MORPHOLOGICAL PRODUCTIVITY IN THE LEXICON

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Abstract.

In this paper we outline a lexical organization for Turkish that makes use of lexical rules for inflections, derivations, and lexical category changes to control the proliferation of lexical entries. Lexical rules handle changes in grammatical roles, enforce type constraints, and control the mapping of subcategorization frames in valency changing operations. A lexical inheritance hierarchy facilitates the enforcement of type constraints. Semantic compositions in inflections and derivations are constrained by the properties of the terms and predicates.

The design has been tested as part of a HPSG grammar for Turkish. In terms of performance, run-time execution of the rules seems to be a far better alternative than pre-compilation. The latter causes exponential growth in the lexicon due to intensive use of inflections and derivations in Turkish.

1. Introduction

Languages like Finnish, Hungarian, and Turkish have relatively rich morphology which governs grammatical information often delegated to syntax in languages such as English. Prominence of morphology puts a greater demand on the information in the lexicon, which may grow to an unmanageable size due to heavy use of inflections and derivations. In Turkish, for instance, the nominal paradigm has three affixes (number, case, relativizer), and the verbal paradigm has eight (for voice, tense, person, aspect, and mood). Generating the full paradigm for a nominal and a verbal root requires 2^3 and 2^8 entries in the lexicon, respectively. The problem is further

complicated by the rich inventory of derivational affixes for both paradigms, as exemplified in (1). Hankamer (1989) argues convincingly that full listing of every word form in the lexicon is untenable for agglutinating languages.

(1) *Yaz-ıcı-lar-a* *gör-ev-ler-i* *bil-dir-il-me-miş-ti*
write-VtoN-PLU-DAT able-VtoN-PLU-ACC know-CAUS-PASS-NEG-ASP-TENSE
'The clerks have not been informed of their duties'

Handling inflections and derivations with lexical rules opens us possibilities for encoding semantic and grammatical changes in the lexicon as well. For instance, a causative suffix will demote an agent to a patient or a recipient, and it will add a new grammatical role for the causer (the new agent). A locative case suffix will mark a NP as an adjunct, which can no longer satisfy subcategorization requirements of the verbs or postpositions. We elaborate on the consequences of these phenomena in section 3.

Another source for economy of representation can be seen in example (2), where attributive adjectives (2a and 2b) are used as nouns in (2b) and (2d). One solution to this problem is underspecification, i.e., grouping the nouns and adjectives under a single lexical category.[1] An alternative is to use a lexical rule for differentiating predicate and term reading of the lexical entry. This seems to be a better alternative for unifying the treatments of nouns, adjectives, derived nouns and derived adjectives. For instance, *yaşlı* in (2c) is a derived adjective produced by a lexical rule. The output can be fed into another lexical rule to obtain zero-derivation of a noun from the adjective (2d).

Dynamic nature of the lexical rules allows control over their application. For the derived adjective *güdüm-lü*[2] *("ballistic")*, one would not like to obtain its nominal reading; it is unlikely to be used as a noun. It would require complex (and perhaps extendible) inheritance hierarchy to achieve the same effect by underspecification.

(2) a. *kuru yaprak*
dry leaf
'dry leaf'
b. *meyve kuru-su*
fruit dry-POSS
'dried fruit'

[1] In fact, traditional Turkish grammar books such as (Lewis, 1967) collectively call them "substantives."

[2] *-lü* is an allomorph of the morpheme that can be represented as *-lI*. Other allomorphs are *-li* (as in example 2c–d), *-lu* and *-li*

c. *yaş-lı hanım*
age-ADJ lady
'old lady'

d. *bütün yaş-lı-lar*
all age-ADJ-PLU
'all elderly'

