Chapter 5

Multiword expressions in multilingual applications within the Grammatical Framework

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The main focus of Grammatical Framework (GF) is in multilingual applications where the same type of content is produced and analyzed in several languages at once. This is achieved by joining the grammars for all languages with a shared interlingual representation. In designing the interlingua, multiword expressions are an important factor that must be considered. Here, I adopt the broader definition where everything that translates non-compositionally accross languages is considered an expression. In this chapter I present multiword expressions from a cross-lingual perspective in relation to an interlingual grammar.

1 Introduction

Grammatical Framework (GF, Ranta 2011) is a programming language for developing multilingual applications. The typical applications are in natural language generation, dialogue systems, machine translation or in question answering systems where it is feasible to assume a limited language domain. In these scenarios it is possible to design a controlled language which can be completely covered with a formal grammar. On the other hand, these applications are typically highly multilingual. It is not uncommon to have a single grammar which supports simultaneously more than twenty languages. There are a number of challenges in this kind of application.

First of all, in order to scale to a high number of languages, GF is designed to work with an interlingua. Every grammar is divided into an abstract syntax and one or more concrete syntaxes. The abstract syntax is a language-independent

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interlingual representation of the application domain, while each of the concrete syntaxes renders an abstract syntax tree into a string in the corresponding natural language. In that setting, translation, for instance, is reduced to parsing the input sentence into an abstract tree and then rendering of the same tree into another concrete language.

Furthermore, developing even a small language fragment would normally require several low-level details, such as word order and gender/number agreement, to be reimplemented from scratch for every language and for every application. This would be highly ineffective if it was not aided by the development of the Resource Grammars Library (RGL, Ranta 2009) in GF. RGL is a library of wide coverage grammars for more than thirty languages developed by a community of linguists and computer scientists. By reusing the library, new applications can be built in short time by people who do not even have to be linguistically trained and who may not be experts in the target languages.

Working on the level of the RGL is still too low-level though. The library is trying to hide syntactic differences across languages but this is still not what we ultimately want in an application. What is needed is a model which can abstract over the language-independent semantics of the sentence. Phenomena like constructions and multiword expressions translate non-compositionally across languages, and thus are recurring obstacles that have to be resolved in every application. For that purpose there is a different grammar for each application. Application grammars, for example, are more semantically oriented. On the other hand, resource grammars are syntactic. Another difference between these two grammars is that resource grammars are highly lexicalized, but lexical entries often become semantic functions in application grammars. This is a key design decision which allows us to have an abstract language-independent representation. For example, such a representation lets us hide the language-specific multiword expressions in the modules for the concrete languages, without affecting the abstract syntax.

This strategy has been proven efficient in limited domains, and most of this chapter will be about how language-specific multiword expressions and constructions are represented in GF.

We have recently started to scale up from limited-domain applications to wide coverage parsing and translation. For this to be successful, it is important to have a library of commonly used constructions across different languages. Although this is still a moving target, I will report on the current efforts to build such a library by either reusing existing resources, or by creating those using automatic methods. This also shows that the strategy used for limited domains can scale to an open domain, when there is a wide-coverage resource of raw data that can be ported to the platform.

Please note that moving from lexicalized syntactic grammars to unlexicalized semantic grammars requires, for many languages, syntax to be represented in a discontinuous way. Just to give a simple example, forming questions in English requires that we move or add auxiliary verbs in front of the sentence, while the rest of the verb phrase is left somewhere in the middle. Other languages might not use auxiliaries at all or they might just form questions differently. This means that the verb phrase in English must be modelled as a single phrase with two discontinuous parts. The implications from this for the implementation of the framework will be discussed as well.

2 The basic principles of GF

GF is designed as a multilingual framework from the ground up. A typical application starts by identifying the relevant domain and then describing the desired phrases within that domain in multiple languages. In order to accommodate and link several diverse languages, the framework separates the grammar into two distinct conceptual layers: abstract and concrete syntax.

The ABSTRACT SYNTAX is a logical framework which acts as a language independent interlingua. It defines a collection of types and functions which can be used to build abstract syntax trees. Each abstract tree represents a phrase which is realized by using one of the available CONCRETE SYNTAXES. In this section, I will informally introduce the abstract and the concrete syntax in GF by example. For a more detailed introduction to GF we refer to Ranta (2011).

