# Accounting for underlying forms in HPSG phonology

Filip Skwarski
University of Warsaw

**1. Why are underlying forms desirable in HPSG phonology?**

The paper aims to present an approach to HPSG phonology which would account for underlying forms of particular phonemes. Phonology in HPSG is largely an undeveloped field, and probably the most significant attempt to expand the value of PHON (in most syntax- and morphology-related papers typically presented as a string equivalent to the word's pronunciation or orthographic spelling) was undertaken by Steven Bird (Bird 1994, Bird 1995).

The framework he proposed expanded PHON into an actual phonological description and allowed formulating constraints determining the well-formedness of surface representations. His approach was based around the principles of COMPOSITIONALITY and a requirement that a framework be MONOSTRATAL (Bird 1995, 1.4.5). The latter meant, in simplified terms, that any phonological representation has only one level, corresponding to forms actually appearing in the surface representations, and no abstract representation is stored.

Although such an approach would seem to be desirable in a computational framework, the phonological phenomena in various languages cannot be adequately described without a further reference to an underlying representation of a phoneme (Shoun 2005, 4.4.). Abby Shoun points out the issue in her study, citing eg. problems arising when representing consonants in Bengali, but does not develop an actual implementation of reference to underlying forms in HPSG phonology - which is the aim of this paper.

Evidence for usefulness of underlying representations can be seen in consonant alternations and voicing processes in languages where those phenomena are complicated, even though Bird seemed to disregard events such as final devoicing as purely phonetic processes which need not be described with binary features (Bird 1995, 3.3.2).

In Polish (my native language), for example, the phoneme /g/ exhibits the following alternations:

| | | | | |
|---|---|---|---|---|
| (1) | księga | a tome (nom.sg.) | [kɕɛŋga] | [g] |
| | ksiąg | of tomes (gen.pl.) | [kɕɔŋk] | [k] |
| | księdze | to a tome (dat.sg.) | [kɕɛndzɛ] | [dz] |
| | książka | a book (nom.sg.) | [kɕɔ̃w̃ʃka] | [ʃ] |
| | książek | of books (gen.pl) | [kɕɔ̃w̃ʒɛk] | [ʒ] |

Although these alternations result from historical palatalisation and voice assimilation processes, all of them are fully productive in modern Polish, in specific morphology-related cases, like noun declension patterns.

Likewise, in Polish - unlike eg. German - the process traditionally called "final obstruent devoicing" is intertwined with a process of "voice assimilation". Voiced obstruents are devoiced word-finally and before voiceless obstruents, while voiceless obstruents become voiced before voiced obstruents, including across word boundaries (Rubach 1982, 4.2, 4.3). As a result, /d/ and /t/ can both surface as [t] and [d] accordingly, phonetically identical with the "default" form of their opposite-voiced counterpart. Before sonorants (except, in most cases, across word boundaries), obstruents retain their "underlying" voice values, and so, in a traditional monostratal framework, we would have no way of arriving at this basic form if we describe sonorants as either alternations of their surface representations or underspecifications (as suggested by Bird 1995, 1.5).

| | | | | |
|---|---|---|---|---|
| (2a) | kod | code | [kɔt] | [t] |
| | kody | codes | [kɔdɨ] | [d] |
| | kod dostępu | access code | [kɔd dɔstɛmpu] | [d] |
| | kod miasta | city code | [kɔt mʲasta] | [t] |
| | kod pocztowy | postal code | [kɔt pɔtʃtɔvɨ] | [t] |

| | | | | |
|---|---|---|---|---|
| (2b) | kot | a cat | [kɔt] | [t] |
| | koty | cats | [kɔtɨ] | [t] |
| | kot perski | a Persian cat | [kɔt pɛrski] | [t] |
| | kot mały | a small cat | [kɔt mawɨ] | [t] |
| | kot domowy | a housecat | [kɔd dɔmɔvɨ] | [d] |

The above data demonstrates that obstruents in Polish can behave in three ways depending on context: assimilate their voice to that of the following segment (before other obstruents, including across word boundaries), retain their "underlying" voice feature (before sonorants, except word-finally), or become voiceless regardless of their "underlying" voice feature (word-finally before a pause or before sonorants) This example will be used as a basis for representing the possibilities of accounting for underlying forms in HPSG phonology, in a further section.

It should be noted that despite the departure resulting from the introduction of underlying descriptions, other crucial ideas of the framework suggested by Bird are not violated. Accounting for the underlying representation does not require "rule ordering", but nonetheless can be used to solve problems traditionally dealt with via rule ordering, eg. opacity in Turkish (as shall be seen in a further paragraph). Similarly, Bird's idea of deletion as an alternation with zero (Bird 1995, 3.2) is still used in the approach I present.

