatives, a rule may even apply more than once.

directly build on these proposals (e.g. Tribout 2010; Desmets & Villoing 2009). Outside, the development of Construction Morphology (Booij 2010) has largely been influenced by the HPSG work on word formation within a hierarchical lexicon.

3 Inflection

3.1 Classical challenges of inflectional systems

Ever since Matthews (1972), it has been recognised in morphological theory that inflectional systems do not privilege one-to-one relations between function and form, but must rather be conceived of as many-to-many (m : n), in the general case. Thus, while rule-by-rule compositionality can count as the success story of syntax and semantics, this does not hold in the same way for inflection.

Classical problems that illustrate the many-to-many nature of inflection include cumulation, where a single form expresses multiple morphosyntactic properties. An extreme example of cumulation is contributed by the Latin verb *am-o* 'love-1.SG.PRS.IND.AV', which contrasts e.g. with forms *amā-v-i* 'love-PRF-1.SG.AV', where perfective tense is expressed by a discrete exponent *-v*, or present subjunctive *am-ē-m* 'love-SUBJ-1.SG.AV' where mood is expressed by a marker of its own.

The mirror image of cumulation is extended (or multiple) exponence: here, a single property is expressed by more than one exponent. This is exemplified by German circumfixal past participles, such as *ge-setz-t* 'PPP-sit-PPP', which is marked by a prefix *ge-* and a suffix *-t*, jointly expressing the perfect/passive participial property. Another case of multiple exponence is contributed by Nyanja, which marks certain adjectives with a combination of two agreement markers, as discussed on page 977 in Section 4.3. See Caballero & Harris (2012) and Harris (2017) for a typological overview.

Possibly more widely attested than pure multiple exponence is overlapping exponence, i.e. the situation where two exponents both express the same property, but at least one of them also expresses some other property: e.g. many German nouns form the dative plural by suffixation of *-n*, but plural marking is often signalled additionally by stem modification (*Umlaut*): while *Kutter-n* 'tug(M)-DAT.PL' merely shows cumulation of case and number, *Mütter-n* 'mother(F).PL-DAT.PL' exhibits plural marking in both the inflectional ending and the fronting of the stem vowel (cf. singular *Mutter* 'mother.SG').

An extremely wide-spread form of deviation from a one-to-one correspondence between form and function is zero exponence, where some morpho-syn-

tactic properties do not give rise to any exponence. In English, regular plural nouns are formed by suffixation of *-s*, as in *jeep/jeeps*, but we also find cases, such as *sheep*, where no overt exponent of plural is present. Likewise, the past tense of English verbs is regularly signalled by suffixation of *-ed*, as with *flip/flipped* or British English *fit/fitted*, but again, there are forms such as *hit/hit* where past is not overtly marked. In German, nouns inflect for four cases and two numbers, yielding eight cells. However, in some paradigms very few cells are actually overtly marked. The feminine noun *Brezen* 'pretzel' does not take any inflectional markings. Similarly, one of the most productive masculine/neuter paradigms, witnessed by *Rechner* 'computer', only shows overt marking for two cells, the genitive singular (*Rechner-s*) and the dative plural (*Rechner-n*), all other forms being bare.

The many-to-many nature of inflectional morphology clearly has repercussions as to how the system is organised. One way to make sense of inflection is in terms of paradigmatic opposition: while it may be hard to figure out what exactly the meaning is of zero case/number marking in German, we can easily establish the meaning of a form like *Rechner* in opposition to the non-bare forms *Rechner-s* 'computer-GEN.SG' and *Rechner-n* 'computer-DAT.PL'. This is even more the case once we consider different paradigms, i.e. different patterns of opposition: the invariant form *Brezen* 'pretzel', for instance, has a wider denotation than *Rechner*, whereas *Auto* 'car' has a narrower denotation, standing in opposition to more cells, cf. Table 21.1(c).

The recognition of paradigms has led to a number of works on syncretism (see, e.g. Baerman et al. 2005), i.e. cases of systematic or accidental identity of form across different cells of the paradigm. Syncretism can give rise to splits of different types (Corbett 2015): natural splits, where syncretic forms share some (non-disjunctive) set of features, Pāṇinian splits, where syncretism corresponds to some default form, and finally morphomic splits, where syncretic forms neither form a natural class nor do they lend themselves to be analysed as a default.

In Table 21.1(a), we find a perfect alignment of syncretic forms along the number dimension. By contrast, Figure 21.1(b) illustrates the case discussed above, where two specific cells constitute overrides to a general default pattern (here zero exponence). Default forms, however, need not involve zero exponence: German features a Pāṇinian split in another paradigm where all forms are marked with *-en* (e.g. *Mensch-en* 'human(s)'), with the exception of the nominative singular (*Mensch* 'human.NOM.SG'), which constitutes a zero override. Table 21.1(c) illustrates how a Pāṇinian split in the singular can combine with a natural split between singular and plural. Finally, Table 21.1(d) illustrates what could be taken

Table 21.1: Paradigmatic splits

'granny'	SINGULAR	PLURAL
NOM	Oma	Oma-s
GEN	Oma	Oma-s
DAT	Oma	Oma-s
ACC	Oma	Oma-s

(a) Natural split

'computer'	SINGULAR	PLURAL
NOM	Rechner	Rechner
GEN	Rechner-s	Rechner
DAT	Rechner	Rechner-n
ACC	Rechner	Rechner

(b) Pāṇinian split

'car'	SINGULAR	PLURAL
NOM	Auto	Auto-s
GEN	Auto-s	Auto-s
DAT	Auto	Auto-s
ACC	Auto	Auto-s

(c) Natural & Pāṇinian split

'wall'	SINGULAR	PLURAL
NOM	mur-s	mur
ACC	mur	mur-s

(d) Morphomic split (Old French)

as a morphomic split, where there is no natural alignment between form and function, and no clear way to establish what is the default and what is the override (cf., however, Crysmann & Kihm 2018 for an analysis of the Old French declension system).

The patterns we have just seen have two clear implications for morphological theory: first, many morphologists believe that a version of Pāṇini's Principle, whereby more specific forms can block more general ones, must be part of morphological theory, since otherwise many generalisations will be lost. Second, the many-to-many nature of exponence has a direct impact on the representation of inflectional meaning, which we will explore in the next two subsections.

3.2 Typology of inflectional theories

Current morphological theories differ as to how they establish the relation between a complex form and its parts and how this relation determines the relation between form and function. The classical morpheme-based view of morphology, where inflectional meaning is a property of lexical elements, such as morphemes, constitutes the text book case of what Hockett (1954) has dubbed the Item-and-Arrangement (IA) model. The general criticism that has been raised against such

models is that they fail to recognise the paradigmatic structure of inflectional morphology and furthermore need to make extensive appeal to zero morphemes (see Anderson 1992 for a systematic criticism).

The alternative model Hockett (1954) discusses is the Item-and-Process (IP) model where inflectional meaning is introduced syncategorematically by way of rule application. Such approaches are less prone to have difficulties with non-concatenative processes like modification and zero exponence. However, IP approaches still do not recognise the $m : n$ nature of inflectional morphology and are therefore expected to have problems with e.g. multiple exponence.

As a reaction to Matthews (1972), new approaches to inflectional morphology were developed taking the notion of paradigms much more seriously. Theories, such as A-Morphous Morphology (Anderson 1992) or Paradigm Function Morphology (Stump 2001) have been classified into the Word-and-Paradigm (WP) category. Crucially, such models locate inflection at the level of the word and rely on realisation rules that associate the word's inflectional properties with exponents that serve to express them. WP approaches contrast with IA in that they do not recognise (classical) morphemes. They differ from IP in that there is neither a notion of incrementality, i.e. that inflectional rules must be information-increasing, nor that rules are necessarily one-to-one correspondences between (alteration of) form and meaning.

3.3 HPSG approaches to inflection

Over the years, several different proposals have been made regarding the treatment of inflectional morphology in HPSG. From the point of view of the underlying logic, there is no a priori expectation as to the type of model (IA, IP, WP) that would be most compatible with HPSG's basic assumptions. Indeed, every one of the three models have been proposed at some point. However, the arguments against morpheme-based models put forth by Matthews (1972), Spencer (1991), Anderson (1992) and Stump (2001) have been taken quite seriously within the HPSG community, such that there is a clear preference for IP or WP models over IA, notable exceptions being Van Eynde (1994) and, more recently, Emerson & Copestake (2015).

One of the most common ways to express lexical alternations is by means of (description-level) lexical rules. Morphophonological changes effected by such a rule are typically captured by some (often undefined) function on the phonology of the daughter. Since morphological marking is tied directly to rule application, approaches along these lines constitute an instance of an IP model of morphology. Work on morphology in grammar implementation typically follows this

line: in platforms like the Linguistic Knowledge Builder (LKB; Copestake 2002, see also Bender & Emerson 2021: 1116, Chapter 25 of this volume) character unification serves to provide statements of morphophonological changes that can be attached to (unary) lexical rules. See Goodman & Bender (2010) for a proposal as to how requirements for certain inflections and dependencies between morphological rules, e.g. the parts of extended or overlapping exponence, can be captured in a more systematic way, and Crysmann (2015; 2017b) for implementations of non-concatenative morphology.

A notable exception to the function approach is the work of Olivier Bonami (Bonami & Samvelian 2015; Bonami 2015): he argued for the incorporation of an external formal model of morphology into HPSG, namely Paradigm Function Morphology (=PFM; Stump 2001), and showed specifically that the integration should be done at the level of the word, rather than individual lexical rules, in order to reap the benefits of a WP model over an IP model. In a similar vein, Erjavec (1994) explores how a model such as PFM can be cast in typed feature descriptions and observes that the only non-trivial aspect of such an enterprise relates to Pāṇinian competition, which requires a change to the underlying logic. See Section 4.3 for detailed discussion.

In the area of cliticisation, several sketches of WP models have been proposed: e.g. Miller & Sag (1997) provide an explication of the function that realises the pronominal affix cluster, but the proposal was never meant to scale up to a full formal theory of inflection. Crysmann (2003) suggested a realisational, morph-based model of inflection. While certainly more worked-out, the approach was too tailored towards the treatment of clitic clusters.

Word-based approaches

Krieger & Nerbonne (1993) As stated above, probably one of the first approaches to morphology in HPSG was developed by Krieger & Nerbonne (1993). What they propose is essentially an instance of a WP model, since they use distributed disjunctions to directly represent entire paradigms, matching exponents with the features they express. Most interestingly, their approach to inflection contrasts quite starkly with their work on derivation (Krieger & Nerbonne 1993), which is essentially a word-syntactic, i.e. morpheme-based, approach.

(5) represents an encoding of the present indicative paradigm for German (cf. the endings in Table 21.2). The distributed disjunction, marked by $1, associates each element in the disjunctive ENDING value with the corresponding element in the disjunctive AGR value.