We start with the lexicon. On an abstract level, the lexicon consists of a simple inventory of word senses. For example, we might have:

```
cat N
fun horse_N : N
```

Here the first line declares that there is a category `N`, which will denote the type of all nouns. The second line defines a function with no arguments, a.k.a. a constant of type `N`. These abstract constants serve as cross-lingual lemmas. By convention we use names composed of an English lemma followed by a part of speech tag. When these are not sufficient to disambiguate the meaning of the word, then we can add more elements. For example, we could use WordNet's sense numbers for disambiguation:

```
    fun arm_1_N : N          (body part)
    fun arm_3_N : N          (weapon)
```

The lexicon starts to get interesting only when we move to the concrete syntax. The concrete syntax for English looks something like:

```
lincat N = Number => Str
lin horse_N = table {Sg => ”horse” ; Pl => ”horses”}
```

Here the keyword `lincat` introduces the linearization category for nouns, i.e. for the type `N`, and `lin` introduces the linearization of the function `horse_N` itself.

In programming language parlance, the abstract category `N` is like an abstract data type, i.e. a mere name with a hidden implementation, while the linearization category in the concrete syntax is its actual implementation. In GF, unlike in other programming languages, a single type or a single function might have several different implementations – one for every concrete syntax. In this case, the implementation in English says that `N` is a table or an array of strings (`Str`) indexed by a `Number`. The number itself is another data type defined as an enumeration with two possible values – singular (`Sg`) and plural (`Pl`):

```
param Number = Sg | Pl
```

The linearization of `horse_N`, on the other hand, gives the actual values in the table. In English these would be the word forms *horse* and *horses*, and in French *cheval*, *chevaux*. In French, however, we also need to know the gender of the noun in order to take care of the word agreement in the syntax. Because of that the corresponding definition in the concrete syntax for French is slightly more complicated:

```
lincat N = {s : Number => Str ; g : Gender}
lin horse_N =
          {s = table {Sg => ”cheval”; Pl => ”chevaux”};
           g = Masc
          }

param Gender = Masc | Fem
```

Here the linearization category for `N` is not a simple table of word forms but a record with two fields – `s` and `g`. The field `s` is still an inflection table like in English, but there is also the field `g` of type `Gender` with two possible values, `Masc` and `Fem`. The linearization for `horse_N` assigns to the field `s` the inflection table for French and sets the field `g` to `Masc`.

It is also possible to have records which combine together more than one string field. This is used for instance in English where phrasal verbs consist of a main verb and a particle. Those verbs are modelled as records:

```
lincat V2        = {s : VForm => Str; part : Str; prep : Str}
lin swith_off_V2 = {s = table {VInf =>"switch";
                               VPres=>"switches";
                               ...};
                    part = "off"
                    prep = ""}
```

The field `part` keeps the particle while the `s` field is the inflection table of the main verb. There is also a third field, `prep`, which stores the potential preposition for transitive verbs. Since there is no preposition in this case, an empty string is added. In prepositional verbs, however, this field will be non-empty. It is even possible to have verbs with both a particle and a preposition.

It is possible to have multiple string fields in nouns as well. This happens for instance in Chinese where a noun is characterized by its lemma and its classifier. Both are string fields and they could be arbitrarily far apart in the final sentence. For that reason they are stored as two different fields in the record:

```
lincat N = {s : Str; c : Str}
lin horse_N = {s = "ma"; c = "pi"}
```

The structure of the lexicon in all languages is conceptually very similar. There might be more numbers and genders, or there might be grammatical cases, but in general a lexical entry in GF is an inflection table indexed by one or more parameters, and there might be additional fields for features such as gender, word class, classifier, or a particle.

The records shown above are rarely what the GF grammarian actually writes. Instead it is possible to isolate common patterns into reusable operations which allow us to have succinct definitions like:

```
lin horse_N = mkN "horse" ;
lin switch_off_V2 = mkV2 (partV (mkV "switch") "off");
```

Here the smart paradigm (Détrez & Ranta 2012) operations `mkN` and `mkV` are responsible for predicting the inflection tables of nouns and verbs from the lemma. When the inflection is not predictable from the lemma alone then it is possible to specify extra arguments, i.e.:

```
lin mouse_N = mkN "mouse" "mice";
```

In this case the second argument of `mkN` is the irregular plural form of *mouse*. Auxiliary operations like `partV` and `mkV2` are used to set the particle or the transitivity of the verb.

