Chapter 22

Morphology

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Berthold: Yes, we need an abstract. Please put one here.

1 Introduction

Lexicalist approaches to grammar, such as HPSG, typically combine a fairly general syntactic component with a rich and articulate lexicon. While this provides 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. This problem is known as lexical redundancy.

Lexical redundancy comes in essentially two ways: vertical redundancy and horizontal redundancy. Vertical redundancy arises due to the fact that 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 linking patterns. From its outset, HPSG successfully eliminates vertical redundancy by means of multiple inheritance networks over typed feature structures.

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, classical instances of grammatical function change, such as passives, applicatives or causatives. The crucial difference with respect to vertical redundancy is that we are are not confronted what is essentially a classificational problem, assigning lexical entries to a more general class and inheriting its properties, but rather a relation between lexical entries.

Berthold Crysmann. 2019. Morphology. In Stefan Müller, Anne Abeillé, Robert D. Borsley & Jean-Pierre Koenig (eds.), *Head-Driven Phrase Structure Grammar: The handbook*. Prepublished version. Berlin: Language Science Press. [Preliminary page numbering]

Most importantly, morphological processes, both in word formation and inflection, crucially involve this latter type of redundancy: e.g. 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. In inflection, change in morpho-syntactic properties, e.g. case or agreement marking, I.e. the generalisation to be captured is about the contrast of form and morpho-syntactic properties between fully inflected words.

Following Bresnan (1982b), the classical way to attack the issue of horizontal redundancy in HPSG is by lexical rule. Early HPSG followed Bresnan's original conception of lexical rules as mappings between lexical items. To some 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. As such, they are amenable to the same underspecification techniques that are used to generalise across classes of basic lexical items.

Tour of the chapter

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 finally 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 (3.1) and rehearse how the different types of inflectional theories (IA, IP, WP) fare with respect to these basic challenges (3.2). Against this backdrop, I shall discuss previous work on inflection in HPSG (3.3).

Section 4 will be consecrated to an introduction of Information-based Morphology, a recently developed companion framework of HPSG for inflectional morphology.

2 Inheritance-based approaches to derivational morphology

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,

[1] Cf. also the work by Meurers (1995; 2002), providing a formal description-level formalisation of lexical rules, as standardly used in HPSG.

as conceived of at the time, remove 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 can be recursive: 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 to model derivation by means of morphological rule schemata, which are underspecified descriptions of complex lexemes, and integrate 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. Concrete derivational rule schemata will then inherit from these super-types. What this amounts to is that different sub-classes 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.

2.1 Riehemann (1998)

The work of Riehemann (1998) takes its starting point based on the previous proposal by 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 strictly transitive verbs and introduce both modality and a passivisation effect, there is a a broader class of similar formations which adhere to some of the properties, but not others.

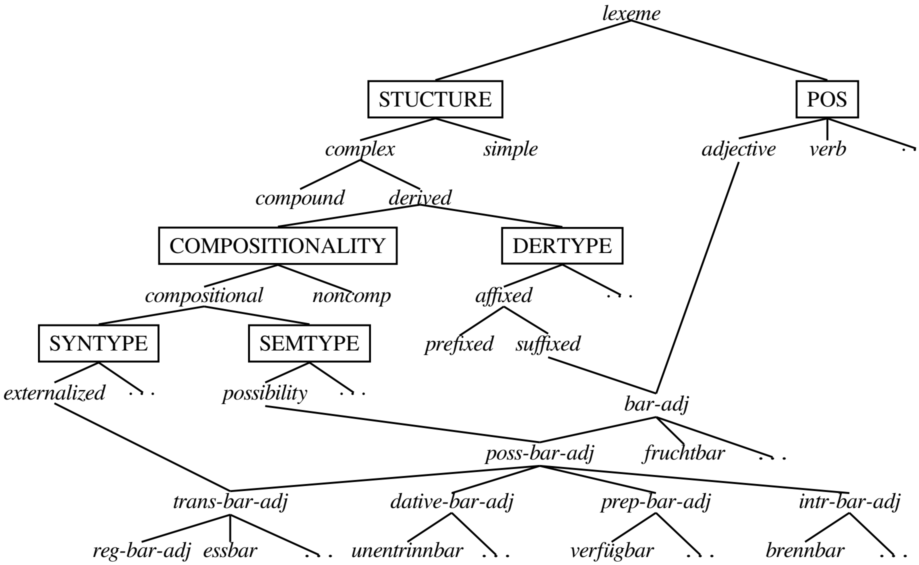

Figure 1: Riehemann's type hierarchy of German *-bar* derivation

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 individual subclasses may inherit.

Figure 1 provides the extended hierarchy suggested by Riehemann (1998). The type for regular *-bar* adjectives given in (4) is treated as a specific subtype that inherits inter alia from more general supertypes that capture the salient properties that characterise the regular formation, but which also hold to some extent for subregular *-bar* adjectives.

One property that is almost trivial concerns suffixation of *-bar*, and it holds for the entire class.

