

# The Role of the Lexicon in Lexical-Functional Grammar - Example on Croatian

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## Abstract

The LFG model is based on an enriched lexicon, which contains associations between grammatical functions and their arguments, enabling decomposition on characteristic features and is suitable for formal description of languages with a rich morphological structure and a relatively free word order. Rejecting syntactic movement of constituents as the mechanism for realization of the surface syntactic structure, it is based on the idea of grammatical functions presented in the lexicon. In the paper the role of the lexicon is presented, as well as its close interaction with constituent and functional structures. In a formalization of Croatian sentence structure based on LFG, a new type of lexicon organization has been proposed, containing grammatical functions relating to argument structure, new features and constraints. Theoretical models are verified through educational version of the LFG model.

## Vloga leksikona pri formalnem modelu LFG – primer hrvaščine

Model LFG temelji na obogatenu leksikonu, ki vsebuje povezave med slovnimi vlogami in argumenti, kar omogoča razčlenbo na značilke, ki se kažejo kot ustrezne za formalni opis jezikov z bogatim oblikoslovnim ustrojem in relativno prostim besednim redom. Model zavrača skladišne pretvorbe konstituentov kot načina za uresničitev površinske skladišne zgradbe in za osnovo vzame idejo o slovnih funkcijah, zajetih v leksikonu. V članku je predstavljena vloga leksikona kot tudi tesnih povezav med gradniki in funkcijsko zgradbo. Pri postopku formalizacije hrvaških stavkov je bil predlagan nov tip organizacije leksikona, ki vsebuje slovnice vloge povezane z zgradbo argumentov, novimi značilkami in omejitvami. Teoretični modeli so preverjeni z izobraževalno verzijo modela LFG.

## 1. Introduction

As the name says by itself, this formal model is based on the idea of representing grammatical functions in the lexicon. In Bresnan (1982) grammatical functions are defined as universal syntactic primitives of the grammar classified according to two main criteria: subcategorization principle and semantic restriction principle.

Starting from the idea that grammatical functions, such as subject and object, exist in all or most of natural languages, the LFG model rejects the syntactic movement of constituents and the surface syntactic realization, but accepts the idea of grammatical functions and enriched lexical component. Grammatical functions are situated as an interface between the lexicon and the syntax.

Since the LFG model integrates linguistic knowledge with computer application and aims to be suitable for description of highly structured languages, as well as for languages with free word order, this model has been applied for various linguistic phenomena in various languages (English, German, French, Italian, Dutch, Icelandic, Russian, Warlpiri, Bantu, Greek, Chinese, Icelandic, etc.), according (Abeillé, 1993).

## 2. Role of the lexicon

In the Lexical-Functional grammar (LFG), the lexical process determines multiple set of associations of arguments (Agent, Theme, etc.) with grammatical functions (Subject, Object, etc.), according Neidle (1994).

A surface structure is realized by constituent (c-) structure, enriched by the lexical component which exists simultaneously with functional (f-) structure that integrates information from the c-structure and from the lexicon.

As the c-structure reflects the surface syntactic structure, it varies across languages, while the f-structure tends to be universal when describing the same language phenomena through different languages.

J. Bresnan (1982) gives arguments in favour of the lexical account, supporting relations between grammatical functions and arguments, rather than syntactic movements.

In languages with relatively free word order, like Croatian, as one of the Slavic languages that has rich morphological system, the possibility to formalize language phenomena through grammatical functions in lexicon that can have various positions in the sentence obtains preference in favor of this formal model.

As the LFG model is based on enriched lexical component containing grammatical functions, enabling decomposition of categories on characteristic features, incorporation of contextual elements and adding various constraints, this model tends to be suitable for formal description of the Croatian sentences having rich morphological structure and relatively free word order.

## 3. Lexical entry

Containing grammatical relations between predicate-argument structure, grammatical functions and characteristic features, the lexicon plays in the LFG model an important role.

