Formal Description of Some Linguistic Phenomena in Croatian by Lexical-Functional Grammar (LFG)

Sanja Seljan

Summary

Lexical-Functional Grammar (LFG) supports several distinct but interrelated levels of analysis: lexical level, constituent, argument and functional structures that integrate morphological, lexical, syntactic and semantic information. Linguistic phenomena are analyzed by grammatical functions presented in the lexicon and integrated in functional structure, after which this grammar has been named.

Belonging to the group of context-sensitive grammars, LFG is supposed to describe words in context. As the main idea of this grammar is to use grammatical functions that exist in natural languages, it is tends to be suitable for description of highly structured languages and for languages with free word order. LFG is generative non-transformational grammar that integrates knowledge from informatics, linguistics and logic.

Although it uses two main levels of representation, functional(f-) structure that tends to be universal across the languages when describing one linguistic phenomena and constituent (c-)structure that is specific for the language, other levels are also mentioned, such as lexical analysis and argument structure. LFG has been used until now for text analysis, text generation and machine translation.

Since the Croatian language has relatively free word order and rich morphological system, one of the central questions is case-marking and formal description of agreement. I propose that the Croatian morphology has a recursive binary structure, which allows association of the first part of the word, which is marked as word category and, possibly marked with semantic constraints, with last part, i.e. with paradigmatic endings.

Sentences are generated by syntactic rules, passing after that through semantic constraints marked in the rules or/and the lexical units. The possibility of decomposing into binary features enables adding of new constraints or introducing contextual elements, which is important characteristic of contextual formal grammars. The theoretical formal descriptions for the Croatian language is tested on the Avery Andrew's LFGW model, developed at University of Brisbane.

Key words: formal grammar, lexical unit, grammatical function, functional structure, constituent structure, argument structure, unification, constraints

Sažetak

Leksičko-funkcionalna gramatika (LFG) podržava nekoliko različitih ali međusobno povezanih prikaznih razina: leksičku razinu, konstituentsku, argumentnu i funkcionalnu razinu na kojima se udružuju informacije morfološke, leksičke, sintaktičke i semantičke obrade jezika. Osnovna ideja ove formalne gramatike jest da se jezične pojave analiziraju preko gramatičkih *funkcija* prikazanih u *leksikonu* i integriranih u funkcionalnu strukturu, otkuda i proizlazi ime *leksičko-funkcionalna* gramatika.

Pripadajući u skupinu kontekstnih gramatika , ova bi gramatika trebala ponuditi formalna sredstva za opis riječi u kontekstu. Temeljna ideja LFG modela jest upotreba gramatičkih funkcija koje postoje u svim prirodnim jezicima, što je jedan od preduvjeta za primjenu ove gramatike u visokokonfiguriranim jezicima, kao i u jezicima sa slobodnim poretkom riječi. LFG je generativna netransformacijska gramatika koja primjenjuje znanja iz informatike, lingvistike i logike.

Iako koristi dvije osnovne prikazne razine, funkcionalnu (f-) strukturu koja bi trebala biti univerzalna kroz različite jezike u opisu iste jezične pojave i konstituentsku (c-) strukturu koja je specifična za svaki jezik, prikazane su i druge razine kroz leksičku i argumentnu strukturu. LFG model do sada je primjenjivan u analizi teksta, u generiranju i u strojnom prevođenju.

Obzirom da hrvatski jezik ima relativno slobodan poredak riječi i bogati morfološki sistem, jedno od središnjih pitanja je formalno određivanje padeža i formalni opis slaganja. U radu se predlaže primjena rekurzivne binarne strukture, koja omogućava konkatenaciju prvog dijela riječi označenog kao kategorija

riječi te eventualno obilježenog semantičkim ograničenjima sa drugim dijelom, odnosno sa paradigmatskim nastavcima.
Rečenice se najprije generiraju preko sintaktičkih pravila, a zatim prolaze testove ograničenja koja su unesena u leksikon ili dodana u generativna pravila. Mogućnost rastavljanja na binarna obilježja omogućuje dodavanje novih ograničenja i unošenje kontekstualnih elemenata, čime navedeni formalni model posjeduje svojstva kontekstualnih formalnih gramatika, što je jedan od temeljnih preduvjeta za formalni opis hrvatskoga jezika.