(1) $$\begin{bmatrix} \textit{suffixed} & \\ \text{PH} & \boxed{1} \oplus \textit{list} \\ \text{MORPH-B} & \left\langle \begin{bmatrix} \text{PH} & \boxed{1} \end{bmatrix} \right\rangle \end{bmatrix}$$

A property which is common to most *-bar* adjectives in German is that they denote "possibility".

(2) $$\begin{bmatrix} \textit{possibility} & \\ \textsc{ss}|\textsc{l}|\textsc{cont}|\textsc{nuc}|\textsc{reln} & \diamond \end{bmatrix}$$

Clearly more specific is the passivisation effect observed with transitive bases.

(3) $$\begin{bmatrix} \textit{externalised} & \\ \textsc{ss} & \begin{bmatrix} \textsc{l}|\textsc{cat}|\textsc{val}|\textsc{subj} & \left\langle \mathrm{NP}{:}\boxed{1} \right\rangle \end{bmatrix} \\ \textsc{morph-b} & \left\langle \begin{bmatrix} \textsc{ss}|\textsc{l}|\textsc{cat}|\textsc{val}|\textsc{comps} & \left\langle \mathrm{NP}[\textit{acc}]{:}\boxed{1}, \ldots \right\rangle \end{bmatrix} \right\rangle \end{bmatrix}$$

Regular *-bar* adjectives inherit from all these supertypes, which accounts for most of their properties, while at the same time capturing the relatedness to subregular formations.

(4) $$\begin{bmatrix} \textit{reg-bar-adj} & \\ \textsc{ph} & \boxed{1} + \textit{bar} \\ \textsc{morph-b} & \left\langle \begin{bmatrix} \textit{trans-verb} & \\ \textsc{ph} & \boxed{1} \\ \textsc{ss}|\textsc{l} & \begin{bmatrix} \textsc{cat}|\textsc{val}|\textsc{comps} \left\langle \mathrm{NP}[\textsc{acc}]{:}\boxed{2} \right\rangle \oplus \boxed{3} \end{bmatrix} \\ \textsc{cont}|\textsc{nuc} & \boxed{4} \begin{bmatrix} \textsc{act} & \textit{nom-obj} \\ \textsc{und} & \boxed{2} \end{bmatrix} \end{bmatrix} \right\rangle \\ \textsc{ss}|\textsc{loc} & \begin{bmatrix} \textsc{cat} & \begin{bmatrix} \textsc{hd} & \textit{adj} \\ \textsc{val} & \begin{bmatrix} \textsc{subj} & \left\langle \mathrm{NP}{:}\boxed{2} \right\rangle \\ \textsc{comps} & \boxed{3} \end{bmatrix} \end{bmatrix} \\ \textsc{cont}|\textsc{nuc} & \begin{bmatrix} \textsc{reln} & \diamond \\ \textsc{und} & \boxed{2} \\ \textsc{soa-arg} & \boxed{4} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

One aspect that Riehemann's approach does not capture as part of the grammar is the productivity of the regular pattern. Riehemann (1998) suggests that this could be accounted for by extra-grammatical properties, such as lexical frequency.

2.2 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 1994), 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 lexical, once cross-classification between types can be performed dynamically.

Online Type Construction (OTC) depends on a hierarchical lexicon that is organised into an AND/OR network of conjunctive dimensions and disjunctive types. While in a standard type hierarchy any two types that do not have a common subtype are understood as incompatible, OTC 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 OTC.

Let us briefly consider a simple example for the active/passive alternation: the minimal lexical type hierarchy 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.

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: e.g. in English, some transitive verbs, like possessive *have* fail to undergo passivisation. Rather than marking these diacritically by features, pre-typing to the active pattern precludes cross-classification with the passive pattern, since leaf types with a dimension are disjoint and pre-typing makes this type already a leaf type in both dimensions.

Online Type Construction successfully integrates systematic alternations into type hierarchies. A crucial limitation is, however, that OTC is confined to fi-