Having set the basics of the lexicon we can move on to the syntax. In the abstract syntax, the syntax is represented as a collection of n-ary functions. For example, adjectival modification requires two functions, `AdjCN` and `UseN`:

```
cat AP; CN
fun AdjCN : AP -> CN -> CN
fun UseN : N -> CN
```

This yields to two syntactic categories: adjectival phrases (`AP`) and common nouns (`CN`). The simplest common noun consists of just a single noun (`N`) and is produced by the function `UseN`. The function `AdjCN` lets us to modify the noun with one or more adjectival phrases. How exactly the adjectival phrases are attached is language specific.

In English, there is no gender and the adjective is always before the noun. The linearizations for `AdjCN` and `UseN` are simply:

```
lincat AP = Str
lincat CN = Number => Str

lin UseN n = n
lin AdjCN ap cn = table {Sg => ap ++ cn ! Sg;
                         Pl => ap ++ cn ! Pl}
```

Note that when building common noun phrases it is still not known whether the phrase should be used in singular or in plural. It will remain unknown until a determiner is fixed and a complete noun phrase built. For that purpose, the linearization category for `CN` is an inflection table indexed by number just like for the `N` category. Since the linearizations for `CN` and `N` are the same, the linearization rule for `UseN` is just the identity function. Since I have defined the linearization for adjectives to be a plain string, the linearization for `AdjCN` simply concatenates the adjective phrase in front of the common noun. Here the `(++)` operator indicates concatenation of token sequences, and the exclamation mark `(!)` is used to fetch the element from the table that corresponds to a given parameter.

Note that the two elements in the table of the last example are identical except that they select different numbers. There is a handy shorthand notation for this case:

```
lin AdjCN ap cn = \\n => ap ++ cn ! n
```

Here the operator `(\\)` creates a table whose index is the variable `n`. After the double arrow `(=>)` is the value itself, which is defined by using the variable `n`. When I substitute `n` with `Sg` and `Pl` I get the same values as in the previous example.

In French, the adjectival modification requires gender and number agreement. In addition, the adjective is sometimes put before and sometimes after the noun. This means that we need a more complex linearization type for `AP`:

```
lincat AP = {s : Gender => Number => Str;
             isPrefix : Bool}
```

This type consists of an inflection table for the adjective and a Boolean parameter which determines whether the adjective should be placed before or after the noun. The linearization rule for `AdjCN` now is:

```
lincat CN = {s : Number => Str; g : Gender}
lin AdjCN ap cn = {
  s = \\n => let
               aps = ap.s ! cn.g ! n;
               cns = cn.s ! n
             in case ap.isPrefix of {
                  True  => aps ++ cns;
                  False => cns ++ aps
                }
  g = cn.g
  }
```

Here, in the `let` expression I first compute the right forms of the adjective and of the basic common noun. After that, I concatenate them in the right order depending on the parameter `isPrefix`. Note that `cn.g` is used in two different places. First it gives the right gender to use for the adjective, and second it is used to propagate the gender from the smaller common noun which is an argument of `AdjCN` to the bigger phrase. The rest of the syntax is built in a similar fashion by adding more and more syntactic combinators.

This section had the goal to demonstrate the essential features of GF and how these make it possible to hide language-specific details. In the abstract syntax I merely say that there are adjectives and nouns and that those can be combined together. How exactly this happens is determined by the concrete syntax. In this way, the abstract syntax can stay language-independent while all language-specific features can still be handled. It could be rightfully argued that the level of abstractness as it is presented so far is still not sufficiently high. For example, I still assume that all languages have adjectives and nouns, which might be questioned for some languages. It did, however, work for the 30+ languages that are already supported in the framework. The most important problem that I will address in the next section, however, is that what is an adjective, noun, or verb in one language might not belong to the same part of speech in another language. This is a source of non-compositional constructions and multiword expressions that need to be handled on a different level in the framework.

3 Constructions and multiword expressions in GF

I shall divide expressions in two non-overlapping classes since they are handled differently in GF. The first class are expressions that have meaning only as a whole and that cannot be understood by interpreting their parts compositionally. Examples for those are *by and large*, *after all*, *long time no see*, *instead of*, *because of*, etc. Such expressions are composed of smaller units which have in general their own semantic and syntactic uses, but inside the expressions they are just tokens constituting a larger unit. MWEs cannot be parsed by using meaningful grammatical rules. For instance, in order to parse *instead of* compositionally, a syntactic rule could be added, which combines an adverb and a preposition to form another preposition:

```
fun foo : Adv -> Prep -> Prep
```