Table 21.2: Regular present indicative endings for German verbs

	Singular	Plural
1	-e	-n
2	-st	-t
3	-t	-n

(5) Encoding paradigms by distributed disjunctions (Krieger & Nerbonne 1993: 105):

$$\left[\begin{array}{l} \textsc{morph} \left[\begin{array}{l} \textsc{stem} \quad \boxed{2} \\ \textsc{ending} \; \boxed{3} \; \{_{\$1}\text{“e”, “st”, “t”, “n”, “t”, “n”}\} \\ \textsc{form} \quad \boxed{2} + \boxed{3} \end{array}\right] \\ \textsc{synsem} \left[\textsc{local}|\textsc{head}|\textsc{agr} \left\{_{\$1} \left[\begin{array}{l}\textsc{per} \; 1 \\ \textsc{num} \; sg\end{array}\right], \left[\begin{array}{l}\textsc{per} \; 2 \\ \textsc{num} \; sg\end{array}\right], \ldots, \left[\begin{array}{l}\textsc{per} \; 3 \\ \textsc{num} \; pl\end{array}\right]\right\}\right] \end{array}\right]$$

They further argue that partially regular formations, such as *sollen* ‘should’, which has no ending in the first and third singular can be captured by means of default inheritance, overriding the ENDING value as in (6).

(6) Partial irregularity by overriding default endings (Krieger & Nerbonne 1993: 105):
$\left[\textsc{morph} \left[\textsc{ending} \; \{_{\$1}\text{“”, “st”, “”, “n”, “t”, “n”}\}\right]\right]$

Suppletive forms, as for auxiliary *sein* ‘be’, will equally inherit from (5), yet override the form value, cf. (7).

(7) Suppletive verbs (Krieger & Nerbonne 1993: 106):
$\left[\textsc{morph} \left[\textsc{form} \; \{_{\$1}\text{“bin”, “bist”, “ist”, “sind”, “seid”, “sind”}\}\right]\right]$

The approach by Krieger & Nerbonne (1993) has not been widely adopted, partially because few versions of HPSG support default inheritance and even fewer support distributed disjunctions. Koenig (1999: 176–178) also argues against distributed disjunctions on independent theoretical grounds, suggesting that the approach will not scale up to morphologically more complex systems.

Koenig (1999) Similar to Krieger & Nerbonne (1993), Koenig (1999) pursues a word-based approach to inflection, in contrast to the IP approach he developed for derivation. He focuses on the distinction between regular, subregular and

irregular formations and explores how these can be represented in a systematic way in lexical type hierarchies using Online Type Construction.

He departs from the observation that words inflect along a finite number of different inflectional dimensions and that within each dimension, pairings of exponents and morphosyntactic features stand in paradigmatic opposition. Furthermore, neither completely uninflected roots, nor partially derived words (e.g. lacking agreement information) shall be able to function as lexical signs, so it is necessary to enforce that inflection be applied. The AND/OR logic of dimensions and types he proposed appears to be very well-suited to account for these properties.

Table 21.3: Future forms of the Swahili verb *taka* 'want'

	POS	NEG		POS	NEG
1SG	ni-ta-tak-a	si-ta-tak-a	1PL	tu-ta-tak-a	ha-tu-ta-tak-a
2SG	u-ta-tak-a	ha-u-ta-tak-a	2PL	m-ta-tak-a	ha-m-ta-tak-a
3SG.M/WA	a-ta-tak-a	ha-a-ta-tak-a	3PL.M/WA	wa-ta-tak-a	ha-wa-ta-tak-a
3SG.KI/VI	ki-ta-tak-a	ha-ki-ta-tak-a	3PL.KI/VI	vi-ta-tak-a	ha-vi-ta-tak-a
etc.					

For illustration, let us consider a subset of his analysis of Swahili verb inflection. As shown in Table 21.3, Swahili verbs (minimally) inflect for polarity, tense and subject agreement.[4]

Koenig (1999: Section 5.5.2) suggests that the inflectional morphology of Swahili can be directly described at the word level. Accordingly, he proposes a type hierarchy of word-level inflectional constructions as given in Figure 4.

As shown in Table 21.3, tensed verbs with plural subjects take three prefixes in the negative and two in the positive, with the exponent of negative preceding the exponent of subject agreement, preceding in turn the exponent of tense. Koenig (1999) proposes three dimensions of inflectional construction types that correspond to the three positional prefix slots. Since dimensions are conjunctive, a well-formed Swahili word must inherit from exactly one type in each dimension. As he states, the AND/OR logic of dimensions and types is the declarative analogue of the conjunctive rule blocks and disjunctive rules in A-Morphous Morphology (Anderson 1992).

Types in the dimensions are partial word-level descriptions of (combinations of) prefixes. As shown by the sample types in (8), these partial descriptions pair

[4]The full paradigm recognises inflection for object agreement and relatives, but this shall not concern us here, it being sufficient that inflectional paradigms may be large but finite.

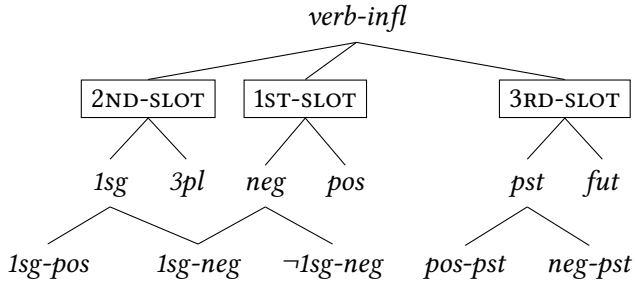


Figure 4: Koenig's (1999: 171) constructional approach to Swahili position classes

some morphosyntactic properties (μ-FEAT) with constraints on the prefixes: the type *¬1sg-neg*, for instance, constrains the first prefix slot to be *ha-*, while leaving the other slots underspecified. These will be further constrained by appropriate types from the other two dimensions. Likewise, the type *1sg-pos*, constrains slot 2 to be *ni-*, but specifies the further requirement that the verb be [NEG −].

(8) Sample types for Swahili:

a. *¬1sg-neg*:

$$\begin{bmatrix} \textsc{ph} & [\textsc{aff}\ [\textsc{pref}\ \langle \text{ha}, \ldots, \ldots \rangle]] \\ \textsc{cat} & [\textsc{head}\ [\mu\text{-}\textsc{feat}\ [\textsc{neg}\ +]]] \end{bmatrix}$$

b. *1sg-pos*:

$$\begin{bmatrix} \textsc{ph} & [\textsc{aff}\ [\textsc{pref}\ \langle \ldots, \text{ni}, \ldots \rangle]] \\ \textsc{cat} & \begin{bmatrix} \textsc{head} & \begin{bmatrix} \mu\text{-}\textsc{feat} & \begin{bmatrix} \textsc{neg} & - \\ \textsc{subj-agr} & \begin{bmatrix} \textsc{per} & 1 \\ \textsc{num} & sg \end{bmatrix} \end{bmatrix} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

c. *1sg-neg*:

$$\begin{bmatrix} \textsc{ph} & [\textsc{aff}\ [\textsc{pref}\ \langle \text{si}, \langle\rangle, \ldots \rangle]] \\ \textsc{cat} & \begin{bmatrix} \textsc{head} & \begin{bmatrix} \mu\text{-}\textsc{feat} & \begin{bmatrix} \textsc{neg} & + \\ \textsc{subj-agr} & \begin{bmatrix} \textsc{per} & 1 \\ \textsc{num} & sg \end{bmatrix} \end{bmatrix} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

Pre-linking of types finally permits a straightforward treatment of cumulation across positional slots: e.g. the type *1sg-neg* simultaneously satisfies requirements for the first and second slot, constraining one of the prefixes to be portmanteau *si-*, the other one to be empty. Thus, by adopting a constructional perspective on inflectional morphology, Koenig (1999) can capture interactions between different affix positions. There is, however, one important limitation to a

direct word-based perspective: situations where exponents from the same set of markers may (repeatedly) co-occur within a word cannot be captured without an intermediate level of rules. Such a situation is found with subject and object agreement markers in Swahili – so-called parallel position classes (Stump 1993; Crysmann & Bonami 2016) –, as well as with exuberant exponence in Batsbi (Harris 2009; Crysmann 2021). We shall come back to the issue in Section 4.5. Finally, since exponents are directly represented on an affix list under Koenig's approach, position and shape cannot always be underspecified independently of each other, which makes it more difficult to capture variable morphotactics (see Section 4.4).

An aspect of (inflectional) morphology that Koenig (1999) pays particular attention to is the relation between regular, subregular and irregular formations. He approaches the issue on two levels: the level of knowledge representation and the level of knowledge use.

At the representational level, regular formations, e.g. past tense *snored*, are said to be intensionally defined in terms of regular rule types that license them: results of regular rule application are consequently not listed in the lexicon. Rather, they are constructed either by Online Type Construction or by rule application. Irregular formations, by contrast, are fully listed, e.g. the past tense form *took* of a verb like *take*. Most interesting are subregular types, e.g. *sing/sang/sung* or *ring/rang/rung*: like irregulars, class membership is extensionally defined by enumeration, but the type hierarchy can still be exploited to abstract out common properties.

With regular formations being defined in terms of productive schemata, an important task is to preempt any subregular or irregular root from undergoing the regular, productive pattern. Koenig (1999) discusses three different approaches in depth: a feature-based approach, and two ways of invoking Pāṇini's Principle. As for the former, he shows that the costs associated with diacritic exception features is actually minimal, i.e. it is sufficient to specify irregular and subregular bases as [IRR +] and constrain the regular rule to [IRR –]. Thus, use of such diacritics does not need to be stated for the large and open class of regular, productive bases. Despite the relatively harmless effects of the feature-based approach, it should be kept in mind that this approach will not scale up to a full treatment of Pāṇinian competition.[5]

Koenig (1999) proposes two variants of a morphological and/or lexical blocking theory. In essence, he builds on a previous formulation by Andrews (1990)

[5]This is because first, every default/override pair would need to be stipulated, and second, if a paradigm has defaults in different dimension (e.g. a default tense, or a default agreement marking), each would need its own diacritic feature.

within LFG to define a notion of morphological competition based on subsumption. Since competition is between different realisations for the same morphological features, he applies a restrictor on form-related features to then establish competition in terms of unilateral subsumption ($\sqsubset$): i.e. a rule-description that is more specific than some other rule (modulo form-oriented features) will take precedence. I shall not go into the details of Koenig's Blocking Principle here, since we shall come back to a highly similar formulation of Pāṇinian competition in Section 4.3. Koenig (1999) discusses two different ways this can be accomplished: one is a compilation approach where complementation is used to make the more general type disjoint, whereas the other relegates the problem to the area of knowledge use. While the usage-based interpretation may appear preferable, because it does not require expansion of the lexical type-hierarchy, it leaves open the question why this kind of competition is mainly restricted to lexical knowledge. On the other hand, the static compilation approach requires prior expansion of the type underspecified lexicon in order to give sound results under restriction, a point made in Crysmann (2003).