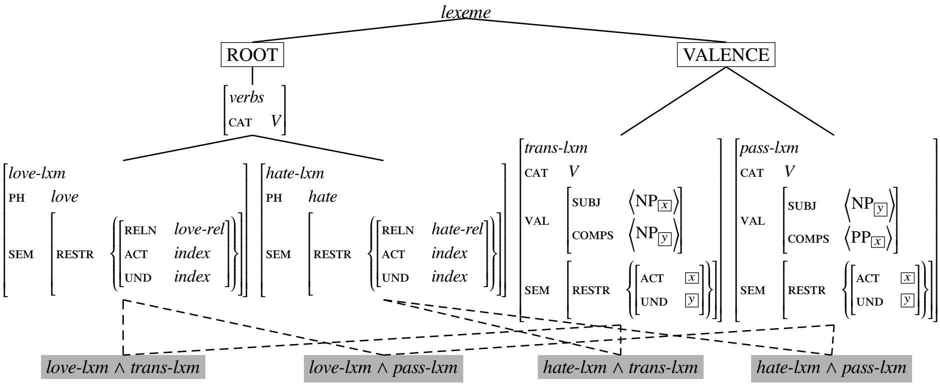

Figure 2: Online type construction

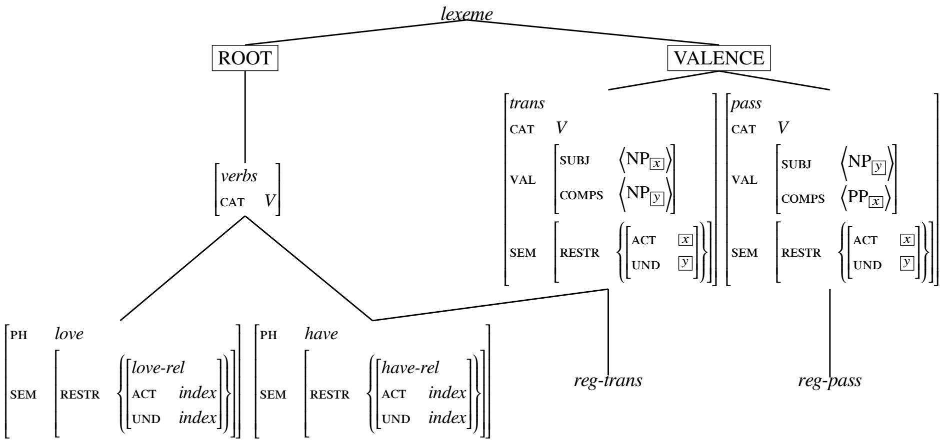

Figure 3: Exceptions via pre-typing

nite domains: by itself, it is suitable for inflection and quasi-inflectional, non-recursive processes as grammatical function change, while a full treatment of derivational processes will still require recursive rule types, which remains a possibility in Koenig's general approach to derivational morphology.

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 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 morpho-syntactic properties. An extreme example of cumulation is contributed by the Latin verb *am-o* 'love-1.S.PRS.IND.AV'.

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, whic marks certain adjectives with a combination of two agreement markers, as discussed on page xxviii in Section 4.3. See Caballero & Harris (2012); Harris (2017) for a typological overview.

Possibly more widely attested than pure multiple exponence is overlapping exponence: 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 *Mutter-n* 'nut-DAT.PL' merely shows cumulation of case and number, *Mütter-n* 'mother.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-syntactic properties do not give rise to any exponence. In German, nouns inflect for four cases and two numbers like, yielding eight cells. However, in some paradigms only very few cells are actually overtly marked. The feminine noun *Mutter* 'nut' does not take any inflectional markings except in the dative plural (*Mutter-n* 'nut-DAT.PL'). 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 on how the system is organised. One way to make sense of inflection is in terms of paradigmatic opposition: i.e. 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.S' and *Rechner-n* 'computer-DAT.PL'. This is even more the case, once we consider different paradigms, i.e. different patterns of opposition: e.g. the bare form *Mutter* 'nut' has a wider denotation than *Rechner* just because it stands in opposition to fewer forms.

The recognition of paradigms has led to 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.

Table 1: Paradigmatic splits

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

(a) Natural split

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

(b) Pāṇinian split

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

(c) Natural & Pāṇinian split

	SINGULAR	PLURAL
NOM	mur-s	mur
ACC	mur	mur-s

(d) Morphomic split (Old French)

In Table 1a, we find a perfect alignment of syncretic forms along the number dimension. By contrast, Figure 1b illustrates the case discusses above, where two specific cells constitute overrides to a general default pattern (here: zero exponence). Default forms need not involve zero exponence. German features a Pāṇinian split in another paradigm where all forms are marked with *-en* (e.g. *Mensch-en*), except the nominative singular (*Mensch*), which constitutes a zero override. Table 1c illustrates how a Pāṇinian split in the singular can combine with a natural split between singular and plural. Finally, Figure 1d witnesses what could be taken 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.

The patterns we have just seen have two clear implications for morphological theory: first, morphologists generally 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 items, 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 Extended Word-and-Paradigm category.

3.3 HPSG approaches to inflection

Over the years, several different proposals have been made as to the treatment of inflectional morphology in HPSG. From the point of view of the 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, any 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. Morpho-phonological changes effected by such a rule are typically effected 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: e.g. in platforms like the LKB (Copestake 2002), character unification serves to provide statements of morpho-phonological changes that can be attached to (unary) lexical rules. See Goodman & Bender (2010) for a proposal as to how dependencies between morphological rules 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: in a series of papers, he argued for the incorporation of a serious formal model of morphology, namely 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 vain, Erjavec (1994) explores how a model such as PFM can be cast in typed feature structures 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 certainly optimised for the treatment of clitic clusters.

Word-based approaches

Krieger & Nerbonne (1993) As stated earlier, probably one of the first approaches to morphology in HPSG has been 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 what their work on derivation (Krieger & Nerbonne 1993), which is essentially a word-syntactic, i.e. morpheme-based approach.