A rule like this would have no other use but to cover controversial syntactic sequences which do not have any compositional meaning anyway. This makes even less sense in a multilingual setting, since the internal structure of those expressions in English does not persist in other languages. In Swedish, for instance, *because of* translates as *på grund av*, and in Bulgarian, *instead of* translates as *vmesto*. In both cases the translation is another prepositional expression, but its internal composition is very different. The solution is very simple: to ignore the bogus internal composition of those expressions and to add them as multiword units in the lexicon:

```
fun instead_of_Prep, because_of_Prep : Prep
lin instead_of_Prep = mkPrep "instead of"
lin because_of_Prep = mkPrep "because of"
```

The implication of this choice is that the parser in GF (Angelov 2011) has to work, not on the level of words, but on a different, more semantic level. In the case of multiword expressions, this semantic level is a cross-words level, and, in agglutinative languages, it is often a sub-word level (Angelov 2015). This complication means, for instance, that unlike in most other statistical parsers, GF parsing is not done on top of a part of speech tagged input. Instead, the parser performs both parsing and tagging, where a single tag might span several tokens or conversely only a part of a token.

A subclass of non-compositional expressions is the class of phrasal and prepositional verbs. Examples of those were shown in the previous section. The complication in this case is that they are not only composed of multiple words but the words are not even consecutive. Unlike in frameworks based on context-free grammars, in GF this is a trivial matter. Discontinuous expressions are modelled by simply using more than one string fields inside a record. On a low-level both tables and records in GF are modelled as tuples of strings which reduces the formalism to a Parallel Multiple Context-Free Grammar (PMCFG, Seki et al. 1991) which is beyond context-free grammars. When an expression is embedded in a sentence, then the syntactic rules know where to put each of the constituents. The assumption, however, is that all lexical units of the same type have the same types of discontinuities. For instance, the linearization type for all two-argument verbs in English is:

```
lincat V2 = {s : VForm => Str; part : Str; prep : Str}
```

However, only some verbs have particles and only some others have prepositions. In a monolingual grammar it is possible to split the category into a category for simple verbs and a category for phrasal/prepositional verbs but this does not scale across languages. Phrasal verbs in English, for example, are often translated to simple verbs in Slavic languages, where the information from the particle is encoded as a prefix attached to the root. Conversely, simple verbs in English might become prepositional verbs in other languages or vice versa.

The second class of expressions is those that have both a compositional and a non-compositional meaning. It is often the case that the second is the most frequent meaning but the former cannot be excluded either. Since GF is a multilingual framework, the most natural way of identifying multiword expressions is cross-lingual. If an expression has a non-compositional meaning then it is quite likely that it will be expressed in a very different way in another language. This is a very empirical criterion which makes it easier to detect multiword expressions, but on the other hand, it fuses multiword expressions with constructions. Basically anything with a non-compositional abstract syntax across languages is considered a multiword expression. This kind of expressions is obviously a problem in an interlingua-based system.

The solution is to identify and factorize expressions. Figure 1 shows the abstract syntax trees for the sentences *My name is John* in English and the equivalent *Ich heiße John* in German. The translation is non-compositional because English has no equivalent for the German verb *heißen*. In a transfer-based translation system, I would have to explicitly manipulate the trees to get the one from the other. In an interlingual system I can factorize.

We add in the abstract syntax a new function which takes as input all fragments from the individual trees that stay invariable. In each of the concrete syntaxes we define that the function produces the corresponding language specific trees where the invariable subtrees are just plugged in the right places. In the particular case we would get:

Abstract:

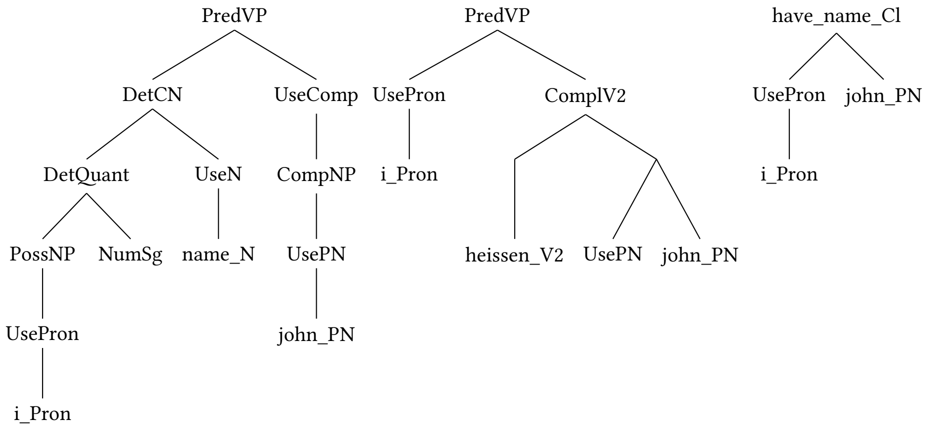
```
  fun have_name_Cl  : NP -> PN -> Cl
```

