

# Modeling of Verbs Using the Node of Knowledge Conceptual Framework

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**Abstract** – The paper analyzes the semantics of verbs in sentences in Croatian and English language. It gives a representation of different verb tenses in both languages and shows how the sentences containing these tenses are modeled using the Node of Knowledge (NOK) conceptual framework. The NOK conceptual framework is used for formal knowledge representation expressed in text, i.e. to represent the knowledge network. The models are presented using the Formalized Node of Knowledge (FNOK) formalism. These models are a part of the meta-model of language that is necessary for the development of an intelligent information system.

**Keywords** - NOK, Node of knowledge, verbs, FNOK, representation, conceptual framework

## I. INTRODUCTION

Knowledge representation is a central problem in artificial intelligence [1]. One of the groups of methods for representing knowledge are semantic networks [2]. Semantic networks are graphs, in which words (or concepts) are represented as nodes, while edges signify relations between them [3]. The Nodes of Knowledge (NOK) method [4], [5] belongs to semantic networks. Node of Knowledge also uses nodes and links, but is simpler than other methods (having fewer elements), more expressive (allows to display knowledge at different levels of abstraction) and easier to read (in the NOK method it is possible to read the knowledge starting from any node, but with the use of the link role) [6].

Creating a system of artificial intelligence that could communicate intelligently with the user is closely related to natural language processing [7]. Natural language systems must map between language and meaning [8]. By studying certain types of words in a sentence, a meta-model of the language is built, which is the basis for building an intelligent information system. The adjective analysis was performed in [9].

In [10], [11] and [12] it was shown that it is possible to use the conceptual framework NOK to model sentences in different languages.

In this paper, the emphasis is on verbs and different verb tenses in two natural languages - Croatian and English. Also, the same examples are given in Croatian and English (wherever possible) and shown that the models are in some cases the same, but there are also cases where they are very different.

The paper is organized in the following way. After introduction in Section I, Section II gives research

motivation. Section III describes the research methodology. In Section IV authors analyze the verbs in Croatian and English language. Also, rules are given to convert verbs and verb tenses from the natural language into a formalized FNOK record, as well as how to graphically display them in DNOK. Section V provides conclusions and plans for future research.

## II. RESEARCH MOTIVATION

The idea of developing an intelligent information system includes/predicts the entry of natural language sentences into a relational database and enabling communication with that database using questions that are also expressed in natural language [13]. Before entering the database, natural language sentences are first enriched and represented in the FNOK record [14] which enables storing knowledge and its processing using a computer program [15], [13].

In order to be able to represent knowledge in a formal form, it is necessary to clearly define the rules. Therefore, it is necessary to analyze and define the rules for all word types in the sentence. The verbs are especially important as the verb is the top of the representation hierarchy in FNOK and DNOK. All the other nodes are underneath it. In other words, a process node (and this is usually a verb) is the backbone of the whole model. Verbs (i.e. process nodes) are first searched for in sentences, and after that the other words and their hierarchical dependence. Then the model is built around the process node, and then around the other nodes.

Research motivation is the development of an intelligent information system whose components are textual records, where it is necessary to create a meta-model of language, of the enrichment process, and also of verbs in all their forms and tenses.

## III. METHODOLOGY

Since the very beginning of the development in 2011, several formalisms have been developed within the NOK method. The method itself is presented in [15] as part of the conceptual framework for knowledge-based system development „Node of Knowledge“, abbr. NOK method conceptual framework.

The conceptual framework „Node of Knowledge (NOK)“ is a set of methods, rules, corresponding analysis tools and the representation of semantics contained in natural language sentences. The conceptual framework NOK includes:

- NOK method
- DNOK formalism (Diagram Node of Knowledge) - formalism for graphic representation (graphic representation in the form of a NOK diagram),
- FNOK formalism (Formalized Node of Knowledge) - formalism for displaying knowledge in textual form (formalized textual entry) and
- QFNOK formalism (Question Formalized Node of Knowledge) - formalism for representing questions in textual form (formalized textual question representation)

DNOK formalism is described in [16], [4], [10]. Algorithms for conversion of sentences to FNOK records and algorithms for the conversion of interrogative sentences (questions) into QFNOK records, i.e. a detailed description of the transformation algorithm and the corresponding software product in Python for the selected positive and interrogative sentences are given in the papers covering the NOK method [14], [15]. Other parts of the conceptual framework „Node of Knowledge” (NOK) are still in development.