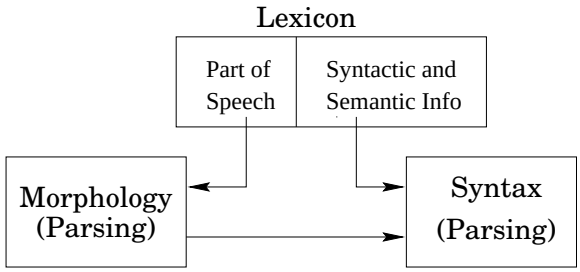
It appears that an agglutinating language will benefit from the lexical rule aproach to morphology. Lexical rules can make use of lexical information to model morphotactic (possible continuations), syntactic (inflectional morphology), and semantic (derivational morphology) aspects, thereby enriching the lexicon without an exponential growth. However, all types of lexical rules for morphology will overgenerate if the language is not purely polysynthetic. The information source for constraining the application of rules is, in most cases (including inflections), lexical semantics. In what follows, we will describe different kinds of lexical rules for morphology-lexicon-syntax interface. They enforce type constraints, perform changes in grammatical information, and subcategorization requirements. We also discuss processing issues such as run-time generation versus pre-compiling of word forms.

2. Morphology-syntax Interface

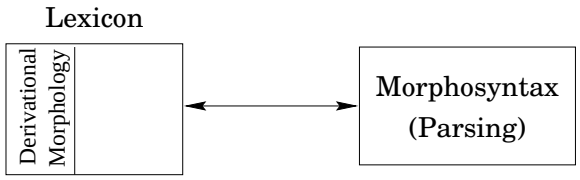
Modelling inflections, derivations, and the corresponding phonological alternations via lexical rules amounts to the lexicalization of morphology (cf. Figure 1(c)). The alternatives to this approach (for Turkish) have also been explored, such as the modularization of syntax and morphology (cf. Figure 1(a)) which keeps them–and their lexicons—as separate systems (Güngördü and Oflazer, 1995). The flow of information is unidirectional in this architecture. The other alternative is the integrative[3] approach to morphology and syntax, which treats morphosyntax in the same manner as syntax with respect to semantic composition (Bozsahin and Göçmen, 1995).

From a computational point of view, the modular approach has efficient lexical access since lexical search is performed on root forms, and bound morphemes are not considered lexical items. This approach tends to isolate morphological information in the lexicon from syntactic information. This seems to be done out of practical considerations rather than

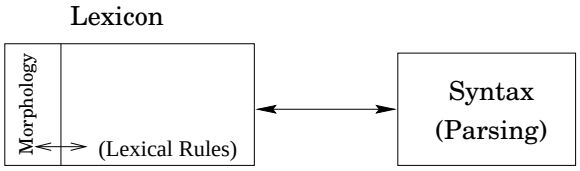
[3]The term 'integrative' is suitable for this approach in the sense that the lexicon contains bound forms as well as free forms, and derivational morphology is considered as part of the lexicon (cf. Figure 1(c)). For it to be fully integrated, the derivational affixes need to have a lexical representation as well.



(a) No embedding of morphology in the lexicon (modular).



(b) Partial embedding (integrative).



(c) Full embedding (lexical).

Figure 1. Architectures for Turkish Morphology-Syntax Interface.

methodological necessity; finite-state component can take care of morphotactics with minimal use of lexical information (e.g., lexical category of the root forms), while the phrase structure component takes care of syntax. This separation, however, causes overgeneration in derivational morphology since lexical semantic information which could rule out exceptional cases in semi-productive derivational affixes will be inaccessible to the morphological component. To a limited extent, this is also true of inflected items in the lexicon. Causativization in Turkish is a good example of this kind. It is very productive; any intransitive (transitive) verb can be causativized into a transitive (ditransitive) verb. But some causative forms have been lexicalized. For instance, *git ("go")* has the lexicalized causative *götür ("deliver")*. To block *git*-CAUSE, the morphological component must have access to semantic information (e.g., $\mp$causative) about the lexical item.

In the integrative (multi-dimensional) approach, the lexicon contains free and bound morphemes; they have complete syntactic and semantic specifications. As lexical items, they must take part in semantic composi-

tion which goes on in parallel with morphology and syntax. Some of the inflections, e.g. person, perform only feature marking, hence their semantic form (or LF) is that of identity. Argument-encoding case marking such as the accusative affect the LF by filling argument positions. Other inflections, such as the causative, compose semantic form of the stem (LF_s) with that of the affix. LF_s can be turned into (*cause* x LF_s) where x is the new argument introduced by the causative affix (cf. example 8). Similar arguments can be made for the semantic contribution of adjunct case markers. The difficulty of this approach is due to the necessity to incorporate different attachment characteristics, such as morphological concatenation and syntactic concatenation.