1 INTRODUCTION

Lexical-Functional Grammar is formal non-transformational generative grammar used to describe various linguistic phenomena in a variety of languages (English, German, Italian, Russian, Arabic, Chinese, Polish, Bantu, Korean, French, Japanese, Arabic etc.). The term LFG first appeared in 1982 in "The mental Representation of Grammatical Relation" edited by Joan Bresnan.

The basic idea of this formal grammar is to analyze linguistic phenomena by grammatical *functions* presented in the *lexicon* or in the functional structure (f-structure), after which this grammar is *named Lexical-Functional* Grammar. This idea to subcategorize grammatical functions and not syntactic categories, make the LFG model suitable for highly configurational and for non-configurational languages.
Since all natural languages have grammatical functions, this grammar tends to be universal, enabling at the same time representations specific for the language in question.

The LFG model is formally characterized as *context-sensitive* grammar, suggesting that words are observed in the context and not isolated one from another. This characteristic is important for describing languages with free order, such as the Croatian language with rich morphological system. Context-sensitive grammars enable to formally describe case marking and various types of *agreement* (between subject and the verb, inside of noun phrase, agreement in passive sentences between subject and past participle, in composed tenses, etc.).

Decomposition of categories on characteristic features and grouping of the categories having the same features (e.g. Refl=+, Neg=+, Coll=+) enable adding new features and incorporation of contextual elements important for resolving of the case-marking problem.

LFG is one of Unification Grammars, using the concept of *unification*, after which the formalisms are named *unification formalisms*. It enables unification of two lexical units (e.g. noun and adjective) in order to create more general structure that include all features from both structures

LFG formalism uses two basic levels of representation to describe linguistic phenomena, although other levels have also been added.
Syntactic analysis is given by *constituent structure* (*c-structure*) that exists simultaneously with *functional structure* (*f-structure)*. While c-structure varies through languages (principle of variability), the f-structure is claimed to be universal (principle of universality).

Aiming to unify *computational efficiency* and *linguistic theory*, this grammar unifies the knowledge from informatics, linguistics and logic. LFG is more restricted than Transformational Generative Grammar, but its application in informatics and has been used for text analysis, text generation and machine translation.

2 GRAMMATICAL FUNCTIONS AND SUBCATEGORIZATION

One of the main ideas of the LFG model is to subcategorize grammatical functions, and not syntactic categories. Grammatical functions in LFG play an essential role. One syntactic category can have more grammatical functions, and one grammatical function can be presented by several word categories.

2.1 Subcategorization

As it has already been mentioned, grammatical functions are regulated through predicate-argument structure that encodes restrictions in subcategorization frame, i.e. completeness and coherence. Every form that has a PRED feature is known as a *semantic form*, which is graphically represented in single quotes. Forms that subcategorize one or more functions are known as *lexical forms*.
The same verb can have several different predicate-argument structures, e.g. the verb *pitati*. It can demand only subject, or subject and direct object. If an object is the whole sentence, then it is called *complement*. The prepositional structures (i.e. adjuncts) can be added to every sentence, but it doesn't have to be explicitly noticed. Adjunct is the only grammatical function that is not subcategorizable.

(↑PRED)='pitati <(↑SUBJ)> '	*On je pitao (u školi).*
(↑PRED)='pitati <(↑SUBJ) (↑OBJ)> '	*Profesor pita gramatiku (na ispitu).*
(↑PRED)='pitati <(↑SUBJ) (↑COMP)>'	*Dječak pita da prijatelj čuje istinu (prije ostalih).*

2.2 Classification of grammatical function

LFG grammar is quite rare grammar that uses the grammatical functions in the traditional sense (subject, object, etc.) although there are some modifications comparing to the traditional grammar as some new distinctions in function categorization are introduced.

According to Bresnan grammatical functions are universal semantic primitives, introduced in syntactic rules or in lexical units. Grammatical functions can be grouped according to two distinctive characteristics:

- (non)subcategorizable functions
- semantically (un)restricted.