Table 2: Regular present indicative endings for German verbs

	SG	PL
1	-e	-n
2	-st	-t
3	-t	-n

Figure 6 represents an encoding of the present indicative paradigm for German (cf. the endings in Table 2. The distributed disjunction, marked by $_{\$1}$, associates each element in the disjunctive ENDING value with the corresponding element in the disjunctive AGR value.

$$\begin{bmatrix} \text{MORPH} & \begin{bmatrix} \text{STEM} & \boxed{2} \\ \text{ENDING} & \boxed{3}\left\{_{\$1} \text{“e”, “st”, “t”, “n”, “t”, “n”}\right\} \\ \text{FORM} & \boxed{2} + \boxed{3} \end{bmatrix} \\ \text{SYNSEM} & \begin{bmatrix} \text{LOCAL}|\text{HEAD}|\text{AGR} & \left\{_{\$1} \begin{bmatrix}\text{PER} & \mathit{1}\\ \text{NUM} & \mathit{sg}\end{bmatrix}, \begin{bmatrix}\text{PER} & \mathit{2}\\ \text{NUM} & \mathit{sg}\end{bmatrix}, \ldots, \begin{bmatrix}\text{PER} & \mathit{3}\\ \text{NUM} & \mathit{pl}\end{bmatrix}\right\} \end{bmatrix} \end{bmatrix}$$

Figure 4: Encoding paradigms by distributed disjunctions (Krieger & Nerbonne 1993)

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 Figure 5.

$$\begin{bmatrix} \text{MORPH} & \begin{bmatrix} \text{ENDING} & \left\{_{\$1} \text{“”, “st”, “”, “n”, “t”, “n”}\right\} \end{bmatrix} \end{bmatrix}$$

Figure 5: Partial irregularity by overriding default endings (Krieger & Nerbonne 1993)

Suppletive forms, as for auxiliary *sein* 'be' will equally inherit from Figure 6, yet override the form value.

$$\left[\text{MORPH}\ \left[\text{FORM}\ \left\{_{\$1}\ \text{“bin”, “bist”, “ist”, “sind”, “seid”, “sind”}\right\}\right]\right]$$

Figure 6: Suppletive verbs (Krieger & Nerbonne 1993)

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, sub-regular 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 morpho-syntactic 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 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 3, Swahili verbs (minimally) inflect for polarity, tense and subject agreement.[2]

Because of this property, Koenig (1999) suggests that the inflectional morphology of Swahili can be directly described at the word level. He proposes a type hierarchy of word level inflectional constructions as given in Figure **??**.

Figure 7: Koenig's constructional approach to Swahili position classes

As shown in Table 3, tensed verbs with plural subjects take 3 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 dimensions. 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 Figure 8, these partial descriptions pair some morpho-syntactic properties (μ-FEAT) with constraints on the prefixes: e.g. the type *¬1sg-neg* 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 −].

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 form 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 n.d.). 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

[2]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.

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

(a) ¬*1sg-neg*

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

(b) *1sg-pos*

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

(c) *1-sg-neg*

Figure 8: Sample types for Swahili

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, sub-regular 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, i.e. results of regular rule application are not listed in the lexicon. They are constructed either by Online Type Construction or rule application. Irregular formations, by contrast are fully listed, e.g. the past tense form *took* of a verb like *take*. Most interesting are sub-regular 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.[3]

Koenig (1999) proposes two variants of a morphological and/or lexical blocking theory. In essence, he builds on a previous formulation by Andrews (1990) 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 uni-lateral 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 how this can be accomplished: one is a compilation approach where complementation is used to make the more general type disjoint, 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 morphophonological function to a lexical rule. Bonami (Bonami & Samvelian 2008; Bonami & Boyé 2006; 2007; Bonami 2011) proposed to directly plug-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, not only begs the question why we need a different formalism in order to implement a theory of inflection, rather than exploit the power of inheritance and cross-classification in typed feature structure hierarchies. 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.

[3]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.

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 sub-theory of inflection that systematically explores underspecification 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 1994) 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. At the top-level, these comprise MPH, a partially ordered list of exponents (*morph*), a morphosyntactic (or morpho-semantic) property set MS associated with the word, and finally a set of RR of realisation rules that establish the correspondence between exponents and morphosyntactic properties.

(5)
$$\begin{bmatrix} \textit{word} & \\ \textsc{infl} & \begin{bmatrix} \textsc{mph} & \textit{list(morph)} \\ \textsc{rr} & \textit{set(realisation-rule)} \\ \textsc{ms} & \textit{set(msp)} \end{bmatrix} \end{bmatrix}$$

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 Figure 9. Throughout this section, I shall use German (circumfixal) passive/past participle (*ppp*) formation, as witnessed by *ge-setz-t* 'put', for illustration.

Since words in inflectional languages typically consist of multiple segmentable parts, realisational models provide means to index position within a word: while in AM and PFM ordered rule blocks perform this function, IbM uses a list

$$\begin{bmatrix} \textsc{ph} & \textit{<gesetzt>} \\ \textsc{infl} & \begin{bmatrix} \textsc{ms} & \left\{ \begin{bmatrix} \textsc{lid} & \textit{setzen} \end{bmatrix}, \begin{bmatrix} \textsc{tma} & \textit{ppp} \end{bmatrix} \right\} \end{bmatrix} \end{bmatrix}$$

Figure 9: Holistic word-level association between form (PH) and function (MS)

of morphs (MPH) in order to explicitly represent exponence. The sample word-level representation in Figure 10 illustrates the kind of information represented on the MPH list and the MS set. 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 consisting of a phonological description (PH) paired with a position class index (PC).