The basic concepts of the NOK method are: node (label: rectangle), process node (label: ellipse) and link (label: straight line) with a single role related to the link between two nodes, closer to the node asking the question. The link connects either two ordinary nodes, or two process nodes or the ordinary and the process node. Each link between the nodes has only one role. It connects the two nodes so that it moves from one node to another. The link between the two nodes is accomplished by asking a question related to the first node, and the response results in another node (which is on the other side of the link). By using the NOK concept, DNOK is created. The verb in the sentence of natural language corresponds to the process node, and the other words correspond to nodes.

In addition to the graphical representation of textual knowledge (DNOK), the formalized representation of knowledge in textual form was developed, the FNOK (Formalized Node of Knowledge). FNOK can textually express sentences with a semantic link between nodes using wh-questions.

Each word in a natural language sentence corresponds to one node in the FNOK record. The verb corresponds to the process node at the highest hierarchical level. Brackets mark the beginning and end of the hierarchy, i.e. different levels within the hierarchy. The end of the hierarchy is marked with a closed bracket. After that label, we return to a higher level.

The representation in the hierarchy also includes a role (question word, question) linking a „lower” node with a higher node, where the lower node is the node at a lower level, i.e. a node at the lower level answers the question word. The question is marked by quotation marks and a question mark („?“)

General FNOK representation:

*process node („role 1?“ node 1, „role 2?“ node 2 („role 3?“ node 3 („role 4?“ node 4, ...), ...), „role n?“ node n)*

where *role 1?* to *role n?* are wh-questions, *node 1* to *node n* are nodes, and *process node* is the process node

Each node can have its own hierarchy. Hierarchical dependence can be defined with [17]:

Let *N1* and *N2* be two nodes. Hierarchical dependence of these two nodes can have two cases:

1. *N1* is hierarchically superior to *N2* (i.e. *N2* is hierarchically subordinate to *N1*), which can be shortly represented as *N1(N2)*, or
2. *N2* is hierarchically superior to *N1* (i.e. *N1* is hierarchically subordinate to *N2*), which can be shortly represented as *N2(N1)*.

Graphical representation of the hierarchical dependence is shown in Figure 1.

The rules for converting verbs and verb tenses and forms into the FNOK record and DNOK diagram will be described below.

#### IV. RESEARCH RESULTS

The verb is a word class that states action, state or event. In Croatian, verbs change in tenses, persons and moods. We differentiate the finite and nonfinite form of the verb (in Croatian, the same verb can be formed as to state an action which has started and finished – a finite form, or an action which has started, but not finished yet – a nonfinite form, with a single form, eg. verb *sit – sjesti* (finite state – *to sit down*) or *sjediti* (nonfinite state – *to be sitting*). Auxiliary verbs in Croatian *to be (biti)* and *to want (htjeti)* serve to form complex verb tenses and the creation of past and future verb tenses [18], [19].

In English, verbs also express action, state and event. The English language verb features are: singular and plural, persons (three persons singular and three persons plural), verb tenses (present, past and future tense), nonperfect and perfect aspect, active and passive voice, and moods (imperative, indicative and conjunctive) [20].

When converting verbs or sentences containing the verbs to FNOK formalized record, we distinguish a few rules explained in detail in the subsections A, B and C.

##### A. Verb at the Beginning of the Record

The verb (which is the process node) in the FNOK record is placed at the highest level of hierarchy. All other word types are hierarchically dependent on it, which we can represent like this:

$V, X \rightarrow V(X)$ , where *V* stands for verb, and *X* for any

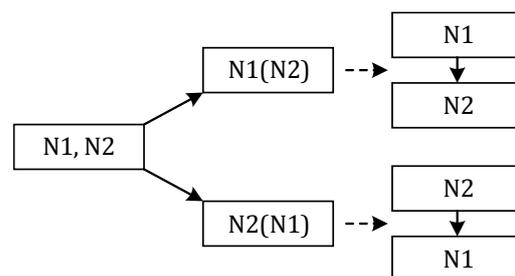


Figure 1. Hierarchical dependence of nodes

other word type.