According to *subcategorization criteria*, argument functions, i.e. subcategorizable functions are noted in the subcategorization frame, such as *Subj, Obj, Obj$_2$,, Obl$_\theta$(Prep-Obj), Comp, XComp, Poss*. Function Obj$_2$ marks the second object, and the function *Obl$_\theta$(Prep-Obj)* an oblique function, i.e. preposition and object.
Unsubcategorized function *Adjunc*t marks independently added constructions, that are not subcategorized and it is not necessary for sentence comprehension. Adjunct function is mobile inside the sentence.

Semantically unrestricted functions can be related to thematic or non-thematic roles, such as *it* in English, *il* in French. Non-thematic subject is noted outside of signs < >. These are *Subj, Obj* and *Obj$_2$.*

Semantically restricted functions are closely related to the semantics, and can be paired only with thematic roles. These are *Obl$_\theta$(Prep-Obj), Comp, XComp, Poss*. The function *Poss* marks the possessive genitive, always paired with thematic role.

2.2.1 OPEN AND CLOSED FUNCTIONS

Another distinction is between *open and closed functions* of complements and adjuncts. Complements are essential parts of argument structure (part of subcategorization frame), while adjuncts provide additional information and are not required grammatically.

Complements and adjuncts may be either *closed* (when subjects are expressed) or *open* with prefix X (lacking subject argument, which is then controlled by another argument in the sentence.) Open complements (XComp) or open adjuncts (XAdj) may be any lexical category (AP, NP, VP, PP). Subject or object of the main predicate control open complements. Closed complements contain all arguments required for interpretation **(***Ivica misli da će svi doći*), where the subject can be phonetically null (equivalent to PRO).

Closed functions (*Comp, Adjunct*) are semantically complete, containing all elements necessary for analysis (e.g. Comp - *On kaže da će svi prijatelji doći na rođendan,* Adjunct - *Kao da se srami, on je bio tiho*). Open functions (*XComp, XAdjunct)* mark clauses without expressed subject, which is then controlled by some other element inside the whole sentence (e.g. XComp - *Marica smatra Ivicu pametnim, Ona je dobra, On želi otići*; XAdjunct – *Sigurna u pobjedu, Janica se natjecala*).

(↑PRED)= 'smatrati <(↑SUBJ) (↑XCOMP)> (OBJ)' *On smatra Ivu prijateljem*.
(↑OBJ)= (↑XCOMP SUBJ)

(↑PRED)='voljeti <(↑SUBJ) (↑XCOMP)>' *Djeca vole čitati. / Dječak voli spavati*.
(↑SUBJ)= (↑XCOMP SUBJ)

In the first example, control equation sets the object of the main predicate, which is equal to the Subject of the XComp. This is formally indicated in f-structure by coindexing.

In the second example, subject of the main predicate is equal to the Subject of XComp, i.e. to the Subject of the infinitive. This type of control is called *grammatical or functional control*. It is important to note that Subject of XComp is not present in c-structure. In f-structure it is introduced by lexical information contained in the lexical entry.

3 LEVELS OF REPRESENTATION

LFG supports several distinct, but interrelated levels of representation. Some authors indicate two main levels of representation to LFG model (*c- and f-structure*), while others support one or two levels more (*lexical and argument structure*). In 1989, Bresnan and Kanerva added *argument structure* as a transitive structure between constituent and functional structure.

Therefore, there are four structures that can be distinguished, although not strictly separated:
- lexical structure
- constituent or c-structure
- argument or a-structure
- functional or f-structure

C-structure corresponds to the superficial phrase structure and works closely with an enriched lexical component. C-structure exists simultaneously with f-structure that integrates information from the lexicon and c-structure.
A-structure is in fact contained in the lexical level, but afterwards it has been separated as a transitive structure between c- and f- structures, pointing out the assignment of grammatical functions (e.g. subject, object, complements) to thematic roles (agent, theme, goal, etc).

3.1 Lexical structure

Lexicon is in LFG model the central point containing grammatical relations between predicate-argument structure and grammatical functions. Lexical unit is connected to the morphological component.