**2. Representing the representations**

This section is concerned with estabilishing the structural side of the framework which would involve underlying features. A well-functional framework should achieve the following aims:

(a) Allow formulated rules to operate at various levels of the structure (stem, word, syllable, utterance, etc.)
(b) Accurately provide just one surface form for any phoneme in the complete utterance.
(c) Append lower-level representations into higher-level representations (words into phrases, syllables into feet, etc.)
(d) Allow for interactions between the underlying representation and the surface representation in cases where the underlying representation is directly relevant to the surfacing form.

Principle (a) is dictated by the observation that certain phonological phenomena operate within boundaries, such as word boundaries or phrase boundaries, and formulated constraints have to be formulated in a way accounting for this (Bird 1994, 2.2).

Principles (b) and (c) are related: because of observation mentioned in (a), various constraints operating solely on one level of the structure (word, phrase, etc.) would predict different criteria of well-formedness. For example, a constraint demanding that the word-final segment be voiceless would apply to the PHON structure of a *word* object, but not to the PHON structure of a *phrase* object. Similarly, constraints operating across word boundaries would not say anything about the PHON structure of a *word* object.

As a result, for a situation like the exemplary interaction between Polish final devoicing and voice assimilation processes (2a & 2b), we are left with a choice of either predicting different phonological structures for different levels of syntactic and morphological representation, or postulating that all surface representations at all levels

have to be the same. Höhle (Höhle 1999) appears to use (presumably for simplification) the first case scenario, and in his representations, the components of an utterance or a morphologically complex word may contain phonemes (defined for the purposes of sorting) where eg. the voicing feature may differ from the voicing feature of the corresponding phoneme sort in the complete utterance / word. Applying this to our Polish devoicing example would yield a situation in which the phrase "kod dostępu" would have a PHON listing [kɔd dɔstɛmpu], but its first daughter element would have a structure ending in a voiceless obstruent: [kɔt].

Such a solution is possible to account for predictions made at different levels, but causes problems with principle (c), that is, it requires a separate system for appending daughter elements together (since we cannot simply append [kɔt] and [dɔstɛmpu] to get [kod dɔstɛmpu]. Again, introducing underlying representation seems to be an advantage here, as it does not require clearly defined and sorted phonemes (which is superfluous, Shoun 2005), but allows forms to combine precisely because higher level structures are appended based on the underlying structure of their elements, while the surface structure may be separately predicted. Furthermore, because surface structure may be generated based on both the underlying structure and the context, it is possible to make individual surface forms equivalent on all levels of syntactic / morphological representation, thus better adhering to the principle of COMPOSITIONALITY (Bird 1995, 1.4.5).
To summarise - a system I propose is a system where the underlying and the surface forms are stored separately, where the higher level lists are appended separately from underlying and surface form lists of daughter elements, and where the underlying and surface forms can interact through formulated rules. The more complicated interactions (principle (d)) will be seen further on in the section on Turkish epenthesis/deletion opacity.

Below is an exemplary PHON structure provided according to my proposed framework for the English word "cat":

| | | | | | |
|---|---|---|---|---|---|
| *word* | | | | | |
| PHON\|SEG_LIST | *segs* | | | | |
| | UR_LIST | [k, æ, t] | | | |
| | SR_LIST | [k, æ, t] | | | |
| | FIRST | *simple* | | | |
| | | UR | [k] | | |
| | | SR | [k] | | |
| | REST | *segs* | | | |
| | | UR_LIST | [æ, t] | | |
| | | SR_LIST | [æ, t] | | |
| | | FIRST | *simple* | | |
| | | | UR | [æ] | |
| | | | SR | [æ] | |
| | | REST | *simple* | | |
| | | | UR | [t] | |
| | | | SR | [t] | |

Note that unlike in typical approaches to PHON expansions, the objects utilised in phonological descriptions are not just lists, but objects of type I called here "*segs*" (for "segments"), which are expanded to contain representations containing both the underlying (UR) and surface (SR) forms, as well as lists used to coordinate and append these elements together. The IPA symbols in brackets are obviously simplifactions of complete phonetic structures of the segments, with which I will not deal in detail (see: Bird 1995, "4. A theory of segmental structure", and Höhle 1999). The FIRST and REST features of *segs* are a simplification and a reference to lists, in reality, HPSG ontology would demand them to be named distinctly.