To summarise, several WP proposals have been made to replace the IP model tacitly assumed by many HPSG syntacticians, which merely attaches some morpho-phonological function to a lexical rule. Bonami (Bonami & Samvelian 2008; Bonami & Boyé 2006; 2007; Bonami 2011) proposed directly "plugging in" a credible external framework, namely Paradigm Function Morphology (Stump 2001), Koenig (1999) suggested a word-based model. Neither approach has proven to be fully satisfactory. Use of an external theory, such as PFM, begs the question why we need a different formalism in order to implement a theory of inflection, rather than exploiting the power of inheritance and cross-classification in hierarchies of typed feature structure descriptions. Word-based approaches suffer from problems of scalability with morphotactically complex systems. These issues led to the development of Information-based Morphology (Crysmann & Bonami 2016), which will be discussed in the next section.

4 Information-based Morphology

Information-based morphology (Crysmann & Bonami 2016) is a theory of inflectional morphology that systematically builds on HPSG-style typed feature logic in order to implement an inferential-realisational model of inflection. As the name suggests, in reference to Pollard & Sag (1987), it aims at complementing HPSG with a subtheory of inflection that systematically explores underspecifica-

tion and cross-classification as the central device for morphological generalisations.

IbM clearly builds on previous HPSG work on morphology and the lexicon: Online Type Construction (Koenig & Jurafsky 1995) can be cited here in the context of the underlying logic. Similarly, the decision to represent morphotactics in terms of a flat lists of segmentable exponents (=morphs) draws on previous work by Crysmann (2003).

4.1 Architecture and principles

The architecture of IbM is quite simple: essentially, words are assumed to introduce a feature INFL that encapsulates all features relevant to inflection.[6] At the top-level, these comprise MPH, a partially ordered list of exponents (*m(or)ph*), a morphosyntactic (or morphosemantic) property set MS associated with the word, and finally RR, a set of realisation rules that establish the correspondence between exponents and morphosyntactic properties.

$$\text{(9)}\quad \textit{word} \Rightarrow \left[\textsc{infl} \begin{bmatrix} \textsc{mph} & \textit{list}(\textit{mph}) \\ \textsc{rr} & \textit{set}(\textit{realisation-rule}) \\ \textsc{ms} & \textit{set}(\textit{msp}) \end{bmatrix}\right]$$

From the viewpoint of inflectional morphology, words can be regarded as associations between a phonological shape (PH) and a morphosyntactic property set (MS), the latter including, of course, information pertaining to lexeme identity. This correspondence can be described in a maximally holistic fashion, as shown in (10), where a phonological form is paired with information about lexemic identity (LID) and a morphosyntactic property (TAM). Throughout this section, I shall use German (circumfixal) passive/past participle (*ppp*) formation, as witnessed by *ge*-setz-*t* 'put', for illustration.

$$\text{(10)}\quad \begin{bmatrix} \textsc{ph} & \langle \text{gesetzt} \rangle \\ \textsc{infl} & \left[\textsc{ms} \left\{ \left[\textsc{lid}\ \textit{setzen}\right], \left[\textsc{tam}\ \textit{ppp}\right] \right\}\right] \end{bmatrix}$$

[6] For the purposes of this chapter, I shall make the somewhat simplifying assumption that inflection is a property exclusively associated with words. However, Koenig & Michelson (2020) present compelling evidence from nominalisation in Oneida, showing that derivational processes in this language may target (partially) inflected bases, including nominalisation of aspectually inflected verbal stems, as well as incorporation of inflected and derived nominals into polysynthetic verbs. It therefore seems necessary to generalise the interface between lexical types and inflectional morphology in such a way that realisational morphology can be applied to sub-word units within a derivational chain.

Since words in inflectional languages typically consist of multiple segmentable parts, realisational models provide means to index position within a word: while in A-Morphous Morphology (=AM; Anderson 1992) and Paradigm Function Morphology (=PFM; Stump 2001) ordered rule blocks perform this function, IbM uses a list of morphs (MPH) to explicitly represent exponents. The sample word-level representation in (11) illustrates the kind of information represented on the MPH list and the MS set.

(11) Structured association of form (MPH) and function (MS)

a. Word:

$$\begin{bmatrix} \textsc{mph} & \left\langle \begin{bmatrix} \textsc{ph} & \textit{<ge>} \\ \textsc{pc} & \textit{-1} \end{bmatrix}, \begin{bmatrix} \textsc{ph} & \textit{<setz>} \\ \textsc{pc} & \textit{0} \end{bmatrix}, \begin{bmatrix} \textsc{ph} & \textit{<t>} \\ \textsc{pc} & \textit{1} \end{bmatrix} \right\rangle \\ \textsc{ms} & \left\{ \left[\textsc{lid} \; \textit{setzen} \right], \left[\textsc{tam} \; \textit{ppp} \right] \right\} \end{bmatrix}$$

b. Abstraction of circumfixation ($1 : n$):

$$\begin{bmatrix} \textsc{mph} & \left\langle \begin{bmatrix} \textsc{ph} & \textit{<ge>} \\ \textsc{pc} & \textit{-1} \end{bmatrix}, \begin{bmatrix} \textsc{ph} & \textit{<t>} \\ \textsc{pc} & \textit{1} \end{bmatrix}, \ldots \right\rangle \\ \textsc{ms} & \left\{ \left[\textsc{tam} \; \textit{ppp} \right], \ldots \right\} \end{bmatrix}$$

While elements of the MS set are either inflectional features or lexemic properties, the latter comprising e.g. information about the stem shape or inflection class membership, MPH is a list of structured elements (of type *mph*, cf. (12)) consisting of a phonological description (PH) paired with a position class index (PC), which serves to establish linear order of exponents. In some previous work on IbM, MPH was assumed to be a set, which is possible since order can be determined on the basis of PC indices alone. More recently, however, it is assumed to be a list, which is slightly redundant, yet permits much more parsimonious descriptions of principles and rules.

(12) $$\textit{mph} \Rightarrow \begin{bmatrix} \textsc{ph} & \textit{list(phon)} \\ \textsc{pc} & \textit{pos-class} \end{bmatrix}$$

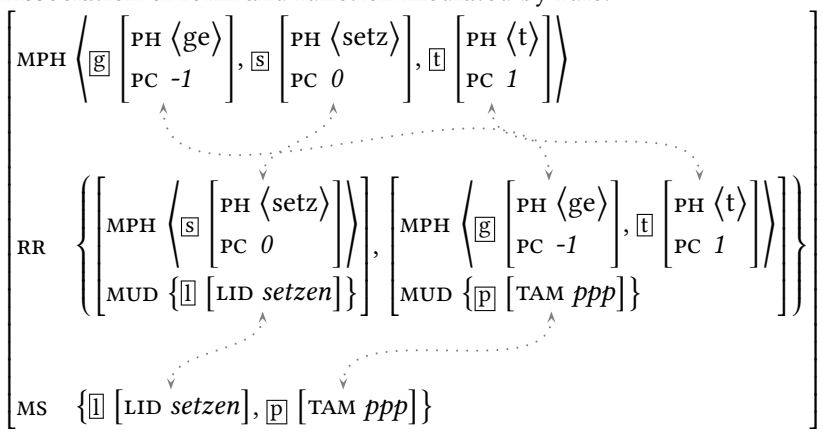
The reification of position and shape as first-class citizens of morphological representation is one of the central design decisions of IbM: as a result, constraints on position and shape will be amenable to the very same underspecification techniques as all other morphological properties. As a consequence, IbM eliminates structure from inflectional morphology, which clearly distinguishes this approach from other inferential-realisational approaches, such as PFM or AM, where order is derived from cascaded rule application. Although IbM recognises a minimal structure in terms of segmentable morphs, there is no hierarchy involved. AM and PFM, by contrast, reject derived structure, to borrow a term

from Tree Adjoining Grammar, but this potential advantage is more than offset by their abundant use of derivation structure.

By means of underspecification, i.e. partial descriptions, one can easily abstract out realisation of the past participle property, arriving at a direct word-based representation of circumfixal realisation, as shown in (11). Yet, a direct word-based description does not easily capture situations where the same association between form and content is used more than once in the same word, as is arguably the case for Swahili (Stump 1993; Crysmann & Bonami 2016; 2017) or Batsbi (Harris 2009; Crysmann 2021).

By introducing a level of realisation rules (RR), reuse of resources becomes possible. Rather than expressing the relation between form and function directly at the word level, IbM assumes that a word's description includes a specification of which rules license the realisation between form and content, as shown in (13).

(13) Association of form and function mediated by rule:



Recognition of a level of realisation rules that mediate between parts of form and parts of function slightly increases the complexity of morphological descriptions beyond a simple pairing of form-related MPH lists and function-related MS sets.

The crucial point about realisation rules is that they take care of parts of the inflection of an entire word independently of other realisation rules. Thus, in IbM, realisation rules are explicitly defined in terms of the set of morphosyntactic features they express, as opposed to contextually conditioning features. To that end, realisation rules introduce a feature MUD (Morphology Under Discussion), in addition to MPH and MS, in order to single out the morphosyntactic features that are licensed by application of the rule. Thus, MUD specifies the subset of the morphosyntactic property set MS that the rule serves to express, as detailed in (14).

(14) $\textit{realisation-rule} \Rightarrow \begin{bmatrix} \textsc{mud}\ \boxed{1}\ \textit{set}(\textit{msp}) \\ \textsc{ms}\ \ \boxed{1} \cup \textit{set}(\textit{msp}) \\ \textsc{mph}\ \ \textit{list}(\textit{morph}) \end{bmatrix}$

Realisation rules (members of set RR) pair a set of morphological properties to be expressed, the morphology under discussion (MUD), with a list of morphs that realise them (MPH). Since MUD, being a set, admits multiple morphosyntactic properties, and since MPH, being a list, admits multiple exponents, realisation rules in fact establish $m : n$ relations between function and form: thus, the many-to-many nature of inflectional morphology is captured at the most basic level. It is this very property that sets the present framework apart from cascaded rule models of inferential-realisational morphology (Anderson 1992; Stump 2001), which attain this property only indirectly as a system: rules in these frameworks are $m : 1$ correspondences between functions and form, but since rules in different rule blocks may express the same functions, the system as a whole can capture $m : n$ relations.