With respect to the place of morphology in the grammar architecture, the lexical approach represents the other extreme of the modular approach. However, as far as the complexity and coverage of the lexicon is concerned, it is in the mid-point of the three approaches. In this view, morphology is not isolated from syntax, but, similar to the modular organization, bound morphemes are not considered lexical items. They can be attached to stems via lexical rules. This implies that lexical rules are responsible for semantic composition and for the changes in syntactic requirements. The integrative approach puts a greater burden on syntax and the lexicon because of greater dependence on morphological information. From this perspective, it is the most demanding view on lexical information.

The degree of integration of morphology and syntax is a question of considerable debate in linguistic theory. GB and LFG explicitly state some degree of integration by considering inflectional morphology as part of syntax, and treating derivational morphology as a matter of the lexicon. Keeping morphology and syntax entirely separate forces one to stipulate different scopes for affixes. For instance, the adverbial suffix *-ken* and the adjectival *-lu* might have phrasal (3a and 3c) or lexical scope (3b and 3d). Multidimensional approach allows affixes to 'pick out' different scopes in mixed morphological and syntactic composition. The lexical approach can accomodate both readings, provided that lexical rules are invoked with relevant syntactic information, e.g., valency of the verb. Morphologically ambiguous cases such as (4) are handled by multiple instantiations of the lexical rules.

(3) a. *Çocuk top-a* [*kaleci-ye* *bakar*]*-ken vurdu*
child ball-DAT goalkeeper-DAT look-ADV hit
'The child hit the ball facing the goalkeeper.'

b. *Çocuklar* [*yürür*]*-ken taş* *toplamışlar*
children walk-ADV stone picked
'The children had picked stones while walking.'

c. [*Uzun kol*]-*lu* *gömlek*
long sleeve-ADJ shirt
'shirt with long sleeves'

d. *Uzun* [*çiçek*]-*li* *gömlek*
long flower-ADJ shirt
'long shirt with flower patterns'

(4) a. *kalem-ler-i*
pencil-PLU-ACC
'the pencils (=object)'

b. *kalem-ler-i*
pencil-PLU-POSS.3SG
'his/her pencils'

c. *kalem-leri*
pencil-POSS.3PL
'their pencils'

It is too early to evaluate the advantages and disadvantages of these approaches in terms of competence grammars and performance issues. But the choice of the strategy also affects the design of lexical organization. For instance, if inflections and derivations are handled by lexical rules, the morphological information need not be kept at all, since lexical rules will reflect the changes in syntactic and semantic requirements coming from morphology. If morphology is treated almost like syntax, lexical knowledge should contain richer morphological information, including a semantic representation for bound forms (affixes), information about boundedness/freeness of morphemes, and the type of attachment (e.g., affixation, cliticization, syntactic concatenation) (Bozsahin and Göçmen, 1995; Hoeksema and Janda, 1988). This will enable the system to rule out, for instance, affixation of two free forms or concatenation of two bound forms. It can also impose selectional restrictions on the stems of affixes.

In this study, a lexical inheritance hierarchy is used in conjunction with the lexical rules. It allows a regimented representation for feature structures, and enforces type constraints on free forms (words). Bound forms are not part of the lexicon. The hierarchy is given in Figure 2.