English:

```
  lin have_name_Cl p n = PredVP (DetCN (PossNP p) (UseN name_N))
                                (UseComp (CompNP (UsePN n)))
```

German:

```
  lin have_name_Cl p n = PredVP p (CompV2 (mkV "heissen") (UsePN n))
```



a) My name is John b) Ich heiße John c) Factorization

Figure 1: An example for non-compositional abstract syntax

The new function takes as arguments the subject (`NP`) and the proper name (`PN`) and produces a clause (`Cl`). In the German example the subject is actually the pronoun *ich* with an abstract syntax `UsePron i_Pron`. In English, on the other hand, the syntactic subject is *my name* but we are only interested in varying *my* so the argument `UsePron i_Pron` is wrapped with `PossNP` which in English generates a possessive determiner from an `NP`, i.e. from *I* we get *my*. The determiner is then applied to the noun *name*. The result is of category clause which is the same as a sentence except that it has variable tense and word order. This makes it possible to reuse it for building relative clauses, questions and sentences. We can also inflect it in tense and polarity. This means that it is enough to factorize the construction only once and then it automatically becomes available in all possible forms. Once we have the new abstract function then we can use a language-independent tree as shown on Figure 1c.

Note that in the linearization rules, unlike in the lexicon and in the syntax of the grammar, tables and records were not used. Instead we are free to reuse the already existing syntactic functions that are available in the grammar. In the previous section, how to define functions, such as `AdjCN` and `UseN`, was introduced. These functions can be used not only for parsing/generating sentences but also inside the definitions of new functions. This is exactly what is done here and thus, a lot of low-level details can be avoided.

For lexical units we can either reuse existing lexical definitions like `name_N` or define locally new ones like `mkV "heissen"`. This is handy since nouns like `name_N` are more common across languages and thus we would probably want them in the general lexicon anyway. On the other hand, verbs equivalent to *heißen* can be found in only some languages.

The previous example can be explained as a construction which differs across languages because of a lexical gap, i.e. the missing *heißen* verb in English. However, exactly the same solution can be also used for pure idioms. For example, a prototypical multiword expression like *kick the bucket* in English can be defined as a lexical verb phrase:

```
fun kick_the_bucket_VP : VP
lin kick_the_bucket_VP = ComplSlash (SlashV2a kick_V2)
                                    (DetCN (DetQuant DefArt NumSg)
                                           (UseN bucket_N))
```

A translation to another language could be realized either as a single verb equivalent to *die* or as another idiom. In either case the translation should still function as a verb phrase. Note that the verb phrase above is not just a complicated way to encode the string *kick the bucket*. When the expression in the example is evaluated it is reduced to a complex data structure which, among other things, contains all inflection forms of *kick* as well as all auxiliary verbs that must be used for forming the different tenses in English.

The common feature between the last two examples is that in both cases we have to move from lexical categories such as noun and verb to a higher-level syntactic categories. For example instead of assuming the existence of a specific verb we just assume that there is a specific verb phrase or a sentence that conveys the same meaning. Similarly instead of nouns we use noun phrases and instead of adjectives – adjective phrases. Basically we move upwards in the hierarchy of syntactic categories until we reach a level where the differences across languages are entirely contained within the selected category.

If the multiword expression contains variable parts then they become arguments of the abstract syntax function. The order in which the arguments are listed in the type of the function is completely irrelevant since in the concrete syntax we are free to use the arguments in an arbitrary order regardless of the order in which they are declared. It is just by convention that we usually choose to use the order in which they are used in English. Note, however, that this freedom does not come for free. For instance, most statistical PMCFG parsers assume that the arguments to a function are used in the order in which they are defined. This assumption is always satisfiable if the grammar is monolingual but in a multilingual setting there is simply no natural order. Moreover, the grammar in a typical statistical parser is learned from corpora and is generally not intended to be interpreted, so any argument order is just as good. In contrast the typical GF grammar is developed by a grammarian who might have his/her own aesthetic preferences.