(15) Morphological well-formedness:

$$\textit{word} \Rightarrow \begin{bmatrix} \textsc{mph}\ \boxed{e_1} \bigcirc \ldots \bigcirc \boxed{e_n} \\ \textsc{rr}\ \ \left\{ \begin{bmatrix} \textsc{mph}\ \boxed{e_1} \\ \textsc{mud}\ \boxed{m_1} \\ \textsc{ms}\ \ \boxed{0} \end{bmatrix}, \ldots, \begin{bmatrix} \textsc{mph}\ \boxed{e_n} \\ \textsc{mud}\ \boxed{m_n} \\ \textsc{ms}\ \ \boxed{0} \end{bmatrix} \right\} \\ \textsc{ms}\ \ \boxed{m_1} \uplus \ldots \uplus \boxed{m_n} \end{bmatrix}$$

Given two distinct levels of representation, the morphological word and the rules that license it, it is of course necessary to define how constraints contributed by realisation rules relate to the overall morphological makeup of the word. Realisation rules per se only provide recipes for matching morphosyntactic properties onto exponents and vice versa. In order to describe well-formed words, it is necessary to enforce that these recipes actually be applied. IbM regulates the relation between word-level properties and realisation rules by means of a rather straightforward principle, given in (15): this very general principle of morphological well-formedness ensures that the properties expressed by rules add up to the word's property set, and that the rules' MPH lists add up to that of the word, such that no contribution of a rule may ever be lost. This principle of general well-formedness in (15) bears some resemblance to LFG's principles of completeness and coherence (Bresnan 1982a), as well as to the notion of "Total Accountability" proposed by Hockett (1947). Since $m : n$ relations are recognised at the most basic level, i.e. morphological rules, mappings between the contributions of the rules and the properties of the word can (and should) be $1 : 1$. We

shall see below that this makes possible a formulation of morphological well-formedness in terms of exhaustion of the morphosyntactic property set.

In essence, a word's morphosyntactic property set (MS) will correspond to the non-trivial set union (⊎) of the rules' MUD values: While standard set union (∪) allows for the situation that elements contributed by two sets may be collapsed, non-trivial set union (⊎) insists that the sets to be unioned must be disjoint. The entire morphosyntactic property set of the word (MS) is visible on each realisation rule by way of structure sharing (0).

Finally, a word's sequence of morphs, and hence its phonology, will be obtained by shuffling (◯) the rules' MPH lists in ascending order of position class (PC) indices (see Chapter Müller (2021a: 391), Chapter 10 of this volume for a definition of the shuffle relation, also known as sequence union). This is ensured by the Morph Ordering Principle given in (16), adapted from Crysmann & Bonami (2016).

(16) Morph Ordering Principle (MOP):

a. Concatenation:

$$word \Rightarrow \begin{bmatrix} \textsc{ph} & \boxed{1} \oplus \ldots \oplus \boxed{n} \\ \textsc{infl} & \left[\textsc{mph} \left\langle \left[\textsc{ph}\ \boxed{1}\right], \ldots, \left[\textsc{ph}\ \boxed{n}\right] \right\rangle\right] \end{bmatrix}$$

b. Order:

$$word \Rightarrow \neg \left(\left[\textsc{infl} \left[\textsc{mph} \left\langle \ldots \left[\textsc{pc}\ \boxed{m}\right], \left[\textsc{pc}\ \boxed{n}\right], \ldots \right\rangle\right]\right] \wedge \boxed{m} \geq \boxed{n} \right)$$

While the first clause in (16a) merely states that the word's phonology is the concatenation of its constituent morphs, the second clause (16b) ensures that the order implied by position class indices (PC) is actually obeyed. Bonami & Crysmann (2013) provide a formalisation of morph ordering using list constraints.

Given the very general nature of the well-formedness constraints and particularly the commitment to monotonicity embodied by (15), it is clear that most if not all of the actual morphological analysis will take place at the level of realisation rules.

4.2 Realisation rules

The fact that IbM, in contrast to PFM or AM, recognises $m : n$ relations between form and function at the most basic level of organisation, i.e. realisation rules, means that morphological generalisations can be expressed in a single place, namely simply as abstractions over rules. Rules in IbM are represented as descriptions of typed feature structures organised in an inheritance hierarchy, such that properties common to leaf types can be abstracted out into more general supertypes. This vertical abstraction is illustrated in Figure 5. Using again German

past participles as an example, the commonalities that regular circumfixal *ge-...-t* (as in *gesetzt* 'put') shares with subregular *ge-...-en* (as in *geschrieben* 'written') can be generalised as the properties of a rule supertype from which the more specific leaves inherit. Note that essentially all information except choice of suffixal shape is associated with the supertype. This includes the shared morphotactics of the suffix.

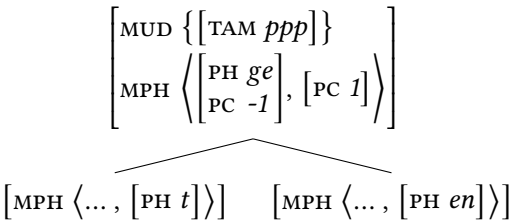


Figure 5: Vertical abstraction by inheritance

In addition to vertical abstraction by means of standard monotonic inheritance hierarchies, IbM draws on Online Type Construction (Koenig & Jurafsky 1995): using dynamic cross-classification, leaf types from one dimension are distributed over the leaf types of another dimension. This type of horizontal abstractions permits modelling of systematic alternations, as illustrated once more with German past participle formation:

(17) a. *ge*-setz-*t* 'put'
b. über-setz-*t* 'translated'
c. *ge*-schrieb-*en* 'written'
d. über-schrieb-*en* 'overwritten'

In the more complete set of past participle formations shown in (17), we find alternation not only between choice of suffix shape (*-t* vs. *-en*), but also between presence vs. absence of the prefixal part (*ge-*).

Figure 6 shows how Online Type Construction provides a means to generalise these patterns in a straightforward way: while the common supertype still captures properties true of all four different realisations – namely the property to be expressed and the fact that it involves at least a suffix –, concrete prefixal and suffixal realisation patterns are segregated into dimensions of their own (indicated by PREF and SUFF). Systematic cross-classification (under unification) of types in PREF with those in SUFF yields the set of well-formed rule instances, e.g. distributing the left-hand rule type in PREF over the types in SUFF yields

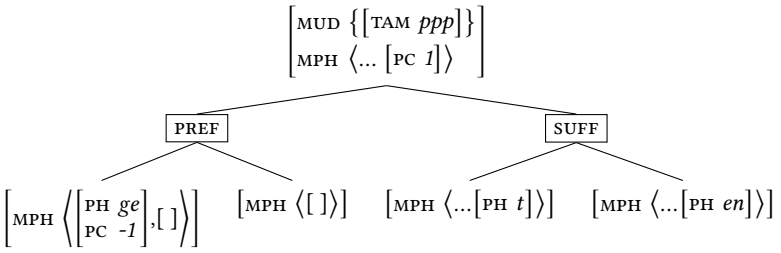


Figure 6: Horizontal abstraction by dynamic cross-classification

the rules for *ge-setz-t* and *ge-schrieb-en*, whereas distributing the right hand rule type in PREF gives us the rules for *über-setz-t* and *über-schrieb-en*, which are characterised by the absence of the participial prefix.

Having illustrated how the kind of dynamic cross-classification offered by Online Type Construction is highly useful for the analysis of systematic alternation in morphology, it seems necessary to lay out in a more precise fashion its exact workings. In its original formulation by Koenig & Jurafsky (1995) and Koenig (1999), Online Type Construction was conceived as a closure operation on underspecified lexical type hierarchies. IbM merely redeploys their approach for the purposes of inflectional morphology. Essentially, a minimal type hierarchy as in Figure 6 provides instructions on the set of inferrable subtypes: according to Koenig & Jurafsky (1995), dimensions are conjunctive and leaf types are disjunctive. Online Type Construction dictates that any maximal subtype must inherit from exactly one leaf type in each dimension. The maximal types of the hierarchy thus expanded serve as the basis for rule instances, i.e. actual rules.[7]

4.3 Pāṇinian competition

In accordance with most theories of inflection (Prince & Smolensky 1993; Stump 2001; Anderson 1992; Noyer 1992; Kiparsky 1985), IbM embraces a version of Morphological Blocking, also known as the Elsewhere Condition (Kiparsky 1985) or Pāṇini's Principle. The basic intuition behind Pāṇinian competition is that more specific rules can block the application of more general rules, where the

[7]There are two ways of conceptualising the status of Online Type Construction in grammar: under the dynamic view, hierarchies are underspecified and the full range of admissible types and therefore the range of instances is inferred online. Under the more conservative static view, the underspecified description is merely a convenient shortcut for the grammar writer. In either case, generalisations are preserved.

most unspecific rule will count as a default. In terms of feature logic, the notion of specificity corresponds to some version of the subsumption relation.

Competition between rules or lexical entries does not follow from the logic standardly assumed within HPSG: if a rule can apply, it will apply, no matter whether there are any more specific or more general rules that could have applied as well (in fact, they would apply as well). Thus, implementation of a notion of morphological blocking necessitates a change to the logic.

As has been discussed already in Koenig (1999), preemption based on specificity of information can be either addressed statically (at "compile-time") as an issue of knowledge representation or dynamically (at "run-time") as a question of knowledge use. Independently of the choice between a static or dynamic version of preemption, the main task is to provide a notion of competitor. In the interest of representing Pāṇinian inferences transparently in the type hierarchy, IbM makes use of a closure operation on rule instances, as detailed in (18), which is clearly inspired by Koenig (1999) and Erjavec (1994).[8]

(18) *Pāṇinian Competition (PAN)*

a. For any leaf type t_1[MUD μ_1,MS σ], t_2[MUD μ_2,MS $\sigma \wedge \tau$] is a morphological competitor, iff $\mu_1 \cup set \sqsubseteq \mu_2 \cup set$.

b. For any leaf type t_1 with competitor t_2, expand t_1's MS σ with the negation of t_2's MS $\sigma \wedge \tau$: i.e. $\sigma \wedge \neg(\sigma \wedge \tau)$ which is equivalent to $\sigma \wedge \neg\tau$.

The first clause establishes competition, ensuring subsumption with respect to both expressed features (MUD) and conditioning features (MS descriptions).[9] If the condition in (18a) is met, the use conditions of the more general rule are specialised in such a way (18b) as to make the two rule descriptions fully disjoint.

For concreteness, let us consider some examples from Swahili: as shown in Table 21.4, the negative in Swahili is typically formed by a prefix *ha-*, preceding the equally prefixal exponents of subject agreement and tense (future *ta-*). However, in the negative first singular, discrete realisation of *ha-* and *ni-* is blocked by the portmanteau *si-*. Here, we have a classical case of Pāṇinian competition, where a rule that expresses both negative and first person singular agreement preempts application of the more general individual rules for negative or first person singular.

[8] Alternatively, for a dynamic approach, it will be sufficient to use clause (18a) and perform a topological sort on rule instances, ordering more specific rules before more general ones.

[9] Since MUD values can be of different cardinality, the subsumption is checked on open sets containing the original MUD sets.