More precisely, if we include the question (role) in the previous record, we can write:

$V, X \rightarrow V(\text{„role?“ } X)$ , where  $V$  stands for verb,  $X$  for any other word type, and *role?* for a wh-question.

For example, the sentence *Vedran drives a car.* (cro. *Vedran vozi auto.*) has one verb, *drives* (cro. *vozi*), which is also a process node. It is placed at the beginning of the FNOK record, and then other words connected to the verb are searched for.

- Vedran **vozi** auto. → **Vozi** (...)
- Vedran **drives** a car. → **Drives** (...)

Symbol „→” marks the mapping of the sentence into FNOK record.

### B. Verb Under a Verb

The verb is always under a verb (hierarchically dependent on the verb) when the action is stated one after the other, in the order in which the verbs appear in the sentence. For example:

- **Daj** mi nešto za **piti**. → **Daj** („što?“ **piti** („što?“ za), „kome?“ mi, „što?“ nešto)
- **Give** me something **to drink**. → **give** („what?“ **drink** („what?“ **to**), „whom?“ me, „what?“ something)

### C. Hierarchy of Verb Tenses

In certain verb tenses, there are one or more auxiliary verbs in the sentence along with the main verb. The question arises as to how to translate the main verb and auxiliary verbs that form a certain verb tense into FNOK.

In the Croatian language we can see the hierarchy in:

- Verb tenses:
  - *Past Tense* (cro. *perfekt*). Form: active verb form + present of the auxiliary verb „*biti*” („to be”). For example: *sam pisao, si pisao, je pisao, smo pisali, ste pisali, su pisali* etc.
  - *Past Perfect* (cro. *pluskvamperfekt*). Form: perfect or imperfect form of verb „*biti*” („to be”) + active verb form. For example: *bijah (bjeh) pisao, bijaše (bješe) pisao, bio sam pisao, bio si pisao* etc.
  - *Future Simple* (cro. *futur prvi*). Form: verb infinitive + present of the auxiliary verb „*htjeti*” („to want”). For example: *ću pisati, ćeš pisati, pisat ću, pisat ćeš, ću ići, ići ćeš* etc.
  - *Future Perfect* (cro. *Future drugi*). Form: finite present of the auxiliary verb „*biti*” („to be”) + active verb form. For example: *budem pisao, budeš pisao, budete pisali* etc.

- Verb moods:
  - *Conditional First or Present* (cro. *kondicional prvi ili sadašnji*). Form: aorist of the auxiliary verb „*biti*” („to be”) + active verb form. For example: *bih trebao, bi trebao, bismo trebali* etc.
  - *Conditional Second or Past* (cro. *kondicional drugi ili prošli*). Form: present conditional of the verb „*biti*” („to be”) + active verb form. For example: *bih bio trebao, bi bio trebao, bismo bili trebali* etc.

The hierarchy of verb form in English language is depicted in Figure 2. Levels of hierarchy depend on the particular verb tense. In English, the hierarchy is observed in the following verb tenses:

- *The Simple Present Tense*. Form: auxiliary verb „to do” + main verb in infinitive form. For example: *works, does work* etc.
- *The Present Continuous Tense*. Form: auxiliary verb „to do” + the present participle of the main verb. For example: *am walking, is watching, are sleeping* etc.
- *The Present Perfect Tense*. Form: auxiliary verb „to have” + the past participle of the main verb. For example: *have written, has written, have lived, has lived* etc.
- *The Present Perfect Continuous Tense*. Form: the perfect of auxiliary verb „to be” + the present participle of the main verb. For example: *have been writing, has been reading* etc.
- *The Past Continuous Tense*. Form: past simple form of auxiliary verb „to be” + the present participle of the main verb. For example: *was reading, were writing* etc.
- *The Past Perfect Tense*. Form: past simple form of auxiliary verb „to have” + past participle of the main verb. For example: *had asked, had written* etc.
- *The Past Perfect Continuous Tense*. Form: had been + the present participle of the main verb. For example: *had been drinking, had been working* etc.
- *The Future Simple Tense*. Form: will / shall + base form of verb. For example: *will learn, will read* etc.
- *The Future Continuous Tense*. Form: will + be + the present participle of the main verb. For example: *will be running, will be competing* etc.
- *The Future Perfect Tense*. Form: will have + the past participle of the main verb. For example: *will have ended, will have left* etc.
- *The Future Perfect Continuous Tense*. Form: will + have + been + the present participle of the main verb. For example: *will have been working, will have been waiting* etc.
- *Going to future*. Form: „to be” + going to + base form of verb. For example: *is going to wait, am going to finish, are going to quit* etc.

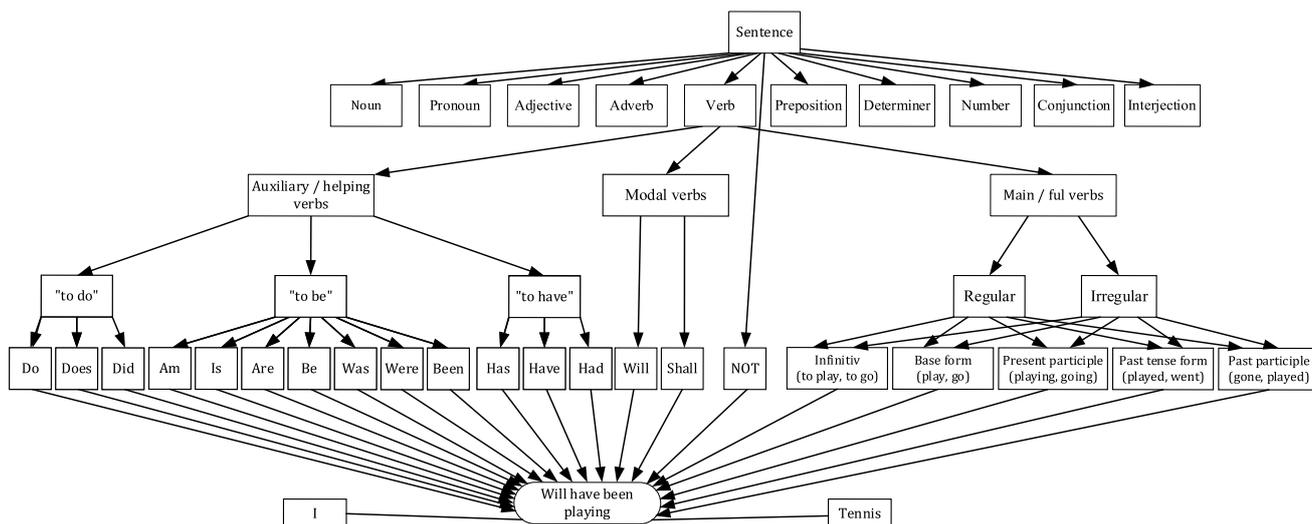


Figure 2. English language verb tense forms and their hierarchy

When creating FNOK we have two options:

1. present all the words that make up one verb tense with one process node, or
2. divide the words (nodes) into several levels of hierarchy in a certain order.

Since we want to keep the sentence structure and semantic content in FNOK, the following rule is set:

*If the verb tense consists of several parts, they are in a hierarchy one below the other. The main verb is placed at the lowest level of hierarchy, and all auxiliary verbs or verb forms are above it (hierarchically dependent, they*

*form a hierarchy).*

A completely opposite order of words would also be a good solution because it contains the same semantics. The solution that better suits the implementation process should be chosen.

The hierarchy in FNOK for verb tenses and verb moods in Croatian language is as follows: at the highest level, there is any form of auxiliary verb „to be” (*biti*) or „to want” (*htjeti*) which is superordinate to the active verb form or verb in the infinitive.