This tree is part of a greater hierarchy which includes inheritance information for words and phrases. We make use of the inheritance and type-checking mechanism of ALE (Carpenter and Penn, 1994) to impose type-specific constraints on words. Words are distinguished from phrases by disallowing any kind of gapping below the word level in the tree. Designating a lexical item as one of the subtypes in the hierarchy will apply all the constraints and incorporate the feature structures of the supertypes along the path to *word*. For instance, a qualitative adjective (e.g., *rahat* "com-

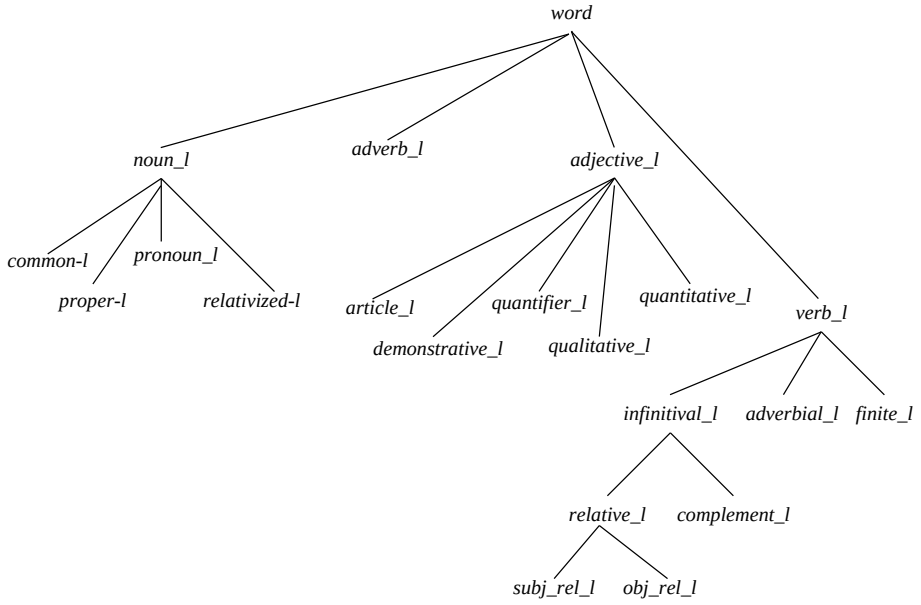


Figure 2. Lexical hierarchy

fortable") is distinguished from a quantitative one (e.g., *çift* "double") by its choice of modifiers; the latter does not allow intensifiers (5).

(5) a. *çok rahat koltuk*
very comfortable couch
'very comfortable couch'
b. * *çok çift koltuk*
c. *rahat çift koltuk*
comfortable double couch
'comfortable twin couch'

The fragments of the type constraints[4] for these subtypes are given in Figure 3. The controlled use of type constraints at different levels of the lexical hierarchy eliminate the need to enumerate type-specific lexical rules to achieve the same effect.

3. Types of lexical rules

We divide the lexical rules for morphology into three main groups. The first two groups have to do with inflections. The division of inflectional morphol-

[4]We use HPSG style feature structures and signatures in our descriptions; see Pollard and Sag (1994).

