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CHAPTER 7

Morphology, typology, computation¹

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Introduction

We were asked to write on computational matters in morphology, and have combined this with a typological view. This is thus a reflective and prospective chapter. We review joint research, including work involving Norman Fraser. We shall draw out general points, which we hope will shed interesting light on our topic. We shall not justify the analyses, which are either already published or will be published: our intention in this chapter is to take a more general view.

1. Morphology and typology

These form an obvious combination. The earliest 'whole language' typologies were based on morphology. The tradition persists, since morphologists tend to be typologically inclined. While a good deal of recent work in typology has been concerned with constructions, alongside this work there has also been work on the typology of categories: aspect, gender, case, number and so on. A newer trend, which was evident at the previous Vienna meeting in 1996, is research on the typology of morphological phenomena, notably defectiveness and suppletion. It seems inevitable, as well as desirable, that morphology will continue to have a strong typological slant.

2. Computation and typology

Typology requires *computational methods* as much as other disciplines, probably more than many. Here are just some possible examples. First,

sampling is a special problem in typology, and computational aids may prove valuable: see the work of Rijkoff, Bakker, Hengeveld and Kahrel (1993) and Bakker (1994: 84–91). Second, databases, with the structuring now possible, have great potential. There are several at different stages. A significant one is Dryer's database which is typological in the most direct way, and from which helpful maps can be derived (<http://wings.buffalo.edu/soc-sci/linguistics/dryer/dryer.htm>). At Surrey we are working on databases on syncretism (Matthew Baerman, Dunstan Brown and Greville Corbett) and on agreement (Julia Barron, Dunstan Brown, Greville Corbett, Andrew Hippisley and Carole Tiberius), which will have a substantial amount of information on a restricted number of diverse languages. Third, statistical techniques, which used to be complex and laborious, are now much easier to apply computationally, and the results can be presented in ways which are easier to grasp.

However, it is not just a matter of appropriate computational tools. Typology belongs also with computational linguistics, in more principled ways. Computational linguistics can offer ways of demonstrating that particular analyses are valid (in the sense of demonstrating that they account for the data). Take the example of an analysis of gender assignment in languages like Russian, which is crucial for a typology of such systems. That account has been published (Fraser and Corbett 1995): here we will just sketch it as an illustration of the general point, that of genuine interaction between computational linguistics and typology.

Gender systems have agreement as their defining characteristic. Nouns of a gender language can be grouped analytically according to agreement evidence. We then ask how the native speaker, who produces the agreement evidence, 'knows' the gender of the different nouns. Assignment to a gender is always possible for the great majority of nouns, from information required independently in the lexical entry (Corbett 1991: 7–69) and the particular type of information used gives us a typology of assignment systems. We find *semantic systems* (where only semantic information is required) and *semantic + formal systems* (where semantic information is supplemented by morphological and/or phonological information). Purely formal systems (where gender would be predicted by formal means but where the different agreement classes of nouns would have no semantic significance) are not found.

Godoberi is an example of a semantic assignment system (Kibrik 1996). In this Nakh-Daghestanian language of the Botlikh area of Daghestan, nouns are assigned to three genders as follows: nouns denoting male rationals, like *ima* 'father', are masculine; female rationals, like *ila* 'mother', are feminine, and all

others, such as *hamaXi* 'donkey', are neuter. This simple assignment system predicts gender without reference to form.

The other main type of assignment system also uses semantic information but supplements it with formal information (phonological or morphological). In Qafar (Afar), an East Cushitic language (Parker and Hayward 1985) nouns denoting male humans and the males of sexually differentiable animals are masculine (*bàqla* 'husband') and females (human and animal) are feminine (*barrà* 'woman, wife'). The phonological assignment rules are that nouns whose citation form ends in an accented vowel are feminine (*catò* 'help') while others are masculine (*gilàl* 'winter', *baànta* 'trumpet'). There are few exceptions to these phonological rules and when the two sets of rules conflict, the semantic takes precedence.

Semantic systems and formal-phonological systems are relatively unproblematic. The most difficult are the formal-morphological systems. These have often been analysed differently; instead of gender being predictable, some treat gender as specified, and from it attempt to predict the morphological class. When the number of genders and the number of declensional classes are the same or nearly so, it is not immediately obvious which analysis is to be preferred. We propose that Russian is one of many languages with a gender assignment system in which morphological information supplements semantics. Russian has fairly standard semantic assignment rules: sex-differentiable nouns denoting males (humans and higher animals) are masculine: *d'ad'a* 'uncle', *lev* 'lion', while sex-differentiable nouns denoting females are feminine: *to't'a* 'aunt', *l'v'ica* 'lioness' (Russian examples are transcribed, with *i* and *y* treated as allophones). There are few exceptions to these rules but many nouns are simply not covered by them. Unlike Godoberi, Russian does not treat all nouns in the semantic residue in the same fashion. They are subject to further rules, notably the following morphological assignment rules. Russian has arguably four inflectional classes of nouns. Given this, we can predict the gender: nouns of declensional class I (*zakon* 'law' type) are masculine; nouns of declensional classes II (*konnata* 'room') and III (*kost'* 'bone') are feminine; others are neuter.