Let us observe this rule over a few examples. Table I.

TABLE I. EXAMPLES FOR MODAL VERBS AND DIFFERENT VERB TENSES IN CROATIAN AND ENGLISH LANGUAGES

| NR | TCRO  | FNOK CRO   | TENG   | FNOK ENG   |
|----|---|--|--|--|
| 1  | Ti <b>možeš kupiti</b> auto.                    | <b>možeš</b> („što?“ <b>kupiti</b> („što?“ auto, „tko?“ ti))                             | You <b>can buy</b> a car.                      | <b>can</b> („what?“ <b>buy</b> („who?“ you, „what?“ car („art?“ a)))   |
| 2  | Ti <b>možeš dotaknuti</b> sestriinu bilježnicu. | <b>možeš</b> („što?“ <b>dotaknuti</b> („tko?“ ti, „što?“ bilježnicu („čiju?“ sestriinu)) | You <b>can touch</b> sister's notebook.        | <b>can</b> („what?“ <b>touch</b> („who?“ you, „what?“ notebook („whose?“ sister's)))   |
| 3  | Mi <b>bismo mogli biti</b> prijatelji.          | <b>bismo</b> („što?“ <b>mogli biti</b> („tko?“ mi, „što?“ prijatelji))                   | We <b>could be</b> friends.                    | <b>could</b> („what?“ <b>be</b> („who?“ we, „what?“ friends))  |
| 4  | On <b>može čitati</b> .                         | <b>može</b> („što?“ <b>čitati</b> („tko?“ on))   | He <b>can read</b> .                           | <b>can</b> („what?“ <b>read</b> („who?“ he))   |
| 5  | Ja <b>ću raditi</b> sutra                       | <b>ću</b> („što?“ <b>raditi</b> („tko?“ ja, „kada?“ sutra))                              | I <b>will work</b> tomorrow.                   | <b>will</b> („what?“ <b>work</b> („who?“ I, „when?“ tomorrow))   |
| 6  | Naš brod <b>je prešao</b> Atlantik.             | <b>je</b> („što?“ <b>prešao</b> („što?“ brod („čiji?“ naš), „što?“ Atlantik))            | Our ship <b>crossed</b> the Atlantic.          | <b>crossed</b> („what?“ ship („whose?“ our), „what?“ Atlantic („art?“ the))  |
| 7  | Marija <b>ne izgleda</b> umorno.                | <b>ne</b> („što?“ <b>izgleda</b> („tko?“ Marija, „kako?“ umorno))                        | Mary <b>doesn't<sup>1</sup> look</b> tired.    | <b>doesn't</b> („what?“ <b>look</b> („who?“ Mary, „how?“ tired))   |
| 8  | Automobil njegovog oca <b>je ukraden</b> .      | <b>je</b> („što?“ <b>ukraden</b> („što?“ automobil („čiji?“ oca („čijeg?“ njegovog)))    | His father's car <b>was stolen</b> .           | <b>was</b> („what?“ <b>stolen</b> („what?“ car („whose?“ father's („whose?“ his)))   |
| 9  | Čovjek <b>ide</b> na putovanje.                 | <b>ide</b> („tko?“ čovjek, „kamo?“ putovanje („kamo?“ na))                               | A man <b>is going on</b> a journey             | <b>is</b> („what?“ <b>going</b> („who?“ man („art?“ a), „where?“ journey („where?“ on, „art?“ a))  |
| 10 |   |  | I <b>will have been working</b> for ten hours. | <b>will</b> („what?“ <b>have</b> („what?“ <b>been</b> („what?“ <b>working</b> („who?“ I, „how many?“ hours („how many?“ for, „how many?“ ten)))) |
| 11 |   |  | Sofia <b>has been playing</b> violin.          | <b>has</b> („what?“ <b>been</b> („what?“ <b>playing</b> („who?“ Sofia, „what?“ violin)))   |
| 12 |   |  | He <b>will have been</b> learning English.     | <b>will</b> („what?“ <b>have</b> („what?“ <b>been</b> („what?“ learning („who?“ He, „what?“ English)))   |
| 13 |   |  | Mark <b>will have played</b> soccer.           | <b>will</b> („what?“ <b>have</b> („what?“ <b>played</b> („who?“ Mark, „what?“ soccer)))  |

<sup>1</sup> negation „does not“ or abbreviated „doesn't“ represents one node

consists of 5 columns: NR (ordinal number), TCRO (sentences in Croatian language), FNOK CRO (FNOK sentence record in Croatian language), TENG (sentences in English language) and FNOK ENG (FNOK sentence record in English).