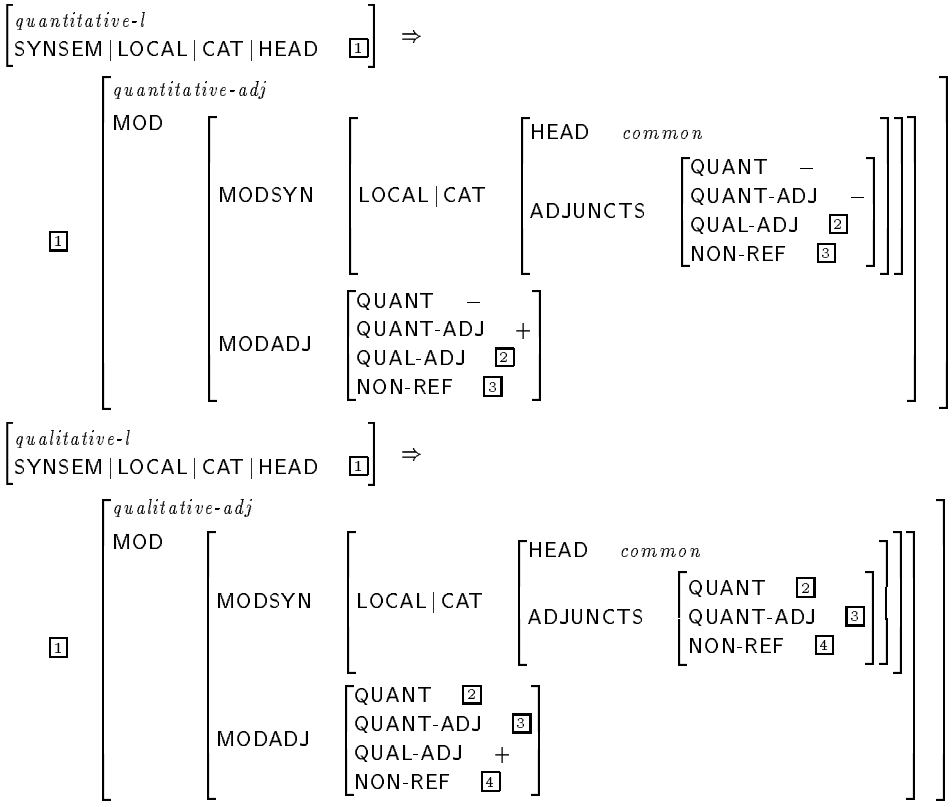


Figure 3. Type constraints for words and some subtypes.

ogy into two sets of rules is primarily for the purpose of highlighting the differing degree of their effects on syntax. The first group can be called 'minor' inflections, which mark the lexical item with features required by syntax, e.g., person and number marking for agreement phenomena. The second group of lexical rules model the so-called 'major' inflections, i.e., the changes in the syntactic frame of the lexical item. These include voice affixes (reflexive, causative, reciprocal, passive), infinitive markers for subordination, and some 'zero' inflections such as non-overt marking of the indefinite object. The third group is for derivational morphology. We provide examples of these rules below. There is no separate morphological parsing component in this approach; the lexical rules incorporate a model of morphotactics for proper ordering of the affixes. We will not elaborate on this aspect of the rules.

3.1. FEATURE-MARKING INFLECTIONS

These rules reflect the grammatical requirements imposed by inflections. Overt case markers that can encode arguments (e.g., accusative, dative, genitive) only affect the CASE feature of the syntactic frame. Adjunct markers must make additional changes. For instance, the locative case suffix in Turkish also marks an NP as adjunct (6).

(6) *Adam araba-da uyu-du* .
man car-LOC sleep-TENSE.3SG
'The man slept in the car'

The lexical rule for locative case is given in Figure 4. This rule is applied when the locative suffix is attached to a nominal stem. In HPSG terms, the head of the NP is marked with the locative case, and the type of NP is changed to an adjunct. This is achieved by modifying the head feature MOD: While the nominative marked noun has null value, a MODSYN value with verbal head is introduced in the head feature of the locative noun. This will allow the locative marked noun to modify a verb. Thus, it cannot be an argument of verbs or postpositions. This issue is critical for parsing relatively free word-order languages where grammatical relations are often indicated by overt case marking rather than structural position. Figure 4 also shows the derivation of the semantic representation for the case marked NP; *at(x,y)* is a second-order predicate that holds between a term x and a predicate y. This predicate is inserted into the set of restrictions for the noun. For (6), this method produces *at(car,sleep(man))*.

3.2. FRAME-CHANGING INFLECTIONS

There are other linguistic phenomena that are on the boundary of lexicon and syntax, which we opted to contain in the lexicon, e.g., non-referential objects, and valency change in the causatives. In the following, we briefly describe the lexical rules for them.

Case assignment is overt in Turkish, which allows for scrambling of the constituents. All six permutations of the SOV order are felicitous if the object NP is case marked (e.g., 7a and 7b). If the object is non-referential or indefinite (cf. 7a and 7c), it is not marked morphologically, which blocks scrambling, and the unmarked SOV order is used (cf. 7c and 7d).