Table 21.4: Future forms of the Swahili verb *taka* 'want'

	POS	NEG		POS	NEG
1SG	ni-ta-tak-a	**si**-ta-tak-a	1PL	tu-ta-tak-a	ha-tu-ta-tak-a
2SG	u-ta-tak-a	ha-u-ta-tak-a	2PL	m-ta-tak-a	ha-m-ta-tak-a
3SG.M/WA	a-ta-tak-a	ha-a-ta-tak-a	3PL.M/WA	wa-ta-tak-a	ha-wa-ta-tak-a
3SG.KI/VI	ki-ta-tak-a	ha-ki-ta-tak-a	3PL.KI/VI	vi-ta-tak-a	ha-vi-ta-tak-a
etc.					

In the case of *si*, we find the portmanteau in the same surface position as the exponents it is in competition with. However, this need not be the case, nor indeed is preemption of this kind limited to adjacency. Relative negative *si-*, for instance, is realised in a position following the subject agreement marker, yet still, by virtue of expressing negative in the context of relative marking, it blocks realisation of negative *ha-* in pre-agreement position. This constitutes a case of what Noyer (1992) calls "discontinuous bleeding".

(19) a. ha- wa- ta- taka
NEG SBJ.PL.M/WA FUT want
'they will not want'

b. watu wa- *si-* o- soma
people SBJ.PL.M/WA NEG.REL REL.PL.M/WA read
'people who don't read'

c. * watu ha- wa- *(si-)* o- soma
people NEG SBJ.PL.M/WA NEG.REL REL.PL.M/WA read

The relevant realisation rules for *ha-*, *ni-*, and the two markers *si-*, can be formulated quite straightforwardly as in (20a–d). For expository purposes, I shall make explicit the fact that MUD is necessarily contained in MS.

(20) a.
$$\begin{bmatrix} \text{MUD } \boxed{1} \{neg\} \\ \text{MS } \boxed{1} \cup set \\ \text{MPH } \left\langle \begin{bmatrix} \text{PH } \langle \text{ha} \rangle \\ \text{PC } 1 \end{bmatrix} \right\rangle \end{bmatrix}$$

b.
$$\begin{bmatrix} \text{MUD } \boxed{1} \left\{ \begin{bmatrix} subj \\ \text{PER } 1 \\ \text{NUM } sg \end{bmatrix} \right\} \\ \text{MS } \boxed{1} \cup set \\ \text{MPH } \left\langle \begin{bmatrix} \text{PH } \langle \text{ni} \rangle \\ \text{PC } 2 \end{bmatrix} \right\rangle \end{bmatrix}$$

c. $\begin{bmatrix} \textsc{mud}\ \boxed{1}\left\{\begin{bmatrix} neg, \\ \begin{bmatrix} subj \\ \textsc{per}\ \ 1 \\ \textsc{num}\ sg \end{bmatrix} \end{bmatrix}\right\} \\ \textsc{mph}\ \left\langle\begin{bmatrix} \textsc{ph}\ \langle \text{si} \rangle \\ \textsc{pc}\ \ 1..2 \end{bmatrix}\right\rangle \end{bmatrix}$ d. $\begin{bmatrix} \textsc{mud}\ \boxed{1}\ \{neg\} \\ \textsc{ms}\ \ \boxed{1} \cup \{rel\} \cup set \\ \textsc{mph}\ \left\langle\begin{bmatrix} \textsc{ph}\ \langle \text{si} \rangle \\ \textsc{pc}\ \ 3 \end{bmatrix}\right\rangle \end{bmatrix}$

On the basis of the definition in (18a), portmanteau *si* in (20c)[10] is a competitor for both *ni-* (20b) and *ha-* (20c), since the MUD of portmanteau *si-* expands, i.e. is subsumed by each of the sets containing the MUD value of *ni-* or *ha-*. Moreover, the MS value of portmanteau *si-* is properly subsumed by *ni-* (and *ha-*). Accordingly, the rule for *ni-* will be expanded as in (21a). Similarly, in a first iteration, *ha-* will be specialised as in (21b).

(21) a. $\begin{bmatrix} \textsc{mud}\ \boxed{1}\left\{\begin{bmatrix} subj \\ \textsc{per}\ \ 1 \\ \textsc{num}\ sg \end{bmatrix}\right\} \\ \textsc{ms}\ \ \boxed{1} \cup set \wedge \neg \{neg, \ldots\} \\ \textsc{mph}\ \left\langle\begin{bmatrix} \textsc{ph}\ \langle \text{ni} \rangle \\ \textsc{pc}\ \ 2 \end{bmatrix}\right\rangle \end{bmatrix}$ b. $\begin{bmatrix} \textsc{mud}\ \boxed{1}\ \{neg\} \\ \textsc{ms}\ \ \boxed{1} \cup set \wedge \neg \left\{\begin{bmatrix} subj \\ \textsc{per}\ \ 1 \\ \textsc{num}\ sg \end{bmatrix}, \ldots\right\} \\ \textsc{mph}\ \left\langle\begin{bmatrix} \textsc{ph}\ \langle \text{ha} \rangle \\ \textsc{pc}\ \ 1 \end{bmatrix}\right\rangle \end{bmatrix}$

However, *ha-* (20a) has another competitor, namely negative relative *si-* (20d): while in this case the MUD values are equally informative, the rules differ in terms of their MS descriptions, with *si-* being conditioned on relative and *ha-* being unconditioned. Expansion by Pāṇinian competition will add another existential constraint to (21b). The fully expanded entry is given in (22).

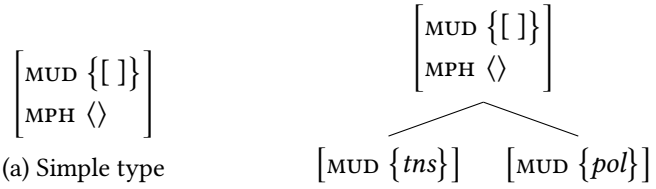
(22) $\begin{bmatrix} \textsc{mud}\ \boxed{1}\ \{neg\} \\ \textsc{ms}\ \ \boxed{1} \cup set \wedge \neg \left\{\begin{bmatrix} subj \\ \textsc{per}\ \ 1 \\ \textsc{num}\ sg \end{bmatrix}, \ldots\right\} \wedge \neg \{rel, \ldots\} \\ \textsc{mph}\ \left\langle\begin{bmatrix} \textsc{ph}\ \langle \text{ha} \rangle \\ \textsc{pc}\ \ 1 \end{bmatrix}\right\rangle \end{bmatrix}$

A common case of default realisation is zero exponence: as illustrated by the German nominal paradigms in Table 21.1, only a small number of the cells feature overt exponents. For example in the paradigm of *Oma* 'granny' (Table 21.1a),

[10] IbM uses the notation *m..n* to represent spans of position classes. See Bonami & Crysmann (2013) for a proposal of how spans can be made explicit.

singular number is solely expressed by the significant absence of any exponents. Particularly relevant to the case of default zero realisation are the paradigms exhibiting a Pāṇinian split, e.g. that of *Rechner* 'computer': here, only two cells are actually marked with a specific exponent (genitive singular and dative plural), all others are zero-marked and receive their interpretation by means of paradigmatic contrast. In order to allow for the possibility of zero realisation and to lend it the status of an ultimate default in the absence of any overt realisation, realisational approaches such as AM and PFM assume that every rule block returns an unmodified base, unless preempted by a more specific rule. In PFM, this property is ensured by the Identity Function Default (IFD) (Stump 2001: 53). Having a default principle, such as the IFD, is economical in that it saves restating the identity function for every rule block. On the downside, the IFD as a meta-level default will always be able to apply, possibly making an account of gaps in paradigms more difficult. In IbM, zero exponence is captured by providing rule types that contribute an empty list of morphs, as shown in Figure 7 below. With an underspecified MUD value, such a rule type may act as a default realisation.

One assertion that has been made repeatedly in IbM work concerns default zero exponence, the thesis being that there is need for only a single instance. The current formulation of Pāṇini's principle works as desired within an inflectional dimension, e.g. tense or polarity, but not for a rule that has a fully underspecified MUD element, since such a rule would only be applicable if neither tense nor polarity had a non-default value. The rule for zero exponence suggested in Crysmann & Bonami (2016), for example, realises a property (one underspecified element on MUD) without contributing any morph, as shown in Figure 7.



(a) Simple type

(b) Simple type with more specific subtypes

Figure 7: Default zero realisation

A simple solution is to provide subtypes of the ultimate default for every inflectional dimension that witnesses zero exponence: the rule type in Figure 7a, for instance, could be specialised by adding appropriate subtypes, e.g. for tense and polarity, as in Figure 7b. While this is slightly less general than what might

have been hoped for, the finer control that this move provides is independently required to strike the right analytical balance between zero exponence as a fall-back strategy and the existence of defectiveness, i.e. gaps in paradigms.[11]

Having seen how Pāṇinian competition can be made explicit, we shall briefly have a look at how this global principle interacts with multiple and overlapping exponence.

Let us start with overlapping exponence, which is much more common than pure multiple exponence. As witnessed by the Swahili examples in (23) and (24), the regular exponent of negation combines with tense markers for past and future. However, while the exponent for future is constant across affirmative and negative (23), the negative past marker *ku-* in (24) displays overlapping exponence.

(23) a. tu- ta- taka
1PL FUT want
'we will want'

b. ha- tu- ta- taka
NEG 1PL FUT want
'we will not want'

(24) a. tu- li- taka
1PL PST want
'we wanted'

b. *(ha-) tu- ku- taka
NEG 1PL PST.NEG want
'we did not want'

There are, in principle, two ways to picture cases of overlapping exponence as in (24b): either *ku-* is regarded as cumulation of negative and past, or else it is an exponent of past, allomorphically conditioned by the negative. Following Carstairs (1987), IbM embraces a notion of inflectional allomorphy by way of distinguishing between expression of a feature and conditioning by some feature.

[11] Alternatively, this expansion could be inferred from the grammar, based on declarations of appropriate morpho-syntactic property sets (MS values). All it takes is to expand, prior to Pāṇinian inference, any leaf rule type by intersecting its MUD value with the value of the appropriateness function for MS. See Diaz et al. (2019) for an example of such a declaration. As a result, fully underspecified MUD values will be expanded into the minimal types appropriate for each dimension of the paradigm, yielding an expanded hierarchy of rule types as in Figure 7b that will give sound results under Pāṇinian competition.