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

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.

Word:

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

Abstraction of circumfixation ($1 : n$):

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

Figure 10: Structured association of form (MPH) and function (MS)

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 Figure 10. 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, even more importantly for Batsbi (Harris 2009).

By way of introducing a level of R(EALISATION) R(ULES), 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 Figure 11.

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

Figure 11: 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 explicitly represent the subset of morphosyntactic features they are about. I.e. 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.

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

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 are fully $m : n$. This property sets this framework apart from cascaded rule models of inferential-realisational morphology (Anderson 1992;

Stump 2001), which attain this property indirectly based on cascaded rules that are basically $m : 1$.

$$word \rightarrow \begin{bmatrix} \text{MPH} & \boxed{e_1} \bigcirc \cdots \bigcirc \boxed{e_n} \\ \text{RR} & \left\{ \begin{bmatrix} \text{MPH} & \boxed{e_1} \\ \text{MUD} & \boxed{m_1} \\ \text{MS} & \boxed{0} \end{bmatrix}, \ldots, \begin{bmatrix} \text{MPH} & \boxed{e_n} \\ \text{MUD} & \boxed{m_n} \\ \text{MS} & \boxed{0} \end{bmatrix} \right\} \\ \text{MS} & \boxed{m_1} \uplus \cdots \uplus \boxed{m_n} \end{bmatrix}$$

Figure 12: Morphological well-formedness

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 rather straightforward principle, given in Figure 12: 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, i.e. no contribution of a rule may ever be lost. This principle of general well-formedness in Figure 12 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 $1 : 1$.

In essence, a word's morphosyntactic property set (MS) will correspond to the non-trivial set union ($\uplus$) of the rules' MUD values.[4] The entire morphosyntactic property set of the word (MS) is exposed on each realisation rule by way of structure sharing ($\boxed{0}$).

Finally, a word's sequence of morphs, and hence: its phonology, will be obtained by shuffling ($\bigcirc$) the rules' MPH lists in ascending order of position class (PC) indices. This is ensured by the Morph Ordering Principle given in Figure 13, adapted from Crysmann & Bonami (2016).

[4]While standard set union ($\cup$) allows for the situation that elements contributed by two sets

$$\textit{word} \rightarrow \begin{bmatrix} \textsc{ph} & \boxed{1} \oplus \cdots \oplus \boxed{n} \\ \textsc{infl} & \begin{bmatrix} \textsc{mph} & \left\langle \begin{bmatrix} \textsc{ph} & \boxed{1} \end{bmatrix}, \ldots \begin{bmatrix} \textsc{ph} & \boxed{n} \end{bmatrix} \right\rangle \end{bmatrix} \end{bmatrix}$$

(a) Concatenation

$$\textit{word} \rightarrow \neg \left(\begin{bmatrix} \textsc{infl} & \begin{bmatrix} \textsc{mph} & \left\langle \ldots \begin{bmatrix} \textsc{pc} & \boxed{m} \end{bmatrix}, \begin{bmatrix} \textsc{pc} & \boxed{n} \end{bmatrix}, \ldots \right\rangle \end{bmatrix} \end{bmatrix} \wedge \ \boxed{m} \geq \boxed{n} \right)$$

(b) Order

Figure 13: Morph Ordering Principle (MOP)

While the first clause in Figure 13 merely states that the word's phonology is the concatenation of its constituent morphs, the second clause ensures that the order implied by position class indices (pc) is actually obeyed. Bonami & Crysmann (2013a) 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 Figure 12, 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 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 14. 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.

In addition to vertical abstraction by means of standard monotonic inheritance

may be collapsed, non-trivial set union ($\uplus$) insists that the sets to be unioned must be disjoint.

Figure 14: Vertical abstraction by inheritance

hierarchies, IbM draws on Online Type Construction (Koenig & Jurafsky 1994): 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:

(8) a. **ge**-setz-**t** 'set/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 (8), 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 15: Horizontal abstraction by dynamic cross-classification

Figure **??** shows how Online Type Construction provide 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 $\boxed{\text{PREF}}$ and $\boxed{\text{SUFF}}$). Systematic cross-classification (under unification) of types in $\boxed{\text{PREF}}$ with those in $\boxed{\text{SUFF}}$ yields the set of well-formed rule instances, e.g. distributing the left-hand rule type in $\boxed{\text{PREF}}$ over the types in $\boxed{\text{SUFF}}$ yields the rules for *ge-setz-t* and *ge-schrieb-en*, whereas distributing the right hand rule type in $\boxed{\text{PREF}}$ 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 (1994); Koenig (1999), OTC 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 **??** provides instructions on the set of inferrable sub-types: according to Koenig & Jurafsky

(1994), dimensions are conjunctive and leaf types are disjunctive. Online Type Construction dictates that any maximal sub-type 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.[5]

4.3 Pāṇinian competition

In accord with most theories of inflection (Prince & Smolensky 1993; Stump 2001; Anderson 1992; Noyer 1992; Kiparsky 1985), IbM embraces a version of Morphological Blocking, aka 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 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 (9), which is clearly inspired by Koenig (1999) and Erjavec (1994).[6]

[5] There are two ways of conceptualising the status of OTC in grammar: under the dynamic view, hierarchies are underspecified and the full range of admissible type 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.