(7) a. *Çocuk kitab-ı oku-du*
child.NOM book-ACC(object) read-TENSE.3SG
'The child read the book.'
b. *Kitab-ı çocuk oku-du*

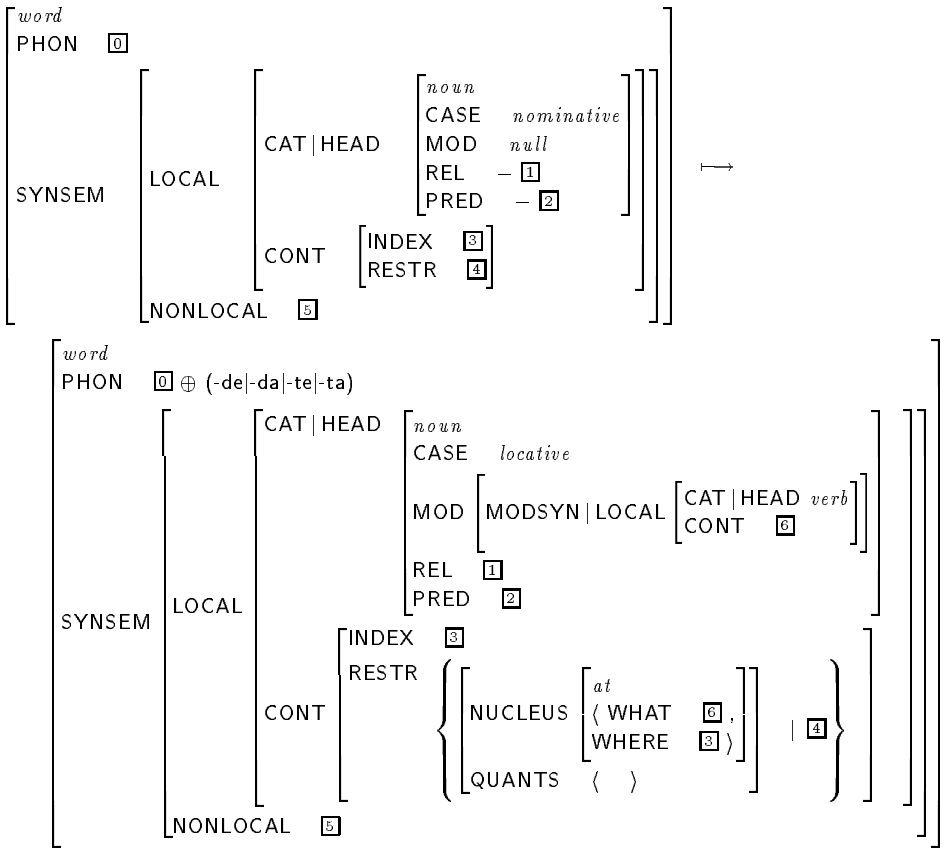
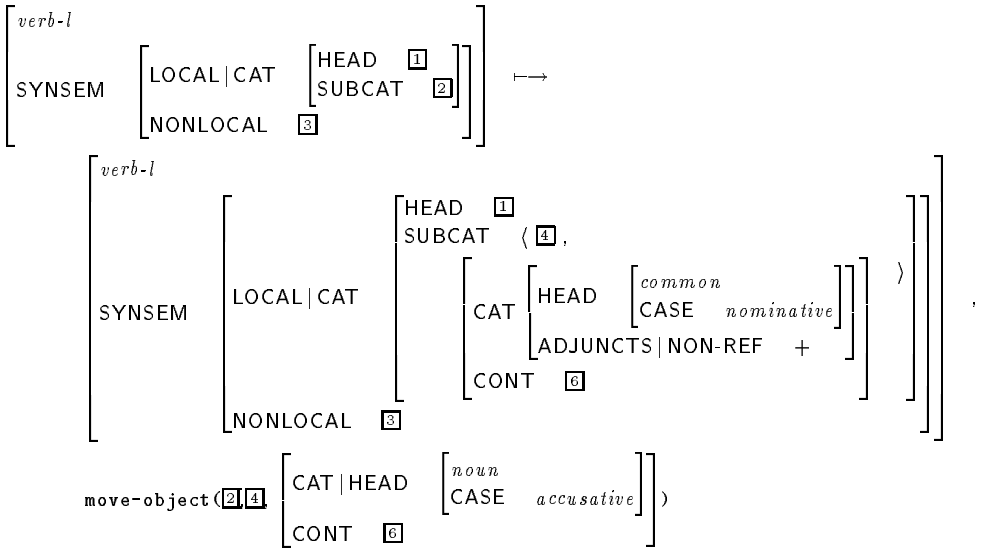