The lexicon contains following types of information:

- form of the item (*on, oni, djeca, čitaju, knjigu, etc.*)
- part of speech (N, V, Adj, etc.)
- functional schemata containing information about meaning inside of quotes ‘ ‘ and grammatical functions (Subj, Obj, etc.) interrelated with thematic roles (Agent, Theme, etc.)
- other characteristic features (attribute-value pairs)

*čita* V [eng. *is reading*]  
 (↑PRED)='čitati<(SUBJ) (SUBJ, OBJ)>  
 (SUBJ, IOBJ, OBJ)>'  
 (↑NUM) = SG  
 (↑PRS) = 3  
 (↑TNS) = PRES  
*knjigu* N [eng. *book*]  
 (↑PRED)='zadaća'  
 ↑GND) = FEM  
 (↑NUM) = SG  
 (↑CASE)= ACC

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 NP). While constituting equations are incorporated into f-structure, constraining equations in the following example (marked with =c) serve as the control mechanism and ensure the proper well-formedness of constructions respecting the constraint (e.g. agreement with subject in number and person).

*čita* V [eng. *is reading*]  
 (↑PRED)='čitati<(SUBJ, IOBJ, OBJ)>  
 (↑SUB NUM) =<sub>c</sub> SG  
 (↑SUB PRS) =<sub>c</sub> 3  
 (↑TNS) = PRES

Constraining equations could be used in the process of agreement which is in Croatian of the considerable importance (e.g. agreement between subject and verb in person and number, in complex tenses, inside of NP in case, number, gender, then between subject and past participle, etc.).

### 3.1. Lexical entry related to c- and f-structures

In the LFG model the sentence is represented by three interrelated levels of representation: lexical structure, constituent (c-) structure and functional (f-) structure, which exist simultaneously (Kaplan & Bresnan, 1982), although other levels of representation have been afterwards added, such as argument (a-) structure (Bresnan & Kanerva, 1989) and morphological (m-) structure (Frank, 2000; Kaplan, 2000).

As grammatical functions are associated by the mechanism of annotation of phrase structure rules with lexical items and its syntactic positions, they mediate between the lexicon and the syntax, i.e. c-structure.

Constituent structure reflects the superficial syntactic structure and encodes linear order, hierarchy and syntactic categories of constituents (in the form of context-free rules enriched with functional annotations or in the form of the annotated tree). This structure varies from one language to another. C-structure corresponds to the superficial phrase structure and works closely with an enriched lexical component.