(25) a. $\begin{bmatrix} \textsc{mud} & \{past\} \\ \textsc{mph} & \left\langle \begin{bmatrix} \textsc{ph} & li \\ \textsc{pc} & 3 \end{bmatrix} \right\rangle \end{bmatrix}$

b. $\begin{bmatrix} \textsc{mud} & \{past\} \\ \textsc{ms} & \{neg\} \cup set \\ \textsc{mph} & \left\langle \begin{bmatrix} \textsc{ph} & ku \\ \textsc{pc} & 3 \end{bmatrix} \right\rangle \end{bmatrix}$

We can provide rules for the two past markers as given in (25), where *ku-* is additionally conditioned on the presence of *neg* in the morphosyntactic property set (MS). While these two rules stand in Pāṇinian competition with each other, rule (25b) is crucially no competitor for the regular negative marker *ha-*, since the MUD sets of (25b) and (21a) are actually disjoint. Thus, by embracing a distinction between expression and conditioning, overlapping exponence behaves as expected with respect to Pāṇini's principle.

Pure multiple exponence works somewhat differently from overlapping exponence: in Nyanja (Stump 2001; Crysmann 2017a), class B adjectives, such as *kulu* 'large' in (26a) take two class markers to mark agreement with the head noun, one set of markers being the one normally used with class A adjectives, such as *bwino* 'good' in (26b), the other being attested with verbs, such as *kula* 'grow' (26c). Both sets distinguish the same properties, i.e. nominal class.[12]

(26) a. ci-pewa ca-ci-kulu
CL7-hat(7/8) QUAL7-CONC7-large
'a large hat'

b. ci-manga ca-bwino
CL7-maize QUAL7-good
'good maize'

c. ci-lombo ci-kula.
CL7-weed CONC7-grow
'A weed grows.'

Crysmann (2017a) shows that double inflection as in Nyanja can be captured by composing rules of exponence for verbs and type A adjectives to yield the complex rules for type B adjectives, as shown in Figure 8.

The difference in treatment for overlapping and pure multiple exponence of course raises the question whether or not the approaches should be harmonised.

[12]The examples in (26) are taken from Stump (2001: 6).

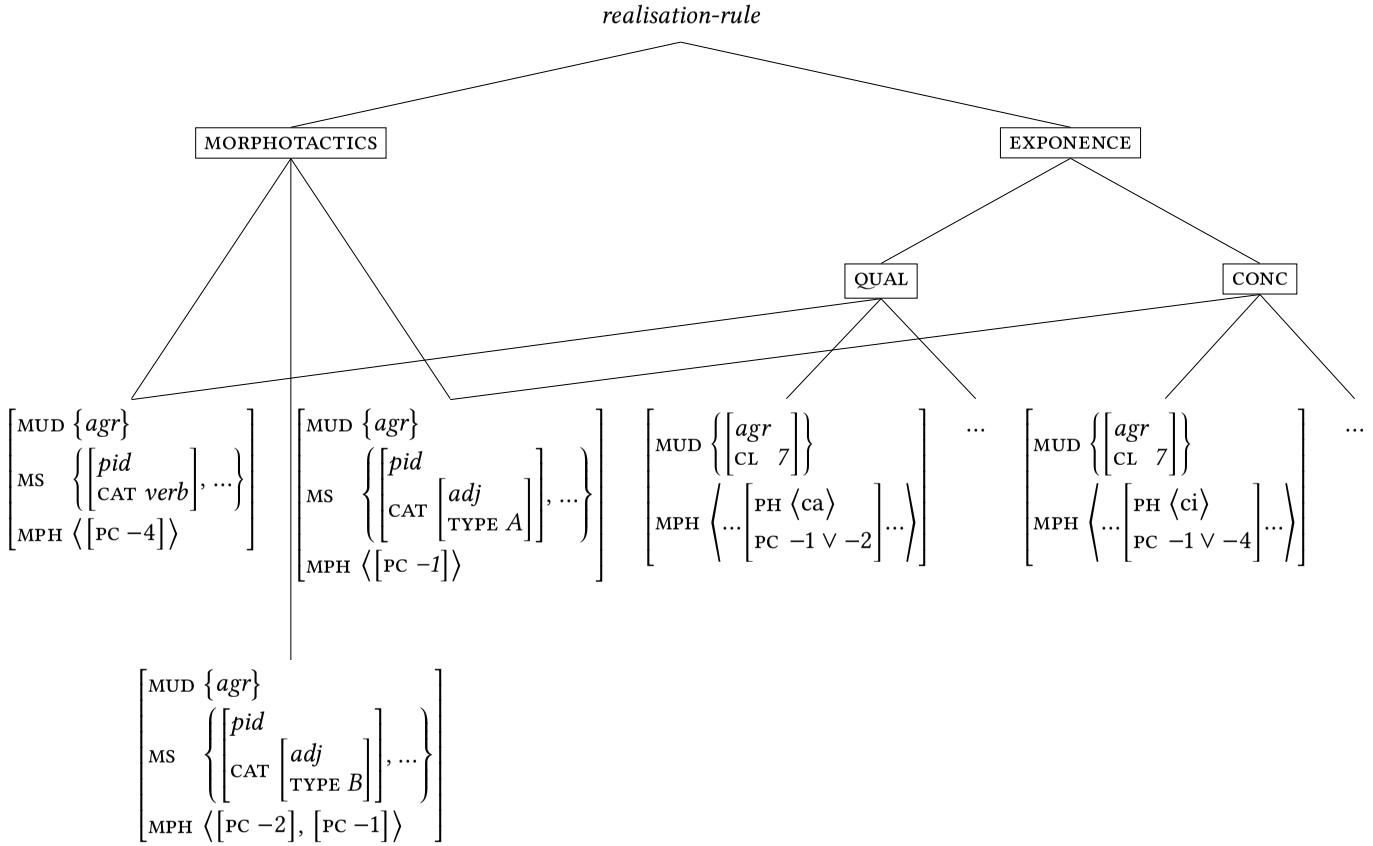


Figure 8: Nyanja pre-prefixation (Crysmann 2017a: 210)

The only way to do this would be to generalise the Nyanja case to overlapping exponence, by way of treating all such cases by means of composing rules. While possible in general, there is a clear downside to such a move: as we saw in the discussion of Swahili above, there is not only a dependency between negative and past tense, but also between negative *si-* and relative marking. As a result, one would end up organising negation, tense and relative marking into a single cross-cutting multi-dimensional type hierarchy. Inflectional allomorphy by contrast supports a much more modularised perspective which greatly simplifies specification of the grammar.

4.4 Morphotactics

The treatment of morphotactically complex systems, as found in e.g. position class systems, was one of the major motivations behind the development of IbM. With the aim of providing a formal model of complex morph ordering that matches the parsimony of the traditional descriptive template, Crysmann & Bonami (2016) discarded the cascaded rule model adopted by e.g. PFM (Stump 2001).[13] Instead, order is directly represented as a property of exponents.

Taking as a starting point the classical challenges from Stump (1993) – portmanteau, ambifixal, reversed, and parallel position classes –, they developed an extended typology of variable morphotactics, i.e. systems, which depart from the kind of rigid ordering more commonly found in morphological systems.

Table 21.5: Masculine singular forms of the Nepali verb BIRSANU 'forget'

	PRESENT	FUTURE
1	birsã-**tʃʰa**-*aũ*	birse-*aũ*-**lā**
2.LOW	birsã-**tʃʰa**-*s*	birse-**lā**-*s*
2.MID	birsã-**tʃʰa**	birse-**lā**
3.LOW	birsã-**tʃʰa**-*au*	birse-*au*-**lā**
3.MID	birsã-**tʃʰa**-*n*	birse-**lā**-*n*

One of the most simple deviations from strict and invariable ordering is misaligned placement: while exponents that mark alternative values for the same feature and therefore stand in paradigmatic opposition tend to occur in the same position, this is not always the case, as illustrated by the example from Nepali in Table 21.5. While the agreement markers (in italics) follow the tense marker

[13] Crysmann & Bonami (2012) was a conservative extension of PFM with reified position class indices, an approach that was rendered obsolete by subsequent work.

(bold) in the present, the relative order of tense and agreement marker differs from cell to cell in the future (LOW and MID constitute different levels in the system of honorifics).

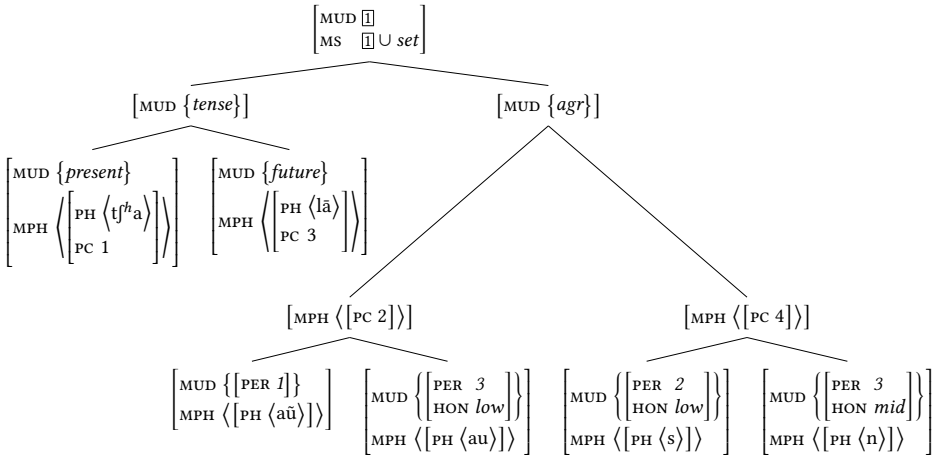


Figure 9: Nepali tense and agreement marking

If position class indices are part of the descriptive inventory, an account of apparently reversed position classes (Stump 1993) becomes almost trivial, as shown in Figure 9: all it takes is to assign the present marker an index that precedes all agreement markers and assign the future marker an index that precedes some agreement markers, but not others.

A slightly more complex case is conditioned placement: in contrast to misaligned placement, assignment of position does not just depend on the properties expressed by the marker itself, but on some additional property. An example of this is Swahili "ambifixal" relative marking, as shown in examples (27)–(28).[14] In the affirmative indefinite tense, the relative marker is realised in a position after the stem, whereas in all other cases it precedes it.

(27) a. a-soma-*ye* (Swahili)
M/WA.SG-read-M/WA.SG.REL
'(person) who reads'

b. a-ki-soma-*cho*
M/WA.SG-KI/VI.SG.O-read-KI/VI.SG.REL
'(book) which he reads'

[14] Conditioned placement is not only attested on alternate sides of the stem, as discussed for Swahili in Stump (1993), but also on the same side. See the discussion of mesoclisis in European Portuguese in Crysmann & Bonami (2016).

(28) a. a-na-*ye*-soma (Swahili)
M/WA.SG-PRES-M/WA.SG.REL-read
'(person) who is reading'
b. a-na-*cho*-ki-soma
M/WA.SG-PRES-KI/VI.REL-KI/VI.SG.O-read
'(book) which he is reading'

Conditioned placement can be captured using a two-dimensional hierarchy, as shown in Figure 10: the MORPHOTACTICS dimension on the left defines the conditions for the corresponding placement constraints, whereas the EXPONENCE dimension provides the constraints on the shape of the 16 relative class markers that undergo the alternation. Cross-classification by means of Online Type Construction finally distributes the morphotactic constraints over the rules of exponence.