Figure 4. Lexical rule for the locative case.

c. *Çocuk kitap oku-du*
child.NOM book.ACC read-TENSE.3SG
'the child read a book (≅ the child did book-reading)'
d. * *Kitap çocuk okudu*

Non-referential objects are not inflected on case, and they must occupy the immediately preverbal position. One way of dealing with nouns, then, is to keep two entries in the lexicon: one for unmarked form which may receive case marking and scramble, and one with lexically assigned case (accusative), which may not scramble. Our solution is to have a lexical rule that changes the subcategorization frames of verbs to handle cases where objects may be case-marked NPs or unmarked Ns. In the second case, the entity is marked indefinite and all scrambling is blocked by the lexical rule. Figure 5 shows the lexical rule in ALE notation (the rule is simplified for

ease of exposition).



Where **move-object** *is a definite clause which deletes the accusative object from the* SUBCAT *structure in first argument and return resulting structure and accusative object in second and third argument respectively.*

Figure 5. Lexical rule for non-referential objects.

Morphological causatives can be modelled in a similar vein. A causative suffix changes the subcategorization frame of the verb by adding one more argument and changing the grammatical constraints on the other arguments. For instance, the new argument becomes the subject (causer), and the old subject (agent) is demoted down the grammatical hierarchy (Comrie, 1976) to direct object or indirect object, depending on the argument structure:

(8) a. *Can arkadaş-ı-nı çağır-dı*
friend-POSS-ACC call-TENSE.3SG
'Can called his friend.'

b. *Mehmet Can-a arkadaş-ı-nı çağır-t-tı*
Can-DAT friend-POSS-ACC call-CAUS-TENSE.3SG
'Mehmet had Can call his friend.'

3.3. DERIVATIONS

Denominal verbs, deverbal nouns, and part of speech changes can be modelled respectively by adding subcategorization frames, discharging subcat-

egorization frames, and type coercions, via lexical rules. The most difficult issue in derivations is the semantic composition. For instance, the -CI morpheme (with allomorphs *-cı/-ci/-cu/-cü/-çı/-çi/-çu/-çü*) adds the meaning "doer/user of something" (9a), "seller/lover of something" (9b), or habitual (9c).

(9) a. *yol -cu*
road
'traveller'

b. *şeker -ci*
candy
'candy seller or lover'

c. *sabah -çı*
morning
'morning person'

Clearly, this ambiguity cannot be resolved without incorporating into lexical semantics a Qualia Structure a la Pustejovsky (1991), or lexical semantic constraints (Fass, 1993). We have been incorporating these types of constraints. Unfortunately, descriptive work on Turkish linguistics in this regard is very scarce, and there is no ontology such as Levin's (1993). Using features like [∓animate], [∓artifact], [∓container], and [∓period], one can define semantic fields for the derivational morphemes. We expand the set of features as more lexical items are added to the lexicon. This is a very labour intensive task; the lack of a large-scale initiative on lexicography in the manner of LDOCE or COBUILD is hindering the efforts for automatic extraction of lexical knowledge from on-line resources.

Our strategy is to obtain complex forms derivationally if the semantic relation of the bound morpheme to its stem is fairly predictable. We use lexicalized forms when the meaning is not compositional. One such case is the denominal verb suffix *-le*, which is very productive but has no predictable meaning that can be derived from the lexical semantics of the stem. Zero derivations are modelled by lexical rules as well, e.g., the nominal use of adjectives is achieved by a single lexical item which may be interpreted as a term or a predicate by a lexical rule.