One of the framework's issues now is the relationship between SR and UR. The two basic possibilities of accounting for a possible number of surface representations (here based on the simple example in (2), but note also case (1)) - are alternatives (3) and underspecification (4):

(3)

| *simple* | |
|---|---|
| UR | [d] |
| SR | [t] v [d] |

| *simple* | |
|---|---|
| UR | [t] |
| SR | [t] v [d] |

(4)

| *simple* | | |
|---|---|---|
| UR | *segment* | |
| | LG\|VOICED | + |
| | SL\|PLACE\|CORONAL | + |
| SR\|SL\|PLACE\|CORONAL | + | |

| *simple* | | |
|---|---|---|
| UR | *segment* | |
| | LG\|VOICED | – |
| | SL\|PLACE\|CORONAL | + |
| SR\|SL\|PLACE\|CORONAL | + | |

However, because we are equipped with underlying representation now, it is possible to leave the surface representation of any lexical item fully unspecified, and unambiguously derive it based on the UR and the phonological context. While this requires a number of rules to relate particular underlying features to surface ones, it saves the need of stating the SR for every single lexical item. This approach is perhaps closer to the original phonology of derivations and transformations, but should not be confused with any sort of rule ordering and destructive processes. It is, rather, based around constraints and context-sensitive correspondence.

**2.1. Word Final Obstruent Devoicing Meets Obstruent Voice Assimilation**

The analysis in this section is based around the data and processes in (2), with the goal of adequately describing Polish obstruent voicing processes through HPSG constraints. As mentioned before, there are three elements of the process:

1. Obstruents before other obstruents, including across word boundaries, assimilate their voice to that of the following obstruent, regressively (obstruent clusters have to agree in voicing).
2. Obstruents before sonorants, but not across word boundaries, retain their underlying, distinctive voice.
3. Word-finally, voiced obstruents become voiceless before sonorants or a pause (all word-final obstruents must be voiceless before sonorants or a pause).

The above is true for mainstream Polish, but in south-western variants, the voicing context may be different (Höhle 1999). This will not be dealt with here, although the provided example may easily be altered to account for different voicing phenomena.

The first of the aforementioned rules can be translated into HPSG phonology rather easily, by forming a constraint requiring the surface voice of any two sonorants to be the same - or, in negative terms, prohibiting any cluster with differently voiced obstruents (we furthermore note that the constraint operates on the level of the entire utterance, introducing a subtype of *segs*: *utterance_segs*, required through a constraint demanding that the first *segs* of an *utterance* be of the *utterance_segs* type, and that the REST feature of *utterance_segs* may only be either an actual segment articulation, or another *utterance_segs*).

(5)

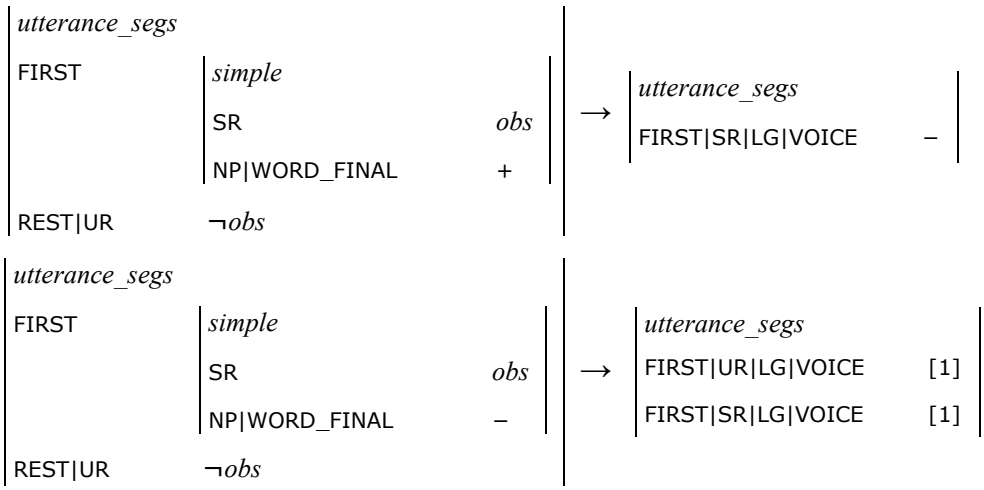
| *utterance_segs* | | → | *utterance_segs* | |
|---|---|---|---|---|
| FIRST\|SR | *obs* | | FIRST\|SR\|LG\|VOICED | [1] |
| REST\|SR | *obs* | | REST\|SR\|LG\|VOICED | [1] |

(6)

| *utterance_segs* | | → | *utterance_segs* | |
|---|---|---|---|---|
| FIRST\|SR | *obs* | | FIRST\|SR\|LG\|VOICED | [1] |
| REST\|FIRST\|SR | *obs* | | REST\|FIRST\|SR\|LG\|VOICED | [1] |