In table I, under ordinal numbers from 1 to 4, examples of modal verbs in English are given, while under 5 to 13, examples of different verb tenses (the future, the past, and the negative form) are given. Where possible, examples are given in both languages. However, examples from 10 to 13 have sentences where the tense implies hidden semantics which cannot be appropriately translated into Croatian. In other words, such sentences cannot be unambiguously translated into Croatian language, so the examples of such tenses are given in English language only. The use of FNOK in other verb tenses and modal verbs is the same as these.

For example, Future perfect continuous tense has the following form:

*Subject + auxiliary verb „will“ + auxiliary verb „have“ + past participle of „be“ + present participle of the main verb.*

Hierarchy in FNOK retains the order of form that appears in the sentence, hence the FNOK hierarchy for Future perfect continuous tense is:

- Auxiliary verb „will“
  - Auxiliary verb „have“
    - Past participle of „be“
      - Present participle of the main verb
        - Subject.

For example, for sentence: *He will have been learning English.*, the corresponding FNOK is:

*will („what?“ have („what?“ been („what?“ learning („who?“ He, „what?“ English))))*

The corresponding DNOK is given in Figure 3.

The model presented in this paper was the basis for development of the first system prototype. It was initially tested on 26 sentences and 36 questions in English language, and 23 sentences and 32 questions in Croatian language. These sentences used different verb tenses and verb modes. The system responded with 83% and 79% of correct answers to questions in English and Croatian respectively. Future work will include development of the second prototype with a goal to increase percentage of correct answers.

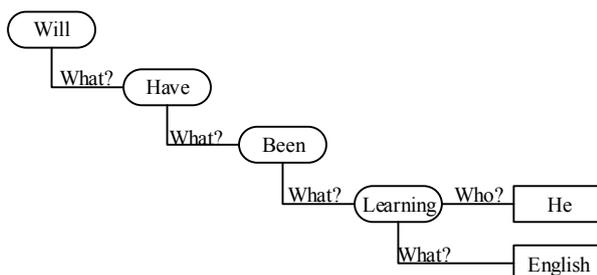


Figure 3. DNOK for sentence *He will have been learning English*

## V. CONCLUSIONS AND FUTURE WORK

The paper presents the representation of verbs and different verb tenses in Croatian and English language and defines the rules for converting them into formalized text expressed knowledge representation (FNOK), as well as DNOK. The definition of hierarchical dependence is given and the hierarchy of English verb tense forms is shown. When creating FNOK, all the words that form a single verb tense are decomposed into several levels of hierarchy in a certain order. A rule was set: „If the verb tense consists of several parts, they are in a hierarchy one below the other. The main verb is placed at the lowest level of hierarchy, and all auxiliary verbs or verb forms are above it (hierarchically dependent, they form a hierarchy)“. A completely opposite order of words would also be a good solution because it contains the same semantics. The solution that better suits the implementation process should be chosen. For a better understanding of the set rules, several examples are shown in both languages.

The presented models are part of the meta-model of language that is necessary for the development of an intelligent information system capable of providing the system with answers to all the questions contained in the text, in a way a human would do it. The meta-model of language will continue to be built in future research.

Previous research has identified many problems, and these are planned to be solved in the future. Some of the plans are improving the rules of transformation according to the word types for interrogative and relative pronouns, conjunctions, interjections and particles, improving algorithms for answering questions, solving the problem of redundancy in sentences, analysis of complex sentences, and analysis of correlated sentences. In general, the work on the improvement of the NOK conceptual framework is in progress.

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