The lexical entry includes different type of information:
- form of the item (*slika, idemo, Ani, lijepe, čitaju*, etc.)
- syntactic category (N, V, Adj, etc.)
- functional schemata containing information about meaning inside of quotes ‘ ‘ and grammatical functions (*subject, object etc.)* interrelated with thematic roles (*agent, theme, etc.*)

zatvara V (↑PRED)= 'zatvoriti <(↑SUBJ) (↑OBJ)>'
(↑NUM) = SG
(↑PRS) = 3
(↑TNS) = PRES

These type of equations called *constituent* equations are incorporated into functional structure, contrary to the constraining equations that serve only to verify the truth (for e.g. to verify agreement between demonstratives or adjectives with noun inside of noun phrase).

3.2 Constituent (C-) structure

C-structure encodes the linear order, hierarchy and syntactic categories. This structure is specific for every language. As it has language specific annotations, grammatical functions may appear in specific syntactic positions.

C-structure can be presented in two ways:

- by context-free rules that contain expressions known as functional equations
- by the annotated phrase tree structure satisfying relations of precedence and domination

For the reasons of commodity Kaplan and Bresnan have introduced metavaribles (↑ and ↓) representing every node in the tree. ↑ is the sign for the node immediately dominating the constituent, under whom the arrow is placed, i.e. it is the sign for the function of the dominating node. ↓ indicates the node itself. The terminal nodes are lexical units.
Annotated rules for the sentence *Djeca gledaju film:*

S →	NP (↑SUBJ)=↓	VP ↑=↓
VP →	V ↑=↓	NP (↑OBJ)=↓
NP →	(Adj) ↑=↓	N ↑=↓

The first rule says that the sentence is composed of noun phrase (NP) and verb phrase (VP). The annotation (↑SUBJ)=↓ says that the NP is the subject in the preceding node (S). The ↑ indicates that the features of that node are shared with the higher one.
C-structure is the tree structure derived from the context-free annotated rules reflecting the surface structure of the sentence.

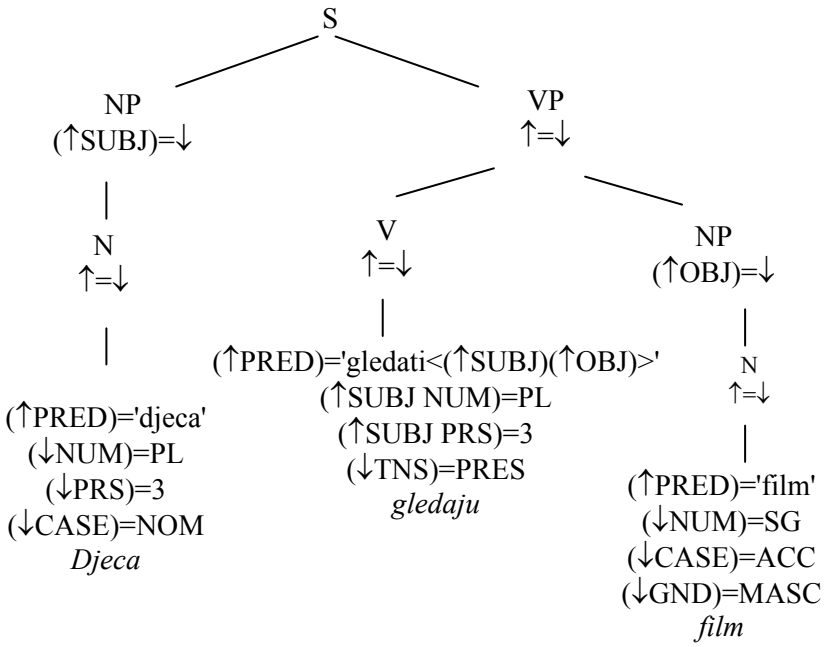

Fig.1. Annotated C-structure for sentence
Djeca gledaju film.

3.3 Argument (A-) structure

One of the basic assumptions of LFG is that grammatical functions are regulated through the predicate-argument structure found in the semantic form paired with PRED. Semantic forms appear graphically as material flanked with single quotes as PRED='Ana', PRED='kuhati (↑SUBJ)(↑OBJ)'). Verbs always incorporate predicate-argument structure.