Using functions with arguments is just one of the ways to make a multiword expression variable. Sometimes general modifiers are admitted in the middle of an expression. Typical examples are light verb constructions such as *I am back* which also admit modifications like *I am* ***already*** *back*. It is not difficult to model the verb phrase `copula+back`:

```
lin am_back_VP = UseComp (CompAdv back_Adv)
```

What is not visible here, however, is that the computed verb phrase is discontinuous. The two important parts are an inflection table with all forms of the copula and a second field which contains the argument of the copula, i.e. the adverb *back*. Now if we modify the new lexical verb phrase:

```
AdVVP already_AdV am_back_VP
```

then the Resource Grammar automatically knows that the adverb *already* should be inserted between the copula and the argument. The insertion is possible only because of the discontinuity of the verb phrase. Note also that the same adverbial modification in another language may not require discontinuity. For example the equivalent in Bulgarian for *I am back* consists of a single verb and then the adverb is placed before the verb. None of this, however, is visible in the abstract syntax.

In general the ability of the framework to deal with discontinuous phrases is heavily exploited in the resource grammar. It is one of the most powerful features that allows us to hide language specific details and it helps in the implementation of some constructions.

4 Libraries of constructions in GF

Constructions and multiword expressions are really abundant in any natural language, and it is part of our mission to collect and organize GF resources for as many languages as possible. The main realization of that mission, so far, is the RGL. In the recent years we have also started to collect general lexical resources. Ultimately we would like to have a Resource Lexicons Library with a multilingual translation lexicon for many languages. Even that is not the end and we should also consider collecting libraries of constructions. There were two pilot projects in that direction: Gruzitis et al. (2015) and Enache et al. (2014).

In Gruzitis et al. (2015) the goal is to formalize the Swedish Constructicon (Lyngfelt et al. 2012). The original constructicon is a semi-formal database which covers common constructions in Swedish relevant for second language learners. There is also an ongoing work to link the resource with the Berkeley Constructicon for English (Bäckström et al. 2014). The focus, however, is in language learning rather than parsing or translation. As such it was not the primary goal to organize the constructicon as a formal grammar usable for automatic processing. Instead each entry in the resource combines an informal textual description with a syntactic pattern written in a semi-formal style. The syntactic patterns were parsed and converted to GF rules which extend the Swedish Resource Grammar.

The original constructicon contains 374 entries of which the project focused on the 105 constructions for verb phrases. Due to inconsistencies in the original resource in the first round only 43 out of the 105 constructions were successfully converted. After several iterations of manual inspection and correction, the number of successful constructions increased to 93. The remaining cases were consistently annotated but are corner cases that are currently not supported by the conversion algorithm. The necessary corrections and inconsistencies were sent back to the developers of the constructicon and are fixed by now. The experiment, however, clearly showed the advantage of using a formal system that can guard against accidental errors that are imminent in a free text format.

At the end each of the constructions was converted to one or more GF functions which in total resulted in 127 abstract functions. For 98 out of these 127 abstract functions, the corresponding concrete syntax was also successfully constructed automatically. A logical continuation of the project would be to also convert the aligned entries from the Berkeley Constructicon and later to add other languages.

Enache et al. (2014) started from a much lower level and tried to find candidates for multiword expressions from the Wikitravel phrase collection in English, German, French and Swedish. The general idea is that, given a pair of parallel sentences, the algorithm extracts all possible abstract syntax trees for each sentence and if there is no common abstract tree for both sentences, then the pair must contain a non-compositional expression. The candidates are then manually examined and the new constructions are added in a library of constructions. The majority of constructions found in this way span over larger syntactic structures and are thus above the level of a simple lexicon. For example out of 171 candidates 142 expressions were syntactic. They can be roughly classified as: greetings, weather reports, time expressions, money, units of measurement and spatial deixis. The remaining 29 expressions are lexical. For example *locker* in English translates as *låsbart skåp* ('lockable closet') in Swedish.

Another experiment in Enache et al. (2014) is to learn a lexicon of compound nouns between English and German. The method uses automatic word alignment in a parallel corpus. The candidates for compounds are pairs of phrases where: the English side must be parsable as a noun phrase with the GF grammar, the German side must consist of a single word, and finally the overall probability for the pair must be above a fixed threshold level. The compound nouns extracted in this way were added to the lexicon of a statistical machine translation system and the evaluation showed a noticeable improvement in the BLEU score.