The third and the second rule, however, are more complicated, since they crucially revolve around the notion of the word boundary. Because they are interweaved (the word-final context has an exception of preceeding obstruents), however, we cannot just resort to *word_segs*. Instead, however, the structure of *simple* (our object corresponding to a single segment) can be expanded to include a binary feature WORD_FINAL, itself a feature of NP (for "non-phonetic"). We can introduce it through *word_segs*, and translate the rules in (2) and (3) by invoking it:

(7)




The above two constraints effectively require that any obstruent followed by a non-obstruent be voiceless when word-final, and have its surface voicing equivalent to underlying voicing if not word-final. However, they only take into account a situation when the REST element is an actual segment, and not another *segs* beginning with a non-obstruent. Another, analogical pair of constraints is required, their conditions being to this one as (6) was to (5).

**2.2. The Issue of Opacity in Turkish: Simultaneous Vowel Epenthesis and Consonant Deletion**

Here, we return to the previous topics of representing epenthesis and deletion, as well as the more complex interactions between the underlying and the surface forms in formalted rules. Turkish (Sanders 2003) is an exemplary language where the processes of consonant-triggered Epenthesis and (in some dialects) vowel-triggered k-Deletion are present:

(8) /bɑʃ/ + /m/ -> [bɑʃɯm]

(9) /ɑjɑk/ + /ɯ/ -> [ɑjɑɯ]

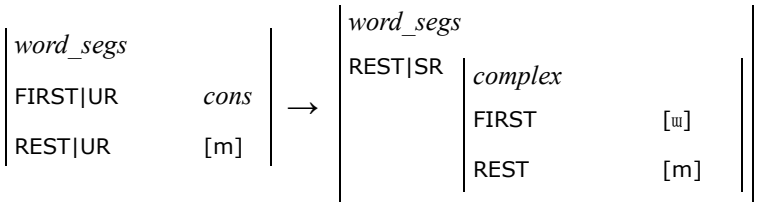
However, in a case traditionally solved through rule ordering, epenthetic vowel may trigger k-Deletion, resulting in both the presence of the epenthetic vowel, and the deletion of /k/:

(10) /ɑjɑk/ + /m/ -> [ɑjɑɯm]

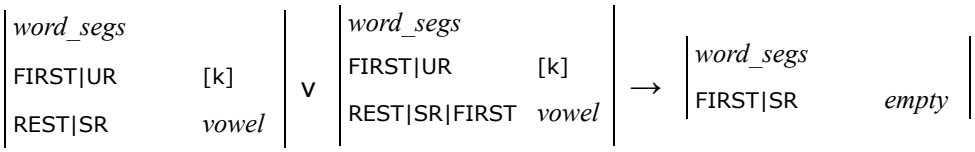
In a rigidly monostratal framework, introducing the constraints prohibiting both consonant clusters and [k] before vowels could, possibly, lead to a situation where neither [ɑjɑkɨm] nor [ɑjɑkm] are considered well-formed while the form [ɑjɑɨm] is, but, first of all, we would have no way to arrive at that form, and secondly, any cluster of two vowels would be acceptable - while in Turkish, that is not the case: except in borrowings, vowel clusters emerge due to the deletion of /k/. To account for this fact, the framework would have to postulate the presence, but not articulation, of /k/, as a ghost segment in the cases where it is deleted, but still present for the purpose of epenthesis.

Ghost segments are an undesired element in phonology, particularly in HPSG, working against the idea of epenthesis as an alternation with zero, and violating the principle perhaps even moreso than introducing underlying features. It is possible, however, to solve the situation in a framework which accounts for underlying representation, by formualting constraints in such a way that they may refer to the underlying context, while affecting the surface structure.

Thus, a constraint translated from the rule of Epenthesis demands any consonant preceeded by an underlying consonant to surface as a complex segment consisting of a vowel and a consonant. It also illustrates the way in which epenthesis is handled in my framework: here, in a simplified situation, /m/ may surface either as a *simple* object, where the surface form is a single phone (as in the cases seen before), or a *complex* object, with its own structure.




The rule of k-Deletion is translated as a constraint demanding that /k/, followed by a surface vowel this time, may not surface, ie. it has to be an *empty* type object, whose phonemic structure contains no surface representation, and so does not appear when appended in higher-level objects.




(note that the context of above constraints is simplified, ignoring situations where the REST object is another *segs*)

Both rules apply precisely at the same time and need not be ordered, but since they refer to different levels of representation, they allow two processes to overlap. On a final note, the *empty* and *complex* types of representation require further rules to establish the technical side of the expanded framework and properly assemble UR and SR lists (in simplified terms, similar to how lists assemble from *segs*), which for space issues are not included in this abstract.

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