Although we were already talking about it in the lexical structure, it will be presented as a separate level. The lexical entry consists of pairing of arguments and functions. If we transform the sentence from active voice into passive, the principle of *Function-Argument Biuniqueness* must be valid. According to this principle each argument can be associated with only one grammatical function (even if the assignment is ∅ like in the sentence *Ivica čita* (*John is reading*). No grammatical function can appear more than once.

The association of grammatical functions to semantic arguments is established by recording the names of functions in a given argument position. Predicate-argument structure also determines which structures can be subcategorized.

Tomislav voli Marka.	(SUBJ) (OBJ)	
'voljeti	(agent, theme)'	SUBJ → ∅ / OBLcase
		OBJ → SUBJ
Marko je voljen.	(∅) (SUBJ)	
'voljen	(agent, theme)'	

The verb *'voljeti'* is a two-place predicate, where the PRED feature has as its value the meaning of the verb, subcategorizing subject and object.

In the case that subject is not alive, i.e. it is non-thematic, it is placed outside the signs <>. In that case the subject can be thematic and non-thematic.

On ju smatra ozbiljnim kandidatom.

smatrati V (↑PRED)= 'smatrati < (↑SUBJ) (↑XCOMP) >(OBJ)'
(↑OBJ)= (↑XCOMP SUBJ)

Treba više čitati.

treba V (↑PRED)= 'trebati <(↑XCOMP)> (SUBJ)'
(↑SUBJ Form)= Ø
(↑SUBJ)= (↑XCOMP SUBJ)

3.4 Functional (F-) structure

Kaplan suggests the functional structure for more abstract representation and considers grammatical functions independently from the position of words in the sentence, which is especially suitable for languages with free word order.
F-structure integrates lexical and structural information from the c-structure, in the way that the lexical item placed as a terminal node of the tree, is inserted into f-structure and every

information of that lexical entry is also included into f-structure.

F-structure is presented in the form of hierarchically organized attribute-value matrix. Each pair of attribute and its value creates one characteristic feature.

Attributes may have three kinds of values:

- atomic symbols as [NUM PL] [PRS 3]
- semantic form which is indicated as the value of PRED and enclosed within '…'
  PRED 'pokloniti<(↑SUBJ)(↑OBL_{DAT})(↑OBJ)>'
- one or more subsidiary f-structures: a value of the attributes SUBJ and OBJ is again new f-structures consisting of attributes and values. The value of that attribute can be f-structure again, composed of attributes and atomic symbols. This is the case with subordinate clauses inside of which there is again new subordinate clause.

In the following example c-structure is represented in the form of tree reflecting the syntactic structure, while f-structure is presented in the form of matrix, consisting of attribute-value pair. The example is obtained using LFGW model for the Croatian language written in Amzi Prolog.

```
parsing: [ona,kaze,da,pametna,djeca,zele,nauciti,citati,.]
structure # 1
```

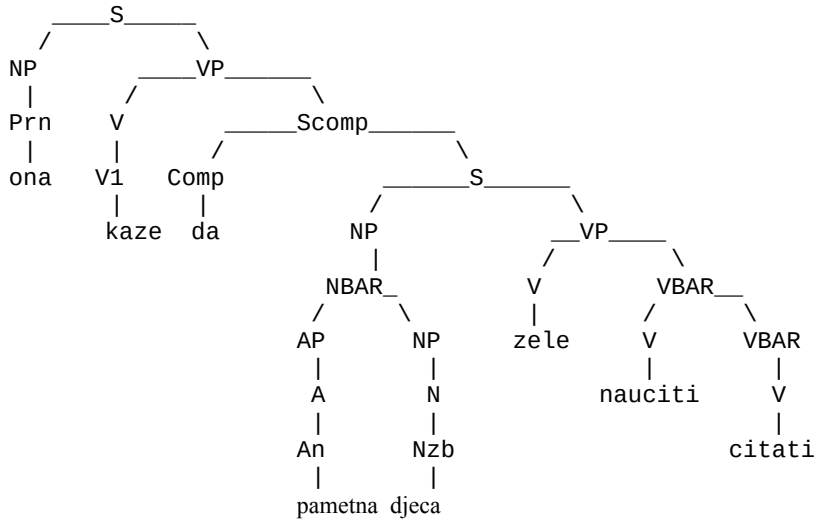

Fig.2. C-structure for sentence
Ona kaze da pametna djeca zele nauciti citati.