5 Application grammars

The discussions so far were on the level of the Resource Grammars. The typical GF applications, however, never use the resource grammars directly. Instead they are used as libraries to build application grammars. The main difference is that while the abstract syntax of a resource grammar describes some kind of abstracted syntactic level, the application grammar describes an abstracted domain semantics. Another way to see the difference is to think about the abstract syntax of the application grammar as an ontological language for describing the application domain. The abstract syntax of the resource grammar, on the other hand, is an ontology which describes the syntactic constructions that someone would expect to find in a natural language.

While in the resource grammar we work with categories like noun phrase and verb phrase, in the application grammar we switch to semantic categories like person, agent, food, drink, etc. The abstract syntax functions, on the other hand, are semantic predicates which take, for instance, an agent and a drink and produce a statement like:

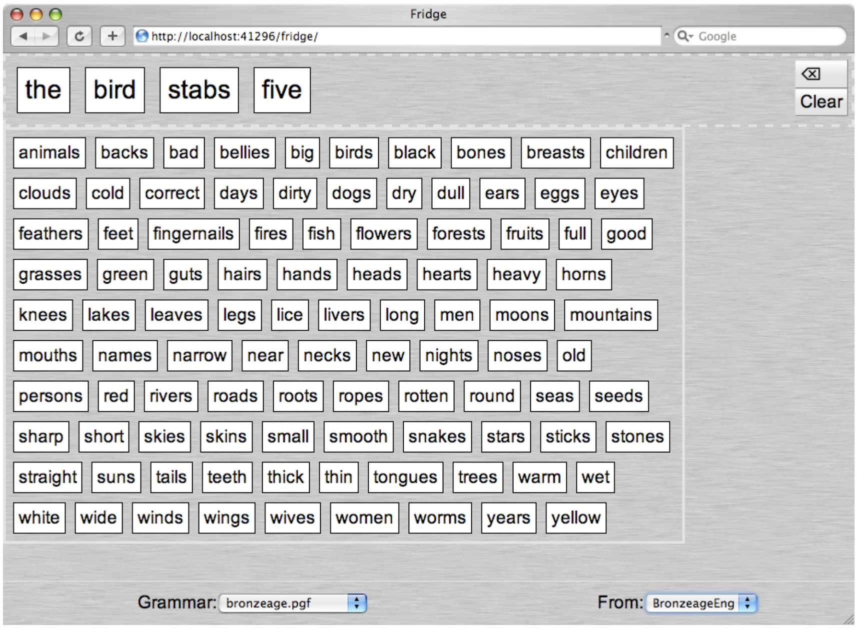
someone`(person)` *drinks something*`(drink)`

The main role of these new semantic categories is to provide sortal restrictions on the types of nouns that can be used for the different arguments of the predicates. Otherwise the predicates are implemented in a fashion that is very similar to the one for multiword expressions presented in Section 3. In particular most of the predicates are de-lexicalized which gives us more freedom to keep the abstract syntax language-independent while hiding all differences in the concrete syntax.

The sortal restrictions might be relevant for general multiword expressions as well. For example part of the annotations in the Swedish Constructicon are about semantic roles such as `Actor`, `Theme`, `Result`, etc. Those were ignored while converting the resource to GF, but it is possible that some of these constructions are valid only when the constraints are satisfied.

There are several advantages in working with application grammars. First, they are typically much smaller than the resource grammars, which also makes them computationally much more efficient. Second, since the application grammars cover only a specific domain, they can guarantee translation with publishing quality. However, when the resource grammars are used directly in translation then the quality is much worse. Most of the problems can be attributed to multiword expressions which are simply not covered by the vanilla resources. Having a comprehensive grammar of multiword expressions should improve the quality a lot, but since building a general and comprehensive resource is very expensive, we currently do it on application by application basis.

The main disadvantage of the application grammars is that they lack robustness. They can analyse input conforming to the grammar but fail completely if there is even a minor violation. For that reason they are mostly used for controlled languages (Angelov & Ranta 2010) where the users must use authoring tools that help them to stay within the scope of the grammar. A screenshot of one of those tools (Ranta et al. 2010) is shown on Figure 2. With this interface the users are not allowed to enter free text but instead they compose a sentence by choosing words from a list of options. The sentence is built incrementally and at each step the list contains only words that are permitted as a possible next word in the sentence.