Given the dispute as to whether this is the right analysis, there are two traditional types of argument available here. First, and most important, there are language-specific arguments. It can be shown that predicting gender on the basis of declensional class is simpler and involves fewer exceptions than the attempt to predict declensional class on the basis of gender (Corbett 1982). Second, there is the typological argument: since there are many languages

where gender is straightforwardly predictable, it is simpler to claim that it is predictable in all languages, with typological variation being restricted to the type of information used for prediction.

There is also a third type of argument; if we can demonstrate that one approach works, this gives it a certain validity. It does not, of course, show that it is right but it removes a potential objection and leaves the onus on those favouring the alternative to investigate whether it actually works. Our demonstration is within the framework known as Network Morphology (Corbett and Fraser 1993, Brown et al. 1996, Fraser and Corbett 1997, Brown 1998). This framework belongs in the Word and Paradigm family of theories. In Stump's helpful characterization it is of the inferential-realizational type (Stump 2001). Network Morphology is typologically informed, and has a tradition of implementing analyses to demonstrate their validity. The means used has been the lexical knowledge representation language DATR (Evans and Gazdar 1996). DATR has been conceptually helpful, since it is based on the notion of default inheritance, which has proved valuable in approaching morphological problems and allows us to demonstrate that our analysis of Russian inflectional morphology and gender assignment does indeed yield the correct results. As an illustration, consider the following lexical entry:

- (1) Komnata:
 <> == NOUN
 <declensional_class> == N_ll: <>
 <gloss> == room
 <infl_root all> == komnat.

Komnata is merely a label or address for stored information: it could equally be '42'. Given this minimal entry, consisting of category, declensional class, gloss and stem, the following information is available from our account:

- (2) Komnata: <gloss> = room.
 Komnata: <mor sg nom> = komnat _a.
 Komnata: <mor sg acc> = komnat _u.
 Komnata: <mor sg gen> = komnat _i.
 Komnata: <mor sg dat> = komnat _e.
 Komnata: <mor sg inst> = komnat _oj.
 Komnata: <mor loc sg> = komnat _e.
 Komnata: <mor pl nom> = komnat _i.
 Komnata: <mor pl acc> = komnat _i.
 Komnata: <mor pl gen> = komnat.
 Komnata: <mor pl dat> = komnat _a _m.

Komnata: <mor pl inst> = komnat _a _m'i.

Komnata: <mor pl loc> = komnat _a _x.

Komnata: <syn gender> = fem.

Komnata: <syn animacy> = inanimate.

The important point is that the inflectional forms and the gender are correctly predicted. The full analysis (Fraser and Corbett 1995) covers much more completely the interrelations of semantics, gender, declensional class and phonology. However, the aim of this section is not to justify that analysis. Rather we want to emphasize that this analysis, that of a theoretical linguist working within the Network Morphology framework, can be shown to work using computational methods. Other analyses of gender in Russian are not backed by similar demonstrations of accuracy. Thus formal tools like DATR can elucidate cases which are crucial for typological purposes.

3. Morphology and computation

We now turn to the interaction of morphology and computation. A useful type of interaction has already been alluded to: computational linguistics can provide means of *validation*, of checking whether a particular theory covers the data it is claimed to cover. This is particularly relevant since morphology is a branch of linguistics where there is frequently a single 'right answer'. Some will ask whether we cannot do the checking by hand. Consider these data from Dalabon, an Australian language of the Gunwinyguan family from central Arnhem Land (Evans, Brown and Corbett forthcoming a).

Table 1 summarizes the transitive paradigm of pronominal affixes, showing how the 102 distinct combinations are generated, the numbers of possibilities in square brackets being multiplied to give the numbers in the cells.² In addition, there are six tense/aspect /mood combinations, giving a total of $102 \times 6 = 612$ forms. Then there are fascinating patterns of syncretism. Faced with paradigms like this, it makes sense to have the computer check that the analysis is indeed valid. This is not an idle example: before the computer check was done, the authors had an incorrect number of combinations in the table.