In the following example, the main verb is *kazati*, tense present, that subcategorizes subject and complement functions. Subject is marked as pronoun in singular, 3rd person, of feminine gender and in nominative case. The main verb of the closed complement (*da pametna djeca zele nauciti citati*) is verb *zeljeti* that subcategorizes subject *pametna djeca*, where pametna is modifier, and open complement (Xcomp) *nauciti citati*. The main verb of the open complement is *nauciti*, which demands subject and open complement. As this is open complement, subject of the verb *zeljeti*, which is marked by coindexing <5778>, controls its subject. Open complement *citati* is given in infinitive, whose subject is again controlled and coindexed by <5778>.

```
PRED  Kazati<SUBJ,COMP>
TNS  PRES
SUBJ  PRED  PRO
      NUM  SG
      PRS  3
      GND  FEM
      CASE  NOM
COMP  PRED  Zeljeti<SUBJ,XCOMP>
      TNS  PRES
      SUBJ   <5778>
            PRED  Djeca
            NUM  PL
            PRS  3
            GND  NEUT
            CASE  NOM
            MOD  PRED  Pametno
                 NUM  PL
                 GND  NEUT
                 CASE  NOM
      XCOMP  PRED  Nauciti<SUBJ,XCOMP>
             MOOD  INF
             SUBJ   <5778>
             XCOMP  PRED  Citati<SUBJ>
                    MOOD  INF
                    SUBJ   <5778>
```

Fig.3. F-structure for sentence
Ona kaze da pametna djeca zele nauciti citati.

To be valid, f-structure must satisfy tree well-formed conditions:

1) *Completeness* - Predicate-argument structure enforces subcategorization restrictions, i.e. completeness and coherence. The principle of completeness states that every grammatical function mentioned in the predicate-argument structure must be represented in the f-structure, e.g. (↑PRED)= 'voljeti <(↑SUBJ) (↑OBJ)> ' then in the f-structure values for attributes of Subject and Object must be stated. Otherwise, the f-structure is incomplete.
2) *Coherence* - The principle of coherence is inverse of completeness, meaning that every grammatical function that appears in f-structure must be governed by some argument in the predicate-argument structure. For example, if in the f-structure there are values for functions of Subject and Object and the predicate-argument structure demands only Subject (e.g. (↑PRED)= 'pasti <(↑SUBJ)>', then the f-structure is incoherent.
3) *Consistency* - According to this criteria every attribute can have at most one value. The values must be consistent. If for the given entry values are PRS=3 and PRS=2, then functional description is inconsistent.

4 Case Marking in Croatian

The term 'case' is used in LFG in a traditional sense, in order to describe use of inflections which in the Croatian language encode syntactic and semantic relations. In LFG, the case is associated with unit that comes from the lexicon. Therefore, lexical entries should include information about case features. The appropriate use of case and grammatical functions is ensured in f-structure.

One of the central questions is case marking in Croatian, i.e. composition of words: what are they made of, do these smaller parts have meanings, how do they combine and what are differences regarding to traditional grammar. Besides case marking, the formalization of agreement is also one of the most important problems to resolve, which will be discusses in another paper.

The question is quite complicated because morphemes are not used in the traditional sense in this formal analysis. In the classical grammars several grammatical morphemes can be added to the lexical one (*prijatelj-ic-a - [feminine friend]*). The morpheme *-ic* is not always a morpheme, but can be part of the stem (*majic*-a - [T-shirt]). Therefore, the same morpheme *-a* can also have two meanings (gender feminine, number plural, case genitive and gender feminine, number singular, case nominative).
The difference between Nominative singular and Genitive plural of noun *prijateljica* is in the accentuation, and, therefore, in its position in the sentence, i.e. grammatical function. Depending on the meaning on this morpheme, it is necessary to accomplish agreement with adjective (in case, number and gender) or with the verb (in person and number).