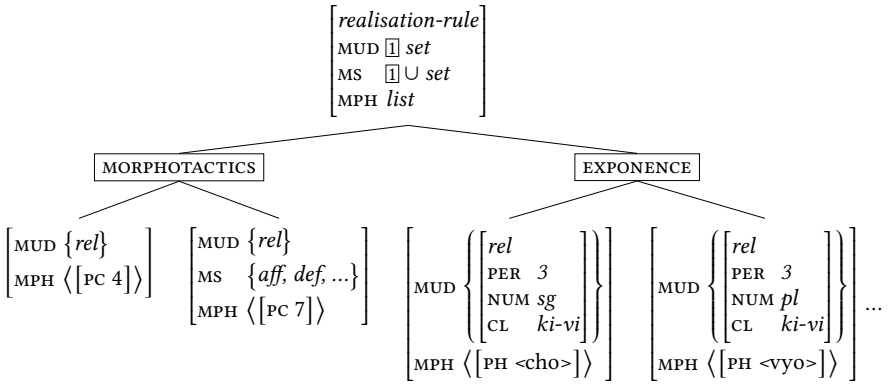


Figure 10: Swahili relative markers

The last basic type of variable morphotactics is free placement, i.e. free permutation of a circumscribed number of markers. This is attested e.g. in Chintang (Bickel et al. 2007) and in Mari (Luutonen 1997).

While markers of core cases follow the possessive marker, and exponents of the lative cases precede it, the dative marker permits both relative orders. Free permutation appears to present a challenge for cascaded rule models, such as PFM, whereas an analysis is almost trivial in IbM, as position can be underspecified.

Relative placement

Inflectional morphology does not provide much evidence for internal structure. This is recognised in IbM by representing morphs on a flat list with simple posi-

Table 21.6: Selected singular forms of the Mari noun *pört* 'house'

	ABSOLUTE	1PL POSSESSED	
		POSS ≺ CASE	CASE ≺ POSS
NOM	pört	pört-**na**	
GEN	pört-*ən*	pört-**na**-*n*	*
ACC	pört-*əm*	pört-**na**-*m*	*
DAT	pört-*lan*	pört-**na**-*lan*	pört-*lan*-**na**
LAT	pört-*eš*	*	pört-*eš*-**na**
ILL	pört-*əš(kö)*	*	pört-*əškə*-**na**

tion class indices. While a simple indexing by absolute position is often sufficient, there are cases where a more sophisticated indexing scheme is called for.

Crysmann & Bonami (2016) discuss placement of pronominal affix clusters in Italian. While placement is constant within the cluster of pronominal affixes itself, *me-lo-* in the example below, as well as between stem and tense and agreement affixes, the linearisation of the cluster as a whole is variable, as shown by the alternation between indicative and imperative in (29).

(29) a. me- lo- da -te (Itialian)
DAT.1SG ACC.3SG.M give[PRS] 2PL
'You give it to me.'

b. da -te -me -lo!
give[IMP] 2PL DAT.1SG ACC.3SG.M
'Give it to me!'

An important question raised by the Italian facts is whether morphotactics is in need of a more layered structure. If so, it will certainly not be the kind of structure provided by stem-centric cascaded rule approaches, like PFM, since it is the cluster that alternates between pre-stem and post-stem position, not the individual cluster members, which would yield mirroring.[15]

Crysmann & Bonami (2016) assume that it is the stem which is mobile in Italian and takes the exponents of tense and subject agreement along. To implement this, they show that it is sufficient to expose the positional index of the stem (the feature STM-PC in Figure 11), such that other markers can be placed relative to this pivot (cf. the agreement rule in Figure 12).

Compared to a layered structure, the pivot feature approach just described appears to be more versatile, since it provides a suitable solution to other cases

[15]See, however, Spencer (2005) for a variant of PFM that directly composes clusters.

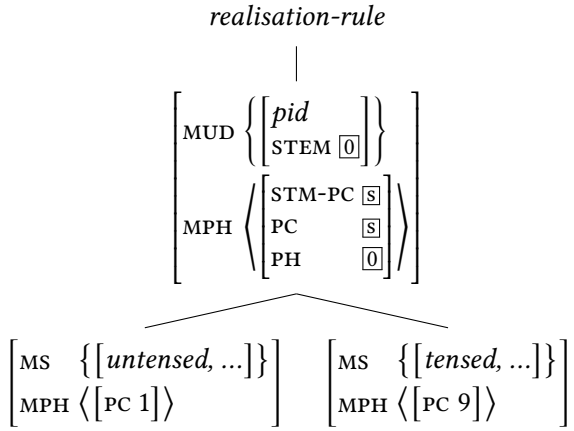


Figure 11: Partial hierarchy of Italian stem realisation rules

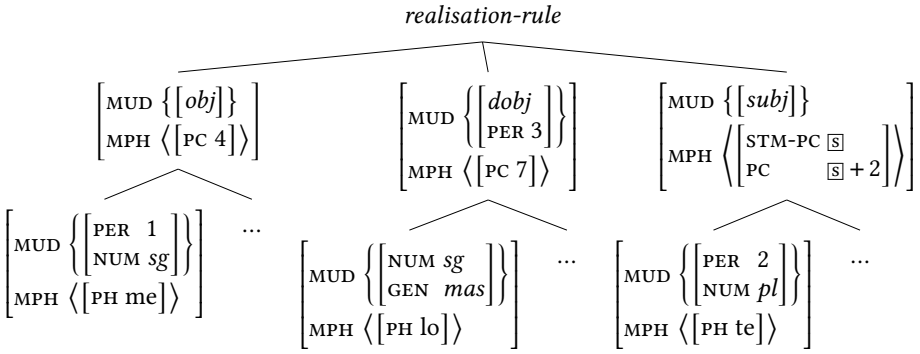


Figure 12: Partial hierarchy of Italian affixal realisation rules

of relative placement, such as second position affixes. Sorani Kurdish endoclitic agreement markers surface after the initial morph, be it the stem, or some prefixal marker (Samvelian 2007). Thus, placement is relative to whatever happens to be the first *instantiated* position index.

Bonami & Crysmann (2013) propose a pivot feature 1ST-PC that is instantiated to the position class index of the first element on the word's MPH list and exposed on all other morphs by the principle in (30).

(30) $word \Rightarrow \left[\text{INFL} \left[\text{MPH} \left\langle \left[\begin{array}{ll}\text{PC} & \boxed{1}\\ \text{1ST-PC} & \boxed{1}\\ \text{STM-PC} & \boxed{\text{S}}\end{array}\right], \left[\begin{array}{ll}\text{1ST-PC} & \boxed{1}\\ \text{STM-PC} & \boxed{\text{S}}\end{array}\right], \ldots, \left[\begin{array}{ll}\text{1ST-PC} & \boxed{1}\\ \text{STM-PC} & \boxed{\text{S}}\end{array}\right] \right\rangle\right]\right]$

Table 21.7: Sorani Kurdish past person markers

1 NEG	2	3 IPFV	4	5 'send'	6	7 3PL	
				nard	**=jân**	im	'they sent me'
na	**=jân**			nard		im	'they did not send me'
		da	**=jân**	nard		im	'they were sending me'
na	**=jân**	da		nard		im	'they were not sending me'

What this principle does is distribute two critical position class indices over every element of the MPH list: one for the position of the stem, in order to capture stem-relative vs. absolute placement as in Italian, the other for the lowest instantiated position class index, to capture second position phenomena.

The realisation rule for a second position clitic can then be formulated as in (31), determining its PC value relative to that of the word's first morph. I use an arithmetic operator here as a convenient shortcut, but note that indices are actually represented as lists underlyingly (Bonami & Crysmann 2013).

(31)
$$\begin{bmatrix} \textsc{mud} \left\langle \begin{bmatrix} \textsc{per} & 3 \\ \textsc{num} & pl \end{bmatrix} \right\rangle \\ \textsc{mph} \left\langle \begin{bmatrix} \textsc{ph} & \langle \text{jân} \rangle \\ \textsc{1st-pc} & \boxed{1} \\ \textsc{pc} & \boxed{1}+1 \end{bmatrix} \right\rangle \end{bmatrix}$$

For illustration, consider the two word forms *nard=jân-im* 'they sent me' and *da=jân-nard-im* 'they were sending me' from Table 21.7. The first one consists of two positionally fixed morphs, the stem in position 5 and the person ending in position 7. According to (30), 1ST-PC will be token identical to the PC of *nard*, so *=jân* will be assigned a PC value of 6. The second example *da=jân-nard-im* has the additional progressive prefix *da-* in position 3, which is the lowest PC index of the word. Accordingly *=jân* is placed relative to the prefix *da-*, in position 4.

To conclude the section, a more general remark is in order: as we have seen, IbM uses explicit position indices to constrain morphotactic position. In essence, these correspond to linear distribution classes, where higher indices are realised to the right of lower indices and no two morphs within a word may bear the same index, resulting in competition for linear position. As a consequence, there is no static notion of a slot: while morphs are ordered according to indices, there

is no requirement for indices to be consecutive. Thus, nothing much needs to be said about empty slots, except that there happens to be no morph in the word with that particular positional index.

4.5 Constructional vs. generative views

IbM departs from previous, purely word-based approaches, such as Blevins (2016) or, within HPSG, Koenig (1999: Section 5.2.2) by recognising an intermediate level of realisation rules that effects the actual $m : n$ relations between form and function. In this section, I shall discuss how this facilitates partial generalisations over gestalt exponence, provides for a better reuse of resources, as witnessed by parallel inflection, and finally ensures a modular organisation of rules of exponence.

4.5.1 Gestalt exponence

One of the strongest arguments for the word-based view and against a generative rule-based approach comes from so-called gestalt exponence in Estonian (Blevins 2005). As shown in Table 21.8, core cases in this language give rise to case/number paradigms where (almost) all cells are properly distinguished by clearly segmentable markers, yet there is no straightforward association between the markers and the properties they express.

Table 21.8: Partial paradigms exemplifying three Estonian noun declensions (core cases; Blevins et al. 2016: 287)

nokk 'beak'

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

õpik 'workbook'

	SG	PL
NOM	õpik	õpik-u-d
GEN	õpik-u	õpik-u-te
PART	õpik-u-t	õpik-u-id

seminar 'seminar'

	SG	PL
NOM	seminar	seminar-i-d
GEN	seminar-i	seminar-i-de
PART	seminar-i	seminar-i-sid

The gestalt nature of Estonian case/number marking can be schematised as in Figure 13.