Second computational work can offer *new ideas*, such as the now prevalent notion of 'default'. Linguists have used this notion in contradictory ways, and we therefore discuss a distinction drawn within the Network Morphology framework: 'normal case default' and 'exceptional case default'. The normal case default is the outcome expected for a given domain, while the exceptional

Table 1. Number of subject/object combinations in Dalabon

Subjects	Objects			
	1st exclusive [3]: 1sg, 1du, 1pl	1st inclusive [2]: 1inc.du, 1inc.pl	2nd [3]: 2sg, 2du, 2pl	3rd [3]: 3sg, 3du, 3pl
1 excl.sg 1 excl.du [4] 1 excl.dis 1 excl.pl			12	12
1inc.du 1inc.dis [3] 1inc.pl				9
2sg 2du [4] 2dis 2pl	12			12
3sg 3dis [4] 3du 3pl	12	8	12	13' [includes distinct 3/3 forms for higher and lower object]

case default is what an item may have as a last resort. Let us return to gender in Russian. By default nouns are assigned to the first inflectional class: this class has the largest number of nouns and takes the majority of borrowings. According to our assignment rules, nouns in inflectional class I are by default masculine, so that we make masculine the default gender for nouns, without specifying it directly (for the implementation see Corbett and Fraser 2000).

While having masculine as the default gender fits with the intuitions of some investigators, it seems unsatisfactory to others. If masculine is the default gender for Russian, then we would expect it to appear, for instance, in examples like the following (transliterated, from Paustovskij, *Sud'ba Šarlja Lonsevilja*):

- (3) *Noč'ju exat' stal-o nevozmožn-o*
 by.night to.travel became-NEUT.SG impossible-NEUT.SG
 'It became impossible to travel by night.'

Here there is no normal subject, that is a noun phrase headed by a noun or pronoun; but the verb and adjective must still take an agreement form and they take the neuter, not the masculine.

The resolution of this apparent paradox is that we are claiming only that the masculine is the default gender for *nouns*. Taking a broader view, we would claim that there is a default for gender at a higher level than the nodes relating directly to nouns. This higher default is necessary for items other than nominals which may head syntactic constituents with which gender agreement is required. The situation arises if an infinitive phrase or a clause stands in subject position, or there is an interjection or other quoted material, or no subject at all. Here we normally find the neuter.

Let us think of defaults more generally. Consider the following situation. Sigrid and Klaus both work for a firm in Salzburg. Sigrid is the personnel manager and has her office in Salzburg. Occasionally, when there are problems or training courses she spends the day at head office in Vienna. By default, then, Sigrid works in the office at Salzburg. Klaus is a salesman. He normally spends Mondays in the south of Austria, Tuesdays in the west, and Wednesdays and Thursdays in the north. If, however, clients cannot see him, or his car is unserviceable, or there is a department meeting, he goes to the office in Salzburg. On Fridays he often plays golf, but if it rains he goes to the office. By default, then, Klaus also works in the office in Salzburg. Intuitively the two cases are rather different. Sigrid is 'normally' at the office, Klaus is not. And yet at a higher level of abstraction it is true to say that the office is the default workplace for both. It is these two types of default, both reasonable uses of the term, which have led to the differences in usage in the literature, both generally and specifically in relation to gender.

In our analysis of the gender system of Arapesh (Fraser and Corbett 1997) based on Aronoff (1992) and Fortune (1942) we distinguish these two types of default. In the first type, the default accounts for the cases when 'everything goes right' (as in Sigrid working in the office); this is the *normal case default*. In the second use, a default is something which applies when the normal system breaks down, when 'something goes wrong' (as in Klaus working in the office). This is the *exceptional case default*. One form of default is concerned with the typical, the other with the exceptional.

4. Morphology, typology, computation

These two types of contribution from computational linguistics, validation and new ideas, come together with morphology and typology in an analysis of the gender and morphological class systems of Mayali, a non-Pama-Nyungan

language of northern Australia. Mayali requires us to extend the typology of gender systems, its system is clarified by use of the notions of 'normal case default' and 'exceptional case default', and using DATR allows us to demonstrate the extent to which our analysis captures the recorded facts of Mayali. This work is outlined very briefly as an example of possible convergences of morphology, typology and computation.