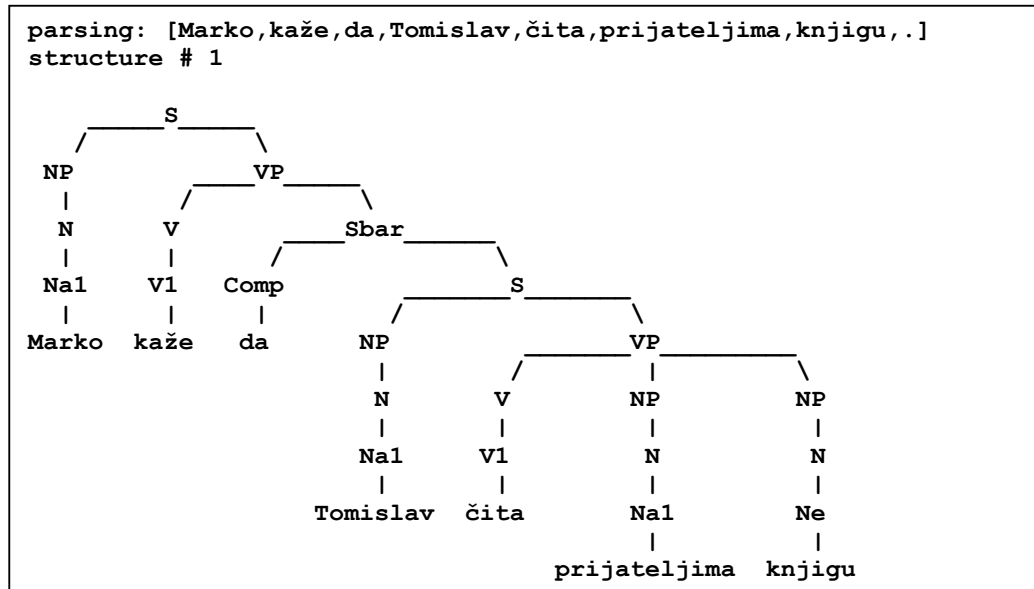


Figure 1. C-structure for the sentence  
*Marko – kaže – da – Tomislav – čita – prijateljima – knjigu*  
 [eng. *Marc – says – that – Tom – is reading – to friends – a book.* ]

C-structure exists simultaneously with functional f-structure. Information contained in the lexicon is integrated together with structural information into functional (f-) structure and presented in the form of matrix, as presented in the following example:

<b>PRED</b>	<b>Kazati</b>	<b>&lt;SUBJ,COMP&gt;</b>
<b>TNS</b>	<b>PRES</b>	
<b>SUBJ</b>	<b>PRED</b>	<b>Marko</b>
	<b>NUM</b>	<b>SG</b>
	<b>PRS</b>	<b>3</b>
	<b>GND</b>	<b>MASC</b>
	<b>CASE</b>	<b>NOM</b>
<b>COMP</b>	<b>PRED</b>	<b>Citati</b>
	<b>&lt;SUBJ,IOBJ,OBJ&gt;</b>	
	<b>TNS</b>	<b>PRES</b>
	<b>SUBJ</b>	<b>PRED</b>
		<b>Tomislav</b>
		<b>NUM</b>
		<b>SG</b>
		<b>PRS</b>
		<b>3</b>
		<b>GND</b>
		<b>MASC</b>
		<b>CASE</b>
		<b>NOM</b>
	<b>IOBJ</b>	<b>PRED</b>
		<b>Prijatelj</b>
		<b>NUM</b>
		<b>PL</b>
		<b>GND</b>
		<b>MASC</b>
		<b>CASE</b>
		<b>DAT</b>
	<b>OBJ</b>	<b>PRED</b>
		<b>Knjiga</b>
		<b>NUM</b>
		<b>SG</b>
		<b>GND</b>
		<b>FEM</b>
		<b>CASE</b>
		<b>ACC</b>

Figure 2. F-structure for the sentence  
*Marko kaže da Tomislav čita prijateljima knjigu*  
 [eng. *Marc - says - that - Tom - is reading - to friends*  
*- a book.* ]

### 3.2. Lexical entry and argument structure

As each lexical entry contains grammatical relation between argument structure (thematic or non-thematic roles) and grammatical functions, the principle of Function-Argument Biuniqueness requires that each argument can be associated with the unique grammatical function, i.e. that no grammatical function can occur more than once.

'udariti (agent, theme)' ← argument structure  
 (SUBJ, OBJ) ← gram. functions

Lexical entry of the verb *udariti* [eng. *hit*] for the unit might look as follows:

(↑PRED)= 'udariti < SUBJ, OBJ >'

indicating that the PRED feature has as its value the meaning of the verb which is a two-place predicate.

The categorization frame of the verb *kuhati* [eng. *cook*] in active and *kuhan* [eng. *cooked*] in passive forms could be the following:

(↑PRED)= 'kuhati < SUBJ, OBJ >'

(↑PRED)= 'kuhan < OBJ, Ø >'

If the grammatical function is not directly associated to the logical argument (e.g. when the agent is not alive or in open complements with functional control principle), the subject is called to be non-thematic. In the sentence *Treba pričekati* [eng. *It is necessary to wait*, fr. *Il faut attendre*]

in Croatian the subject doesn't have even the form, as in French *Il* or in English *It*.