[6] Alternatively, for a dynamic approach, it will be sufficient to use clause (9a) and perform a topological sort on rule instances, ordering more specific rules before more general ones.

(9) **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 $\sigma \wedge \tau$: $\sigma \wedge \neg(\sigma \wedge \tau) \equiv \sigma \wedge \neg\tau$.

The first clause establishes competition, ensuring subsumption with respect to both expressed features (MUD) and conditioning features (MS descriptions).[7] If the condition is met, the use conditions of the more general rule are specialised in such a way as to make the two rule descriptions fully disjoint.

Table 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.					

For concreteness, let us consider some examples from Swahili: as shown in Table 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.

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. E.g. relative negative *si* 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".

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

(10) 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 (11a-d), in that order. For expository purposes, I shall make explicit the fact that MUD is necessarily contained in MS.

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

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

c.
$$\begin{bmatrix} \text{MUD} & \boxed{1}\left\{\begin{pmatrix} \textit{neg}, \\ \begin{bmatrix} \textit{subj} & \\ \text{PER} & \textit{1} \\ \text{NUM} & \textit{sg} \end{bmatrix} \end{pmatrix}\right\} \\ \text{MS} & \boxed{1} \cup \textit{set} \\ \text{MPH} & \left\langle \begin{bmatrix} \text{PH} & \text{<si>} \\ \text{PC} & \textit{1..2} \end{bmatrix} \right\rangle \end{bmatrix}$$

d.
$$\begin{bmatrix} \text{MUD} & \boxed{1}\{\textit{neg}\} \\ \text{MS} & \boxed{1} \cup \{\textit{rel}\} \cup \textit{set} \\ \text{MPH} & \left\langle \begin{bmatrix} \text{PH} & \text{<si>} \\ \text{PC} & 3 \end{bmatrix} \right\rangle \end{bmatrix}$$

On the basis of the definition in (9a), portmanteau *si* in (11c) is a competitor for both *ni* (11b) and *ha* (11c), since the MUD of portmanteau *si* is subsumed by either the set 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 (12a). Similarly, in a first iteration, *ha* will be specialised as in (12b).

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

b. $$\begin{bmatrix} \textsc{mud} & \boxed{1}\left\{\textit{neg}\right\} \\ \textsc{ms} & \boxed{1} \cup \textit{set} \wedge \neg\left\{\begin{bmatrix} & \textit{subj} \\ \textsc{per} & \textit{1} \\ \textsc{num} & \textit{sg} \end{bmatrix}, \ldots\right\} \\ \textsc{mph} & \left\langle\begin{bmatrix} \textsc{ph} & \text{<ha>} \\ \textsc{pc} & \textit{1} \end{bmatrix}\right\rangle \end{bmatrix}$$

However, *ha* (11a) has another competitor, namely negative relative *si* (11c): 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 add another existential constraint to (). The fully expanded entry is given in (13).

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

One assertion that has been made repeatedly in IbM work concerns concerns default zero exponence, the thesis being that there is need for only a single instance, in contrast to PFM, which has one instance of the identity function default in every rule block. 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 have a non-default value. A simple solution is to provide subtypes of the ultimate default for every inflectional dimension that witnesses zero exponence. While this is slightly less general than what might have been hoped, the finer control that this move offers is independently required to mitigate between the zero exponence as a fallback strategy and the existence of defectiveness, i.e. gaps in paradigms.

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 (14) and (15), 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 (14), the negative past marker *ku* in (15) displays overlapping exponence.

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

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

(15) 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 (15b): 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.

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

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

We can provide rules for the two past markers as given in (16), 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 (16b) is crucially no competitor for the regular negative marker *ha*, since the mud sets of (16b) and (12a) are actually disjoint. Thus, by embracing a distinction between expression and conditioning, overlapping exponence behaves as expected with respect to Pāṇini's principle.

Purely symmetrical multiple exponence works somewhat differently from overlapping exponence: e.g. in Nyanja (Stump 2001; Crysmann 2017a), class B adjectives (17) take two class markers to mark agreement with the head noun, one set of markers being the one normally used with class A adjectives (19), the other being attested with verbs (18). Both sets distinguish the same properties, i.e. nominal class.

(17) ci-pewa ca-ci-kulu
cl7-hat(7/8) qual7-conc7-large
'a large hat'

(18) ci-lombo ci-kula.
cl7-weed conc7-grow
'A weed grows.'