4.1 Morphology: gender and morphological class in Mayali

We use Mayali as a cover term for a dialect chain with a number of named varieties: Gundjeihmi, Kunwinjku, Kundedjnjenghmi, Kuninjku, Kune and Manyallaluk Mayali. See Evans (forthcoming) for a full discussion of these varieties, and see Evans (1997) and Evans, Brown and Corbett (1998, forthcoming b) for details of the analysis of Mayali. In Mayali both gender and the morphological class of the noun are assigned on the basis of semantics, but the semantic assignment systems for gender and morphological class differ. These systems overlap, but the exceptional behaviour of certain noun types can be accounted for only if the two are treated as separate. Although all dialects have basically the same system of morphological classes, they have significant differences in gender systems: Kunwinjku has all four genders, Gundjeihmi has lost the neuter gender, extending vegetable agreement to what in Kunwinjku are neuter nouns, and Kune has extended masculine agreement to all nouns and in the process got rid of all gender contrasts. It retains the formal marker of masculine gender on modifiers, and the full set of class prefixes on nouns. We give examples from Kunwinjku in Table 2.

The systems of gender and morphological class are logically independent, even though there is a large measure of congruence between them. (We use

congruence for the situation exemplified by *man-me* and *ngal-kohbanj*, in which a noun has gender agreement of the same form as its (non-zero) class prefix.) A large proportion of animate nouns, and some inanimate nouns, have no overt class prefix (hence belonging to Class V, the 'zero class'); zero class nouns, nonetheless, belong to one of the four genders, as shown by the behaviour of their modifiers. See the right hand side of Table 2.

Finally there is a significant number of lexemes where morphological class and gender are non-congruent, e.g. *man-djewk* 'rain, rainwater', which controls masculine agreement. One of the formal challenges for our analysis, then, was to give semantic rules for class assignment that capture the large measure of congruence between the two systems of gender and noun-class, but can also operate independently in one domain or another.

4.2 Typology: relations between morphological class and gender

The semantics of assignment to gender, on the one hand, and morphological class, on the other, are independent but linked. We now ask what combinations are logically possible, and what representational mechanisms we use to allow specifications for gender and morphological class to be made independently, while exploiting the many predictable relations to avoid overspecification. Table 3 displays the grid of logically possible combinations between gender and morphological class. Many of the cells are empty or have just one or two highly marked entries: vegetable agreement is not found with nouns belonging to the basically animate Classes I and II; neuter agreement is not found with Classes I, II or III; feminine agreement is not found with Class III nouns, and with only one Class IV noun (*kun-dung* 'sun'). These gaps are due to the general principle that feminine gender will not be found with inanimates, nor the inanimate genders (vegetable and neuter) with nouns from the basically animate classes (I and II), and that the most marked gender (neuter) can only occur with nouns of the congruent class (IV) or the zero class.

In Table 3, dark shaded areas are unattested and pale shaded areas are attested only with a very few lexemes under highly specifiable conditions. We have space to consider here only the cells with substantial populations, which fall into three categories:

(a) the four 'congruent' cells, in which the gender and morphological class match formally, e.g. *na-worneng* 'joker at ceremony' (masc.), *ngal-yod* 'rain-bow serpent', who is mythologically female (fem.), *man-dubang* 'ironwood

Table 2. Typical gender/morphological class correlations in Kunwinjku

	Congruent examples	Examples with σ -class nouns with parallel semantics
Masculine	'good boy' <i>na-rangem na-mak</i>	'good man' <i>biminj na-mak</i>
Feminine	'good old.woman' <i>ngal-kohbanj ngal-mak</i>	'good woman' <i>daluk ngal-mak</i>
Vegetable	'good food' <i>man-me man-mak</i>	'good cheeky.yam' <i>kamarn man-mak</i>
Neuter	'good rock' <i>kun-wardde kun-mak</i>	'good water' <i>kukku kun-mak</i>

tree' (veg.) and *kun-ngey* 'name' (neut.). For most types of noun with inanimate referents, e.g. nouns denoting plants and body parts, the default situation is for them to be in the appropriate one of these cells. For animates, on the other hand, this is the second rather than the first choice, since animates normally take no overt prefixation, going into class V but with the semantically appropriate gender. However, going into the congruent cell is then their second preference: in other words, simply by marking a lexical entry for such an entity as 'marked', one can predict with near certainty that it will go into the cell containing an overt morphological class congruent with its (semantically determined) gender.

This is of particular value for non-human animates: although we have to make an additional lexical stipulation concerning the choice between masculine and feminine, or I and II, we only have to do so on one dimension. For example, for a bird in the feminine gender with a class II prefix, we need to

Table 3. Possible combinations of gender and morphological class

Morpho-logical class	I na-	II (ng)al-	III man- /(ng)an-	IV kun-	V Zero class
Masculine na-	congruent	Exceptions: biological sex	A few lexically specified exceptions	Many cases	Many cases (commonest pattern for animate masculines)
Feminine (ng)al-	Exception: biological sex	congruent		One exception: <i>kun-dung</i> 'sun'	Many cases (commonest pattern for animate feminines)
Vegetable man-/(ng)an-			congruent	Many cases	Some cases (occasional pattern for vegetable nouns)
Neuter kun-				congruent	Some cases (occasional pattern for neuter nouns)

specify that it is 'marked' for morphological class; from this we determine that it must take the congruent class, i.e. II. As an animate it would take class V by default. We would need to specify the morphological class directly in the lexical entry only if it had an overt prefix that was not congruent with its gender, e.g. a *na-* prefix but obligatory feminine agreement or vice versa. So far we have not found any such cases.