*Treba pričekati.*

(↑PRED)= 'trebati <(XComp) > (Subj)'

(↑Subj Form)=<sub>c</sub> Ø

fr. *Il faut attendre.*

(↑PRED)= 'falloir <(Xcomp) > Subj'

(↑Subj Form)= il

eng. *There are some books.*

(↑PRED)= 'be <Obj > Subj'

(↑Subj Form)=<sub>c</sub> there

In the following sentence *On ju smatra dobrom prijateljom* [eng. *He considers her a good friend*] the object of the verb *smatrati* [eng. *consider*] is in the same time the logical subject of the open complement – *dobrom prijateljom* [eng. *a good friend*], which is indicated by placing the function Obj outside the angled brackets.

*On ju smatra dobrom prijateljom*

[eng. *He considers her a good friend*]

*smatra*, V [eng. *considers*]

(↑PRED)= 'smatrati <(SUBJ, XCOMP) > (Obj)'

(↑OBJ)=(↑XCOMP SUBJ)

In the Croatian it is also necessary to make an agreement between the subject *on* [eng. *he*] and the verb *smatra* [eng. *considers*] in person and number, between the object *ju* [eng. *her*] and *dobrom prijateljom* [eng. *a good friend*] in gender, although they are in different cases (*ju* in accusative and *dobrom prijateljom* in instrumental). Therefore, *dobrom prijateljom* [eng. *a good friend*] is treated as an XComp - the open complement whose subject is controlled grammatically by the Object function.

## 4. Formalization process

Since this work represents attempt to describe formally subset of Croatian natural language sentences at different levels and to verify computationally the theoretical models, informatics and linguistic approaches are closely interrelated. The presented approach distinguishes from the classic Croatian grammars, which is conditioned by the LFG model itself, by the program which is educational by purpose, by the specific language demands, supporting relatively simple morphological component. Although there are much better solutions for Croatian, especially at morphological level, the advantage of this model represents an attempt to describe the sentence at different levels.

Very rich inflectional and derivational morphological system enables relatively free word order. For the purpose of formal description, a recursive binary structure has been proposed. The concatenate morphology, different from traditional grammar, allows association of the first part of the word, marked as word category, with the last part, i.e. with endings and, eventually, with prefixes. Endings are marked with standard characteristic features, such as case, number and gender for NP, and with special features introduced because of formal distinction between cases having the same form, but different meanings.

Since the form of the word (morphological component) can not be considered separately from the structure and word relations (syntax), neither independently from the context (semantics),

morphological component is strongly related in the Croatian to the syntax and to the semantics.

In order to formalize certain language segments, the following steps were undertaken:

- Definition of syntactic groups (NP, VP, PP, AP, AdvP)
  - As formal constituents (noun, adjective, pronoun, etc.)
  - As functional constituents (determiners, premodifiers, head, postmodifiers)
- Definition of parts of the speech and subgroups
- Definition of attribute-value pairs
- Lexicon organization (part of speech, paradigms, constraints)
- Generative rules and constraints

#### 4.1. Syntactic groups, subgroups, features

In the Croatian words are basically divided into changeable (that change the form through the paradigms) and unchangeable (that do not change the form through the paradigm). Changeable types of words are those that change through cases (nouns, adjectives, pronouns, noun numbers behaving like nouns, adjective numbers behaving like adjectives) and verbs that change through persons. All changeable types of words are described by characteristic features. Unchangeable types of words are adverbs, number adverbs, prepositions, exclamations and particles. Some Croatian authors consider adverbs unchangeable type of word (Raguž, 1997; Batnožić, Ranilović, Silić, 1996; Anić, 1994), some authors consider it as partly changeable (Barić et al., 1979:65), and some consider the adverb as changeable type of word (Tadić, 1994.) with regular changes in gradation.

Although the basic division into parts of speech has been retained, some formal distinctions, subgroups and additional features have been introduced, because of formal constraints.