(19) ci-manga ca-bwino
cl7-maize qual7-good
'good maize'

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 16.

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

Figure 16: Nyanja pre-prefixation (Crysmann 2017a)

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).[8] Instead, order is directly represented as a property of exponents (=morphs).

Taking as a starting point the classical challenges from Stump (1993), 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 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 marking alternative values for the same feature, i.e. which 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 5.

While the agreement markers follow the tense marker in the present, the relative order of tense and agreement marker differs from cell to cell in the future.

Figure 17: 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 ??: 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

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

of this is Swahili "ambifixal" relative marking, as shown in examples (20–21)[9] In the affirmative indefinite tense, the relative marker is realised in a position after the stem, whereas in all other cases it precedes it.

(20) a. a-soma-**ye** '(person) who reads'
M/WA.S-read-M/WA.REL

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

(21) a. a-na-**ye**-soma '(person) who is reading'
M/WA.S-PRES-M/WA.REL-read

b. a-na-**cho**-ki-soma '(book) which he is reading'
M/WA.S-PRES-KI/VI.REL-KI/VI.REL-read

Condition placement can be captured using a two-dimensional hierarchy, as shown in Figure ??: 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.

Figure 18: Swahili relative markers

Cross-classification by means of Online Type Construction finally distributes the morphotactic constraints over the rules of exponence.

The last basic type of variable morphotactics is free placement, i.e. free permutation of typically 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 follow 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 position class indices. While a simple indexing by absolute position is often sufficient, there are cases where a more sophisticated indexing scheme is called for.

[9] 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).

Table 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)*	*	

Crysmann & Bonami (2016) discuss placement of pronominal affix clusters in Italian. While placement is constant within the cluster itself and 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 (22).

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

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

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.[10]

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 19), such that other markers can be placed relative to it (cf. the agreement rule in Figure 20).

Compared to layered structure, the pivot feature approach appears to be more versatile, since it provides a suitable solution to second position affixes. In Sorani Kurdish (Samvelian 2007), an endoclitic agreement marker surfaces after the initial morph, be it the stem, or some prefixal marker. Thus, placement is relative to what ever happens to be the first instantiated position index.

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

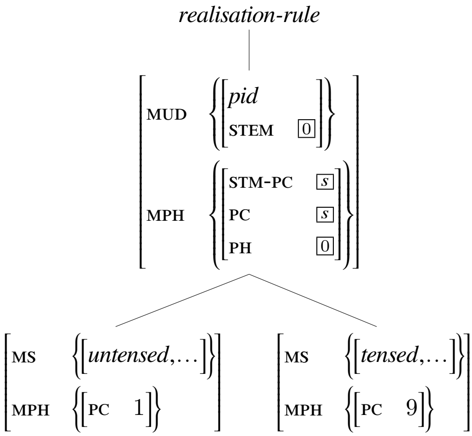

Figure 19: Partial hierarchy of Italian stem realisation rules

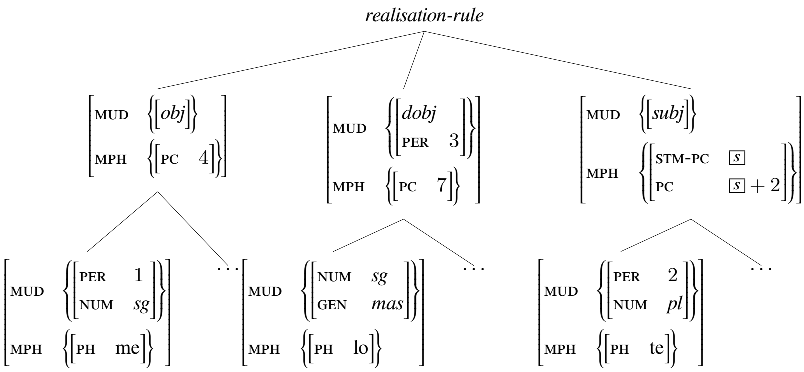

Figure 20: Partial hierarchy of Italian affixal realisation rules

Bonami & Crysmann (2013b) 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 (23).

(23) $$\textit{word} \rightarrow \left[\text{INFL}\ \left[\text{MPH}\ \left\langle \begin{bmatrix}\text{PC} & \boxed{1}\\ \text{1ST-PC} & \boxed{1}\\ \text{STM-PC} & \boxed{s}\end{bmatrix}, \begin{bmatrix}\text{1ST-PC} & \boxed{1}\\ \text{STM-PC} & \boxed{s}\end{bmatrix}, \ldots, \begin{bmatrix}\text{1ST-PC} & \boxed{1}\\ \text{STM-PC} & \boxed{s}\end{bmatrix} \right\rangle\right]\right]$$

The realisation rule for a second position clitic will the look as follows, determining its PC value relative to that of the word's first morph.