When defining cases and, therefore, grammatical functions there are several rules in Croatian: the Subject function appears in Nominative, direct Object in Accusative, indirect Object in all other cases (Genitive, Dative, Vocative, Locative, Instrumental).

4.1 Word composition

What I propose here is new way of *delimitation* inside of words, which are to be divided in two parts: the first and the last part, or beginning and end. The last part would be formalized in the sense of declination endings and the first part is marked as word category having eventually semantic constraints.

The word *prijateljica* (feminine friend*)*, would consist of two parts *prijateljic-a,* the last part consisting of declination endings for singular (a, e, i , u, e/o, i, om) or plural (e, a, ama, e, e, ama, ama). The word *prijatelj* (masculine friend) consists of *prijatelj-ø,* where the last part denotes declination endings for cases in singular (ø, a, u, a, u, u, em) and in plural (i, a, ima, e, i, ima, ima).
Quite often, there are changes on the border of merging morphemes, e.g. *knjig-a* (Nominative) - *knjiz-i* (Dative, Locative), *stric-∅* (Nominative) - *strič-e* (Vocative), *duh-∅* (Nom, sing) – *dusi* (Nom, pl), *dusima* (Dative, Locative, pl) etc. Such examples must be stated explicitly in the lexicon.

4.2 Identical forms

Another part of the problem is how to determine the case for words having the same endings for several cases (e.g. *djevojčic-e* [girls]- gender feminine, number singular, case Genitive/ Vocative

or number plural, case Nominative/ Accusative/ Vocative etc.). It is possible to introduce here syntactic limitations in order of appearance. Besides, the general rule of subject in nominative, direct object in accusative, vocative used in imperative can be very useful.

4.3 Criteria of prepositions and semantic criteria

It is possible to introduce the criteria of prepositions that require certain cases and to describe it formally. There are 92 prepositions going with only one case. It does not represent any particular problem, since each preposition is followed by exact case.

But there are 10 prepositions going with 2 or 3 cases, some of them having the same endings. Prepositions can be combined with direct and indirect Object.
The problem is to define case in prepositional phrase composed of preposition and cases having the same forms (e.g. *za prijatelja* – genitive / accusative; *u dječaka* – genitive / accusative; *prema mogućnostima* – dative / locative; autima – dative / instrumental).
One possible solution is to introduce semantic criteria, i.e. to decompose into binary values and to add some new constraints (e.g. Soc=+, Thg=+, Coll=+) marking in that way characteristic features that will be incorporated into functional structure. Therefore, the sentence where case can be marked as dative or instrumental such as *Oni idu autima*, will have different functional structure. Although the verb *ići* demands in both examples subject and indirect object functions, in one example indirect object will be analyzed as dative and in another as instrumental containing the feature Thg=+ marking the instrument.

5 CONCLUSION

LFG formalism is relatively new type of formal grammar, providing tools for description of various linguistic phenomena in highly structured and in free-order of languages. Using two main levels of representation, c-structure that varies through languages, and f-structure that tends to be universal, as well as lexical and argument structure, this grammar tries to describe formally morphological, lexical, syntactic and semantic information.
As case marking and agreement are one of the crucial problems for formal description of the Croatian language, this could be the starting point for application of the LFG grammar for some Croatian linguistic phenomena. Because of its possibility to decompose categories on characteristic features, its is possible to introduce some new features and to incorporate contextual elements, which is important characteristic for case marking and for unification. Characteristic features noted in the lexicon are the represented in then functional structure as attribute-value pairs.
Although many linguistic phenomena are described, especially for English, such as agreement, subcategorization, long-distance dependencies, clitic placement, passive and relative sentences, negation, questions, etc., there are linguistic phenomena that are not described yet, such as too long dependencies, some co-ordinated and causative structures, ambiguities etc. Although this grammar includes semantic component trying to approach as much as possible to the natural language, it doesn't offer always reliable and adequate solutions.
LFG formalism is not perfect in the sense to describe all types of linguistic phenomena, or all types of sentences, but if one is aware of its possibilities, it can be very useful for formalization of natural language, for text analysis, generation and machine translation.

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