3.4. MORPHOPHONEMIC RULES

The rules for inflectional and derivational morphology might also take into account the archiphonemes that are not marked for certain features. For instance, the locative case marker has allomorphs *-de/-da/-te/-ta*. They may be represented uniquely by two metaphonemes -DA where D is a dental

stop unmarked for voice and A is a low unround vowel unmarked for backness/frontness. Vowel harmony and voicing constraints[5] determine their surface realization during morphological composition. These kinds of rules are not lexical rules per se since they do not operate on lexical properties of the words. In our model, they are embedded in lexical rules for inflections and derivations.

4. Evaluation of Lexical Rules

As far as lexical rules for Turkish morphology are concerned, there is one phenomenon which clearly calls for a dynamic ('on demand') evaluation of the rules: The relative *-ki* suffix can be attached to nominal stems if the noun is in the genitive or the locative case. (10a) and (10c) show the full paradigm, with corresponding examples in (10b) and (10d). Its semantics can be informally described as 'the one that x' where x is the semantics of the case-marked nominal stem. The result is a nominal stem, and all noun inflections can be applied again. This leads to recursive expansions such as (10e). Examples like this are not uncommon among native speakers. Finding the closure of this relation during compilation leads to non-termination. Settling for a finite closure of *-ki* relativization would not be a principled solution to this phenomena. It also runs the risk of leaving out many creative uses of *-ki*.

(10) a. *meyve -ler -i -nde -ki*
fruit -PLU -POSS -LOC -REL

b. *meyve-de-ki kurt*
fruit-LOC-REL worm
lit. 'the worm, the one in the fruit'

c. *arkadaş -lar -ı* -nın *-ki*
friend -PLU -POSS -GEN -REL

d. *Benim arabam çalışmıyor ama onun arkadaş-ı-nın-ki çalışıyor*
my car does not work but his/her friend-POSS-GEN-REL works
'My car doesn't work, but his friend's (car) does'
lit. 'My car doesn't work but the car, the one that belongs to his/her friend', does.'

e. *ev-de-ki-ler-in-ki*
house-LOC-REL-PLU-GEN-REL
'lit. the ones that belong to the ones that are in the house'

[5]cf. (Oflazer, 1994; Oztaner, 1996) for a description of these processes. (Hankamer, 1986) is the original work on Turkish that combines finite state morphotactics with morphophonemic alternations.

We have been testing our lexicon design as part of an HPSG grammar for Turkish (Sehitoglu, 1996). The grammar development environment, ALE, had to be modified to allow run-time evaluation of lexical rules. Compiling out the lexical rules off-line is quite impractical, since generating every possible form for a large lexicon of roots causes exponential growth or even inifinite expansion in case of *-ki* relativization. Compilation of all surface forms for a lexicon of only 40 root forms produces around 2800 entries. Delayed evaluation (Johnson and Dorre, 1995; van Noord and Bouma, 1994), or pre-compiling the lexical rules for on-line expansion as suggested by Meurers and Minnen (1995), are viable options for avoiding off-line expansion. However, it is not clear to what extent the lexical rules for morphology can benefit from these techniques. There is not much of rule interaction, and the constraints for evaluating the rules are instantiated by the time the stem is parsed and the affix is about to be attached. For these reasons, we allow run-time evaluation of the lexical rules without prior processing. Of course, run-time execution of rules puts the burden on parsing or generation. But this seems to be tolerable as far as morphological lexical rules are concerned.

5. Conclusion

For a language with rich morphology, lexical rules can be used for controlled generation of surface forms. Inflections and derivations can be seen as word-based (local) operations on the root, and thus be modelled as lexical rules. Phonological alternations in stems can be embedded in the rules as well. Grammatical role changes, type constraints on word subtypes, and noun to NP promotions (as in non-referential objects) control the proliferation of lexical entries. Semantic contribution of inflections seems to be morpheme specific: All derivations take part in semantic composition, but some inflections (such as case and causatives) contribute semantically as well. Most inflections (e.g., person and number markers), however, have grammatical functions only. This is not to say they do not have a semantic form, just that in many cases the form is that of identity. Productive use of derivations is limited by the predictability of the semantic relation of the stem to the affix.

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