Fridge
http://localhost:41296/fridge/
Google
⌫
Clear
animals backs bad bellies big birds black bones breasts children
clouds cold correct days dirty dogs dry dull ears eggs eyes
feathers feet fingernails fires fish flowers forests fruits full good
grasses green guts hairs hands heads hearts heavy horns
knees lakes leaves legs lice livers long men moons mountains
mouths names narrow near necks new nights noses old
persons red rivers roads roots ropes rotten round seas seeds
sharp short skies skins small smooth snakes stars sticks stones
straight suns tails teeth thick thin tongues trees warm wet
white wide winds wings wives women worms years yellow

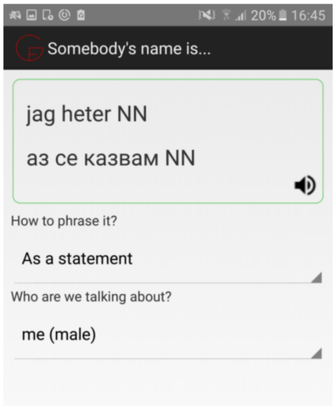
the bird stabs five

Grammar: bronzeage.pgf From: BronzeageEng

Figure 2: An authoring interface for writing Controlled Languages

The controlled language authoring is useful only when the grammar is restrictive. If the same interface is used with the resource grammar, then since there are very little restrictions, almost every word can appear almost everywhere. The analysis of a strange combination of words, however, could be equally strange. The other disadvantage of that interface is that it is not possible to get an overview of all constructions that are available in the grammar. In a sense, that interface gives us the ant's point of view which sees each word one by one. What we sometimes want is the bird's view which sees the grammar from the top.

One such interface was developed in Hedström et al. (2016). With that interface the user is first presented with a list of all possible constructions. When a particular construction is chosen then he/she is guided to a customization interface like the one on Figure 3. There the user sees an example of the construction rendered in two languages. Below the example, there is a list of options that can be used to customize the construction. On the figure, the example is the construction is `have_name_Cl` from Section 3 rendered in Swedish and Bulgarian. The possible customizations are to turn the construction from a statement to a question or to change the subject, i.e. *Who are we talking about?*.


Somebody's name is...

jag heter NN

аз се казвам NN

How to phrase it?

As a statement

Who are we talking about?

me (male)

Figure 3: A browsing interface for an application grammar

This particular interface is not restricted to controlled languages. It can be configured to work with any grammar where the configuration describes which phrases should be included in the browser. For example, if it is coupled with the resource grammar, then it is not necessary to make the whole of the grammar visible. Instead the browser can only include phrases that are relevant for a particular purpose. For example, the interface is currently used in an offline mobile translation application (Angelov et al. 2014) which can translate free text. The browsing interface, however, does not expose the entire grammar, and instead it only covers common tourist phrases for which we can guarantee publishing quality.

6 Wide coverage grammars

The resource grammars and the application grammars are the two main types of grammars that we usually deal with in GF. Just in the last few years, however, we have started scaling up the framework to an open domain. The milestone that made that possible is the numerous improvements in the compiler and the interpreter for bigger grammars, and in particular the improvements in the GF parser (Angelov 2011).

There are two challenges that we have to deal with in the open domain. The first is robustness and the second disambiguation. We get the robustness by using a wide coverage grammar which basically consists of the resource grammar plus a large lexicon. On top of that we added minor extensions that deal with ungrammatical input. The disambiguation relies on a statistical ranking trained on the Penn Treebank (Angelov 2011).

As we mentioned earlier, translation via the vanilla resource grammar is far from perfect. We compensate, however, by plugging a high-quality application grammar for a particular domain. By combining the two we get decent quality as long as we stay close to the target domain. For example, Ranta et al. (2015) reports BLEU scores above 70% for technical descriptions of places and objects related to accessibility by disabled people. Translations outside of the domain are still possible thanks to the resource grammar.

Again, one of the major roles of the application module in the wide-coverage translator is to provide proper translations for non-compositional expressions. We expect that scaling further the quality of the generic translator will also critically depend on the availability of a wide-coverage resource of constructions.

7 Conclusion

In general we have no doubt that GF can cope with multiword expressions. Almost every application grammar in GF must deal with some of them. Moreover, we often have to deal with constructions across languages. The key enabling device to allow variability in the constructions is the fact that the framework allows for discontinuities. The interesting challenge that we see, however, is how to collect a good inventory of constructions. Our current case by case solution does not scale well for open-domain applications.

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