- 1) Determiners are formally subdivided into indefinite PDet: *neki, svaki* [eng. *some, every, etc.*], referential Det: *ovaj, taj, onaj* [eng. *this, that*], relative DetRel: *tko, što, koji* [eng. *who, what, whose, etc.*], quantifiers DetQ - number adjectives: *prvi, prva, prvo* [eng. *first* in 3 genders] and possessives Dposs - possessive adjectives, possessive pronouns, possessive and reflexive pronoun. Distinction has been introduced: determiners are not recursive, opposed to ex. modifiers, but subgroups of determiners can be combined among themselves.
- 2) Premodifiers in NP are recursive (nouns, adjectives, past participles).
- 3) In the Croatian formal model, past participle has two forms:
  - a) past participle in active form formally marked as Adj\_Part (Adjective Participle), having different suffixes denoting gender and number as *čitao-čitala-čitalo*, eg. *on je čitao, ona je čitala, ono je čitalo* [eng. *he/she/it was reading*]
  - b) past participle in the passive form formally described as Adj\_Part, PASS +, ASP FIN/PROG having also different suffixes denoting 3 genders, eg. *čitan, čitana, čitano* [eng. *was read*], containing also features of progressive (*čitani*) or finite aspect (*pročitani*). The basic form of the word is related to

the paradigm number, giving information on gender and number

- 4) Numbers are subdivided into following groups: noun numbers behaving like nouns, eg. *stotina, tisuća* [eng. *hundred, thousand*], adjective numbers that agree with noun in gender, number and case, eg. *prvi, prva, prvo* [eng. *first*], adverb nouns that do not change and behave like adverbs (cardinal numbers)
- 5) Possessive and reflexive pronouns - *se, sebe* [eng. *himself, herself, itself*] are defined as clitics Cl, placed inside of VP, but distinguishing strong and weak form Str= +/-.
- 6) Demonstrative pronouns marked by proximity PROX= 1/ 2/ 3 denoting 3 distances
- 7) Interrogative pronouns are marked with QU=+
- 8) Relative pronouns are marked with REL=+ and ANI=+ to distinguish the same form *koji* [eng. *which*] between animate in nominative case and inanimate in accusative
- 9) Collective nouns have characteristic feature COLL=+
- 10) Instrumental case is marked with SOC=+ and THG=+ in order to distinguish between dative and instrumental when having the same form.
- 11) Past participles are formally divided into:
  - a) past participle in active form (Adj-Part) that can have prefix marking finite aspect (ASP FIN) or suffix marking gender and number, which must agree with subject
  - b) past participle in passive form, finite aspect (Adj-Part, PASS +, ASP FIN)
  - c) past participle in progressive aspect Adj-Part, PASS +, ASP PROG
- 12) In the formal description of preterit and future, auxiliaries subcategorize XComp function, and are marked by tense, number, person, optionally as negative or strong forms. Although the author adopts the m-structure, the older version of formal composite tenses was adopted because of formal reasons.
- 13) Adverbs in this work are treated as unchangeable type of words, marked with degree level (Deg = pos/ com/ sup).

#### 4.2. Case-marking

One of the central questions for representing the Croatian language is case-marking and agreement. The term 'case' is used in LFG in a traditional sense, in order to describe use of inflections, which in the Croatian encode syntactic and semantic relations. In LFG syntactic case is associated with specific grammatical function and a morphological form that comes from the lexicon with the suitable case inflection. Case-marked forms are generated in the lexicon. The suitable case form is inserted into c-structure and then appropriate use verified in the f-structure.

In Croatian there are seven cases (nominative, genitive, dative, accusative, vocative, locative, instrumental), some of them having the same written form (genitive - accusative, dative - locative, dative - instrumental). In the formalization process some additional constraints have been introduced for the purpose of distinguishing homographic cases.