Table 7: Sorani Kurdish past person markers

1	2	3	4	
		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'

(24)
$$\begin{bmatrix} \text{MUD} & \left\{\begin{bmatrix}\text{PER} & \mathit{3}\\ \text{NUM} & \mathit{pl}\end{bmatrix}\right\} \\ \text{MPH} & \left\langle\begin{bmatrix}\text{PH} & \langle\text{jân}\rangle \\ \text{1ST-PC} & \boxed{1} \\ \text{PC} & \boxed{1}\ \mathit{+1}\end{bmatrix}\right\rangle\end{bmatrix}$$

To conclude the section, a more general remark is in order: as we have seen, IbM uses explicit ...

4.5 Constructional vs. generative views

IbM departs from previous purely word-based approaches, such as Blevins (2016) or, within HPSG, Koenig (1999) by recognising an intermediate level of realisation rules that effects the actual $m : n$ relations between form and function. In this section,

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 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.

The gestalt nature of Estonian case/number marking can be schematised as in Figure 21.

While it is clear that this kind of complex association between form and function requires a constructional perspective, but it is far from clear that i. this association has to be made at the top-level and ii. that this requires word-to-word correspondences in the sense of Blevins (2005; 2016). To the contrary, the system

Table 8: Partial paradigms exemplifying three Estonian noun declensions (core cases; Blevins 2005)

NOKK 'beak'			ÕPIK 'workbook'		
	SG	PL		SG	PL
NOM	nokk	nok-a-d	NOM	õpik	õpik-u-d
GEN	nok-a	nokk-a-de	GEN	õpik-u	õpik-u-te
PART	nokk-a	nokk-a-sid	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

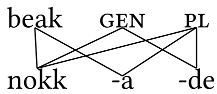

Figure 21: *m*:*n* relations in Estonian

depicted in Table 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 it is realisation rule which 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 pretyping, 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.

While it is straightforward to implement constructional analyses within IbM, non-constructional analyses are actually preferred whenever possible.

4.5.2 Reuse of resources

Cases of reuse of resources constitute a particularly strong case against overgeneralising to the constructional view: parallel position classes are a case at hand, as exemplified in Swahili (Stump 1993; Crysmann & Bonami 2016) or Choctaw (Broadwell 2017).

Table 9: Swahili person markers (Stump 1993)

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	—

$$
\begin{bmatrix} \text{MPH} & \left\{\begin{bmatrix} \text{PH} & \langle \textit{ni} \rangle \\ \text{PC} & \textit{-3} \end{bmatrix}\right\} \\ \text{MUD} & \left\{\begin{bmatrix} \textit{subj} & \\ \text{PER} & \textit{1} \\ \text{NUM} & \textit{sg} \end{bmatrix}\right\} \end{bmatrix}
\begin{bmatrix} \text{MPH} & \left\{\begin{bmatrix} \text{PH} & \langle \textit{wa} \rangle \\ \text{PC} & \textit{-1} \end{bmatrix}\right\} \\ \text{MUD} & \left\{\begin{bmatrix} \textit{obj} & \\ \text{PER} & \textit{3} \\ \text{NUM} & \textit{pl} \end{bmatrix}\right\} \end{bmatrix}
\begin{bmatrix} \text{MPH} & \left\{\begin{bmatrix} \text{PH} & \langle \textit{wa} \rangle \\ \text{PC} & \textit{-3} \end{bmatrix}\right\} \\ \text{MUD} & \left\{\begin{bmatrix} \textit{subj} & \\ \text{PER} & \textit{3} \\ \text{NUM} & \textit{pl} \end{bmatrix}\right\} \end{bmatrix}
\begin{bmatrix} \text{MPH} & \left\{\begin{bmatrix} \text{PH} & \langle \textit{ni} \rangle \\ \text{PC} & \textit{-1} \end{bmatrix}\right\} \\ \text{MUD} & \left\{\begin{bmatrix} \textit{obj} & \\ \text{PER} & \textit{1} \\ \text{NUM} & \textit{sg} \end{bmatrix}\right\} \end{bmatrix}
$$

Figure 22: Rule type hierarchy for Swahili parallel position classes (Crysmann & Bonami 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 poly-synthetic language. According to Diaz et al. (2019), the inflectional system alone comprises 7 prefixal position classes in which up to 8 non-modal and 3 modal categories can be expressed (cf. Table 10). Given the number of categories and position 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: e.g. the factual 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 10: Position classes of Oneida inflectional prefixes

1	2	3	4	5	6	7	8
Negative Contrastive Coincident Partitive	Translocative Factual	Dualic Future	Factual Optative	Cislocative Repetitive Optative	Factual Optative	Pronominal Factual	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 by building essentially 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 morpho-syntactic 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. E.g. 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 morpho-semantic 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, an comprehensive introduction to recent development within HPSG inflectional morphology was still missing.

In the area of derivation and grammatical function change, a consensus has been 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. Beyond HPSG these works have influenced the development of Construction Morphology (Booij 2010).

Much more recently, some consensus model seems to have arrived for the treatment of inflectional morphology: Information-based Morphology (Crysmann & Bonami 2016; Crysmann 2017a) build 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 network to capture linguistic generalisations. Furthermore, like its syntactic parent, it permits to strike a balance between lexicalist and constructional views.

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