(b) the four cells with class V nouns. For animates, which normally eschew overt prefixation, as well as for implement terms, these are the default cells: zero prefixation, plus the semantically appropriate gender. For most inanimates, which prefer overt prefixation, these are the second choice in a way that mirrors the congruent cells as the second choice for animates: by simply marking inanimate nouns as 'marked', one can predict that they go into class V, with gender determined by their semantics.

(c) the two cells in which class IV nouns belong to one of the two default genders, i.e. masculine or vegetable. For masculine class IV nouns, this can reflect either the use of masculine gender for many implement and painting terms, e.g. *kun-rodjbe* 'red ochre' (masc.), or dual principles of semantic assignment. For vegetable class IV nouns, the situation is more complex. For many, their assignment results from two semantic principles, one in the domain of gender and one in the domain of morphological class.

Let us sum up. Some semantic principles are identical for both gender and morphological class. Some are specific to one domain or the other, e.g. the rules of assigning life-form plants to class IV, where the category of 'plant life-form' is relevant to morphological class but not gender, or 'fire', which operates (at least at this higher level of generality) just for gender. Many others, such as principles for assigning gender on the basis of sex, are most economically represented just for gender, with congruence rules and default-specification taking care of whether marking actually shows up as a non-zero morphological class. The model we are proposing thus allows us to distribute the semantically-based decisions in a number of ways, so that we can capture the interdependencies of the two systems without being forced to locate all semantic information in one or the other.

4.3 Results

We cannot discuss all the possible combinations. Rather we refer readers to the implementation at <http://www.surrey.ac.uk/LIS/SMG/mayali/>. Here we

Table 4. Exceptional case defaults versus total idiosyncrasy

	Morphological class		Gender	
	Exceptional Case Default	Direct specification	Exceptional Case Default	Direct specification
Proportion of 258 nouns in the lexicon	63 (24%)	16 (6%)	33 (13%)	13 (5%)

simply point out that a major benefit of formal implementation is that we can check our claims on a portion of the actual lexicon and see how it fares. We tested the theory on 258 Mayali ordinary language nouns. We were not in a position to choose a totally rigorous sample, as agreement information is currently not available for every noun. However, our selection has been guided by the Swadesh list and other lists of basic vocabulary.

In Table 4 we give the figures for exceptional case default and direct specification of morphological class and gender. Our analysis requires no lexical specification of morphological class for 70 per cent of the nouns in the lexicon, and no lexical specification of gender for 82 per cent of nouns in the lexicon.

From our approach it can be seen that 30 per cent (24 per cent + 6 per cent) of the nouns in the lexicon are irregular in some way with regard to morphological class, but only 18 per cent (13 per cent + 5 per cent) with regard to gender. So even under a system in which morphological class may for certain items be assigned according to gender, the gender system is still highly predictable, and more so than the morphological class system.

Our use of the exceptional case default construct is further justified in that we find that there is predictable exceptionality: only 6 per cent of the nouns have to be specified for a particular morphological class which is not predictable (either as the normal case default or exceptional case default); only 5 per cent of the nouns have to be specified for a particular gender which is not predictable (again as either the normal case default or exceptional case default).

5. Conclusions

We have shown that gender should be separated from morphological class in Mayali, and that both are assigned according to different, but overlapping, semantics. We have suggested that the notion of 'Exceptional Case Defaults' allows for restricted lexical specification. Given our implementation, we are

able to show that the analysis gives appropriate forms and to quantify the degree of coverage of the theory. Though we have only been able to indicate analyses in this chapter, rather than to demonstrate them, we hope to have shown that the interactions between morphology, typology and computation have great potential.

Notes

1. Versions of this chapter were given at the 9th International Morphology Meeting in Vienna (February 2000) and at Stockholm University (May 2000). We are grateful for the invitations to present this research. We also wish to thank those present for constructive discussion, an anonymous reviewer for useful comments, and the ESRC (UK) for support under grant R000238228.

2. Coreferential combinations are excluded, as they are encoded by the intransitive set plus a reflexive/reciprocal suffix.

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