### 4.3. Lexicon organization

Word composition in the highly flexive languages with rich morphological system represents one of the dominant questions in creation of the electronic lexicon. What are smaller parts, their meanings, how do they combine and differences regarding to traditional grammar in formal description. The presented method combines linguistic and informatic approaches.

In the classical grammar, next to the lexical morpheme, eg. *prijatelj* [eng. *friend*] several grammatical morphemes (*-ic*, *-a*) denoting gender feminine, number singular and case nominative can be added. The morpheme *-ic* is not always a morpheme, eg. *majic-a* [eng. *T-shirt*] but can be part of the stem. The same morpheme *-a* and the same lexical unit *majica* can also have also another meaning (gender feminine, number plural, case genitive). Differences in the meaning between nominative singular and genitive plural are reflected in the grammatical functions.

What is proposed is a 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 as part of speech. Therefore, morphemes are not used in the traditional sense in this formal analysis and lexical units are formally delimited in the following way:

- Flextive unit – stem, marked as part of speech (which can be subdivided)
- Paradigms containing prefixes or suffixes with characteristic features
- Irregular forms that are marked separately, not related to the paradigm

In this formal model there are 135 lemmas related to 260 allomorph basic forms. Using the concatenation principle by adding suffixes of paradigms to stems, there are around 1.370 different generated forms (e.g. *knjig* and *knjiz* represent two allomorph basic forms – stems of one lemma *knjiga* [eng. *book*], generating 14 forms, some which are the same, differentiating in case and in number.

While some consider the paradigm of endings to be marginal, but diagnostically relevant, others consider it an important morphological phenomena. Vincent and Börjars (1996) indicate that if certain morphological system requires to be analyzed in terms of morphosyntactic representations which consist of feature bundles rather than X'-projections and if there is inevitable continuity between morphology and syntax, that in consequence the best model of the morphology-syntax interface would be featural rather than configurational.

### 5. Computational model

Theoretical models are verified through the computational model using LFGW code (Andrews, 1991.). LFGW is a basic LFG system adapted for doing small (homework-assignment sized) grammar fragments. It includes simple morphology and lexical inheritance, as well as an 'error-tolerant parsing' facility (to help find mistakes in the grammar), but does not implement any of the advanced features of recent LFG theories (functional uncertainty, anaphoric binding), and also lacks a workable treatment of long-distance dependencies. LFGW is licensed for free use for any educational or noncommercial purpose. This educational version of the LFG model is used for description of certain linguistic

phenomena of Croatian language (case-marking and some agreement phenomena).

The program gives for the sentence in the Croatian two structures:

- a) Constituent (c-) structure using tree form and defining the surface level with parts of speech and cases
- b) Functional (f-) structure in the matrix form unifying information from the constituent structure and from the lexicon, which has to satisfy principles of uniqueness, coherence and completeness.

Sentences are firstly generated by syntactic rules, passing then constraining tests introduced in the lexicon or added in generative rules. The program surely does not represent the best solution (especially on the morphological level) but one possible model of sentence analysis, where special attention is given to the lexicon.

### 6. Conclusion

Being context-sensitive, non-transformational grammar using constraints and unification principle, the LFG formal model aims to be suitable for description of various linguistic phenomena in various languages, and therefore in Croatian.

As the LFG model is based on grammatical functions and enriched lexical component, permitting also decomposition on characteristic features and introduction of new constraints, which are in meta-language reflected as attribute-value pairs, it has shown to be adequate for description of some language phenomena of the Croatian, like case-marking and agreement. Lexical component, containing information about meaning, characteristic features and subcategorization principles, and closely relating to constituent, argument and functional structures, enable description of the language through lexical and functional component. Having also possibility to add new features and constraints, characteristic for the specific language, this formal model becomes suitable for description of various languages, including Croatian with rich morphological system and relatively free word order. The LFG could be seen as the bridge between linguistics and informatics helping us to better understand our proper language in order to approach the theoretical linguistic models and practical application.

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