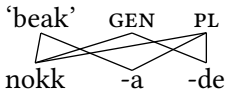


Figure 13: *m*:*n* relations in Estonian

While it is clear that this kind of complex association between form and function requires a constructional perspective, it is far from evident that (i) this association has to be made at the level of the word rather than at the level of $m : n$ rules and (ii) that this therefore requires word-to-word correspondences in the sense of Blevins (2005; 2016).[16] To the contrary, the system depicted in Table 21.8 displays partial generalisations that are hard to capture in a system such as Blevins': e.g. theme vowels are found in all cells except the nominative singular, only the nominative singular is monomorphic, all plural forms are tri-morphic, to name just a few.

In IbM, $m : n$ correspondences are established at the level of realisation rules, and these realisation rules are organised into (cross-classifying) type hierarchies. Crysmann & Bonami (2017) argue that this makes it possible to extract the kind of partial generalisation noted in the previous paragraph and represent them in a three-dimensional type hierarchy that specifies constraints on stem selection independently of theme-vowel introduction and suffixation. Using pre-typing, idiosyncratic aspects can be contained, while more regular aspects, such as theme vowel and stem selection, are taken care of by Online Type Construction.

Furthermore, encapsulating gestalt exponence as a subsystem of realisation rules has the added advantage that it does not spill over into the rest of the Estonian inflection system, which, as a Finno-Ugric language, is highly agglutinative.

Composing complex pairings of morphological forms and functions by means of cross-classification of partial rule descriptions is not only beneficial to the treatment of gestalt exponence, but also lends itself more generally to capturing syntagmatic dependencies between exponents: see Crysmann (2021) for dependent agreement markers in Batsbi, and Crysmann (2020) for discontinuous morphotactic dependencies in Yimas.

While it is straightforward to implement constructional analyses within IbM, involving complex $m : n$ relations between form and function, non-constructional analyses are actually preferred whenever possible, generally yielding much more parsimonious descriptions.

[16] See also Guzmán Naranjo (2019) for a formalisation of word-based morphology in HPSG.

4.5.2 Reuse of resources

Reuse of resources constitutes a particularly strong argument against over-generalising to the constructional, or word-based, view: parallel position classes are a case at hand, as exemplified in Swahili (Stump 1993; Crysmann & Bonami 2016) or Choctaw (Broadwell 2017).

Table 21.9: Swahili person markers (Stump 1993: 143)

PER	GEN	SUBJECT		OBJECT	
		SG	PL	SG	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	—

Consider the paradigms of Swahili subject and object agreement markers in Table 21.9: as one can easily establish, agreement markers draw largely on the same set of shapes. Grammatical function is disambiguated mainly by position, with subject agreement placed to the left of tense markers, and object agreement to the right.

Under a constructional approach, such as the word-based analysis in Koenig (1999), the generalisation about identity of shapes is essentially lost, which is due to the fact that under this view, markers that can potentially combine must be introduced in different cross-classifying dimensions, e.g. one for subject marking in slot 2, the other for object marking in slot 5. Likewise, in order to distribute shape constraints over subject and object agreement, they must constitute yet another cross-cutting dimension, but there is simply no way in this set-up to enforce that every shape constraint must be evaluated twice.

However, once we move from word-based statements to realisation rules, the problem simply vanishes, since we are not trying to solve the problems of parallelism of exponence and combination at the same time. As illustrated in Figure 14, constraints about shape can be straightforwardly distributed over realisation rules for subject and object agreement (which are types), because their

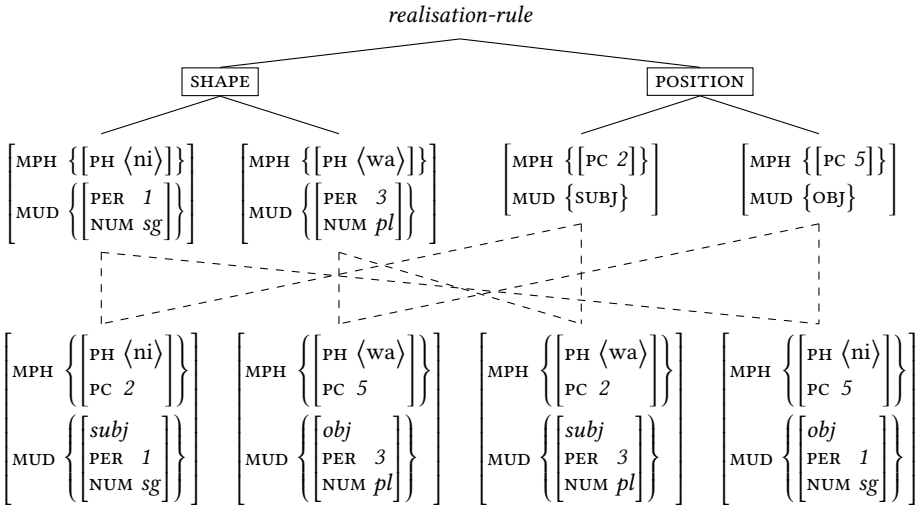


Figure 14: Rule type hierarchy for Swahili parallel position classes (Crysmann & Bonami 2016: 356)

combination is effectively factored out. Thus, by abstracting over rules instead of words, generalisation regarding parallel sets of exponents can be captured quite easily. Sharing of resources is in fact a more general problem that tends to get overlooked by radically word-based approaches such as Blevins (2016).

4.5.3 Modularity

The final argument for combining constructional or holistic with generative or atomistic views is that it provides for a divide and conquer approach to complex inflectional systems.

Diaz et al. (2019) discuss the pre-pronominal affix cluster in Oneida, an Iroquoian language. Oneida presents us with what is probably the most complex morphotactic system that has been described so far within IbM.

Oneida is a highly polysynthetic language. According to Diaz et al. (2019), the prefixal inflectional system alone comprises seven position classes in which up to eight non-modal and three modal categories can be expressed (cf. Table 21.10). Given the number of categories and positions alone, it comes at no surprise that the system is characterised by heavy competition. Adding to the complexity, several markers undergo complex interactions, even between non-adjacent slots. Finally, Oneida pre-pronominal prefixes also display variable morphotactics: the

factual, for instance, appears in four different surface positions, and the optative in three. Moreover, we find paradigmatic misalignment (cf. the discussion of Nepali above), with the cislocative in a different surface position from the translocative.

Table 21.10: Position classes of Oneida inflectional prefixes (Diaz et al. 2019: 435)

1	2	3	4	5	6	7	8
Negative Contrastive Coincidental Partitive	Translocative Factual	Dualic	Factual Optative Future	Cislocative Repetitive	Factual Optative	Pronominal Factual Optative	Stem

Diaz et al. (2019) discuss three different types of interaction within the system: (i) positional competition, exhibited in slot 1 (negative, contrastive, coincidental, partitive) and slot 5 (cislocative, repetitive); (ii) borrowing, a particular case of extended exponence exhibited in slot 2 (translocative borrowing vowels from the future and factual); and (iii) sharing, witnessed by the factual and the optative, which are distributed across different positions. Cross-cutting these subsystems, we find a great level of contextual inflectional allomorphy.

Diaz et al. (2019) contain the complexity of the system by building on several key notions, the first three of which are integral parts of IbM: first, the fact that IbM recognises $m : n$ relations at the rule level make it possible to approach the Oneida system in a more modular fashion, carving out four independent subsystems for competition (slot 1 and slot 5), borrowing (slot 2), and sharing (factual). Second, they draw on the distinction between realisation (MUD) and conditioning MS to abstract out inflectional allomorphy. Third, they capture discontinuous exponence of the factual and optative in terms of Koenig/Jurafsky style cross-classification in order to derive complex discontinuous rules.

The two innovative aspects of their analysis concern the treatment of competition and an abstraction over morphosyntactic properties in terms of syntagmatic classes. Oneida resolves morphotactic competition of semantically compatible features (slots 1 and 5) by means of a markedness hierarchy: features that are outranked on this hierarchy are optionally interpreted if the exponent of a higher feature is present. For example the negative outranks the partitive, so if the negative marker is present, it can be interpreted as negative or negative and partitive. If, by contrast, the partitive marker is found, the negative cannot be understood. Diaz et al. (2019) approach this by modelling the ranking in terms of a type hierarchy upon which realisation rules can draw. Their second innovation, i.e. the

segregation of morphosemantic properties according to the positional properties of their exponents into e.g. inner or outer types, has enabled them to give a much more concise representation of allomorphy that can abstract over strata of positions.

The combination of design properties of IbM with their two innovations have permitted Diaz et al. (2019) to provide an explicit and surprisingly concise analysis of an extremely complex system: in essence, their highly modular analysis (with only 36 rules) reduces the number of allomorphs by a factor of ten.

In sum, having $m : n$ relations at the most basic level of realisation rules means that constructional views can be implemented at any level of granularity, combining reuse and recombination, as favoured by an atomistic (generative) view, with the holistic (constructional) view necessitated by discontinuous or gestalt exponence. To quote Diaz et al. (2019), "IbM's approach to morphology [...] is something unification-based approaches to syntax have stressed for the last forty-years or so". In addition to the model-theoretic aspect they capitalise on, the similarity of IbM to current HPSG syntax also pertains to the fact that both integrate lexicalist and constructional views.

5 Conclusion

This chapter has provided an overview of HPSG work in two core areas of morphology, namely derivation and inflection. The focus of this paper was biased to some degree towards inflection, for two reasons: on the one hand, a handbook article that provides a more balanced representation of derivational and inflectional work in constraint-based grammar was published quite recently (Bonami & Crysmann 2016), while on the other, a comprehensive introduction to recent developments within HPSG inflectional morphology was still missing.

In the area of derivation and grammatical function change, a consensus was reached relatively early, toward the end of the last century, with the works of Riehemann (1998) and Koenig 1999: within HPSG, it is now clearly understood that lexical rules are description-level devices organised into cross-cutting inheritance type hierarchies. One of the distinctive advantages of these approaches is the possibility to capture regular, subregular, and irregular formations using a single unified formal framework, namely partial descriptions of typed feature structures. Beyond HPSG, these works have influenced the development of Construction Morphology (Booij 2010).[17]

[17]See Müller (2021b), Chapter 32 of this volume for a comparison of HPSG with Construction

Much more recently, a consensus model seems to have arrived for the treatment of inflectional morphology. Information-based Morphology (Crysmann & Bonami 2016; Crysmann 2017a) builds on previous work on inflectional morphology in HPSG (Bonami), Online Type Construction (Koenig 1999), morph-based morphology (Crysmann 2003), and finally unification-based approaches to Pāṇini's principle (Andrews 1990; Erjavec 1994; Koenig 1999) to provide an inferential-realisational theory of morphology that exploits the same logic as HPSG, namely typed feature structure inheritance networks to capture linguistic generalisations. Furthermore, like its syntactic parent, it permits to strike a balance between lexicalist and constructional views. By recognising $m : n$ relations between function and form at the most basic level, i.e. realisation rules, morphological generalisations are uniformly captured in terms of partial rule descriptions.

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