

Adverb and Preposition Representation in Croatian and English using the Node of Knowledge Method

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Abstract. *A conceptual framework Node of knowledge enables, among others, presentation of knowledge in a formalized record suitable for insert into a relational database. To correctly transform all words from natural language sentences to formalized records, it is necessary to design a metamodel of a language and define rules for transformation of each sentence part. This paper focuses on adverbs and prepositions and their representation in Croatian and English language. It presents rules and examples for their transformation into formalized records in both languages and discusses results of preliminary testing of the system with a small set of sentences and questions.*

Keywords. Knowledge representation, Node of Knowledge, NOK, Adverb, Preposition

1 Introduction

In the field of artificial intelligence and knowledge representation, many methods have been developed to record knowledge. Some of these methods are semantic networks (Brachman & Levesque, 2004), (Gomez-Perez & Benjamins, 2002), frames (Liao et al., 2012), ontologies (Cali et al., 2012), Fuzzy Petri nets (H.-C. Liu et al., 2017), neural networks (Neelakantan, 2017), the Node of Knowledge method (NOK) (Jakupovic et al., 2014), (Pavlic et al., 2013) or other graphical methods for knowledge representation (Jakupovic et al., 2013).

The Node of Knowledge method (NOK) is an integral part of the conceptual framework "Node of Knowledge (NOK)", which, in addition to the NOK method, consists of a formalism for graphical representation (Diagram Node of Knowledge, DNOK), a formalism for representing knowledge in textual form (Formalized Node of Knowledge, FNOK), and a formalism for representing questions in textual form (Question Formalized Node of Knowledge, QFNOK) (Candrlic et al., 2019).

The NOK conceptual framework enables the entry of knowledge, texts expressed in sentences of natural written language, into the Question answering (QA) system in such a way that the knowledge expressed in sentences of natural language is formatted into a record suitable for input into a relational database. This database is an integral part of the QA system. Once the knowledge is written into the QA system, it enables the retrieval and questioning of that knowledge, i.e., searching for and answering questions expressed in natural language sentences.

Previous research by the authors (Rauker Koch et al., 2017), (Rauker Koch et al., 2015), (Rauker Koch et al., 2014), (Candrlic et al., 2020) has shown that using the NOK conceptual framework, it is possible to write different texts in different languages in a formalized format suitable for input to a relational database. In parallel with the human transformation of natural language into FNOK record, an application for automatic transformation of natural language sentences into FNOK record was developed (Dovedan Han, 2021) and the results were compared with the transformation performed manually (Rauker Koch et al., 2022). To convert natural language sentences into a formalized record suitable for storage in a relational database, it is necessary to analyse each word type and define the rules for formalization or create a metamodel of the language. Previous research has analysed nouns (Asenbrener Katic et al., 2021), verbs (Asenbrener Katic et al., 2018), and adjectives (Pavlic et al., 2017). The question is whether and how adverbs and prepositions can be written in a formalized record.

This paper is primarily focused on rules for manual transformation of adverbs and prepositions from natural language sentences in Croatian and English into FNOK record. The tests were performed with sentences containing these word types.

The paper is organized as follows. After the introduction in Section 1 and the presentation of related work in Section 2, Section 3 presents the motivation for the research. Section 4 describes the research methodology. In Section 5, authors analyse adverbs and prepositions in Croatian and English and

give examples and rules for their transformation from natural language to formalized records.

2 Related work

In (Timko, 2018) adverbs are described as a specific and important word type, in terms of their structure, morphological, syntactic and semantic properties. Many works deal with the analysis of adverbs and prepositions from different aspects.

Socher (Socher et al., 2012) presented a recursive neural network (RNN) model that learns compositional vector representations for phrases and sentences of arbitrary syntactic type and length. This model assigns a vector and a matrix to every node in a parse tree: the vector captures the inherent meaning of the constituent, while the matrix captures how it changes the meaning of neighbouring words or phrases. Each word and phrase is represented by a vector and a matrix. Adverbs are studied within adverb-adjective pairs, while NOK method allows representation of all combinations of adverbs and other types of words.

Pollin (Pollin et al., 2018) describes the annotation process and model of the Open Access Database 'Adjective-Adverb Interfaces in Romance' (AAIF) project. Their approach is to create a domain-specific ontology and the data is annotated in TEI/XML, formalized and enriched with RDF, and its conceptual data model is stored in and published via the GAMS digital repository. In (Gerhalter, 2021), only adjective - adverbs - i.e. adjectives with adverbial functions - are tagged and annotated, while adjectives with adjectival syntax are not tagged in the AAIF-database.

Prepositions play an important role in syntax and semantics of sentences in Croatian and English. This leads to difficulties in automatic processing of sentences. According to (Pawar et al., 2021), prepositions have been explored using various classical machine learning techniques, for example: they have used heavy linguistic tools and resources such as part-of-speech taggers, chunkers, dependency parsers, named entity extractors, Word-Net based super-sense taggers, and semantic role labelers for feature engineering. Implementations of such approaches can be evaluated with varying degrees of success.

Recent studies aimed at solving prepositional attachment and prepositional selection problems rely heavily on external linguistic resources and use dataset-specific word representations (Gong et al., 2018). In (Gong et al., 2018), word-triples are counted (where one of the triples is a preposition) to capture the interaction of a preposition with its attachment and complement.

Prepositions have been studied, among others, as part of the BERT language representation model (Devlin et al., 2019) and its derivatives such as RoBERTA (Y. Liu et al., 2019) and Big Bird (Zaheer

et al., 2020), which were developed to pre-train contextualized deep representations of words based on large unlabeled corpora (Wiedemann et al., 2019).

In our approach using FNOK, each word in a sentence is examined and its type is determined using a dictionary. The rules for translation into a formalized notation apply to all words in a sentence. First, the type of each word in the sentence is determined. Then, depending on the word type of the word we associate it with, a particular rule is applied. The author's previous research has shown that the system is very accurate in answering questions. For example, in (Asenbrener Katic et al., 2021) it is shown that the prototype provided 93% of correct answers in English and 94% of correct answers in Croatian. The prototype was tested with 30 sentences and 55 questions in English and 30 sentences and 54 questions in Croatian. These sentences contain nouns and noun phrase structures.

The rules for adverbs and prepositions, as well as the results of the preliminary research, are presented in this paper.

3 Research Motivation

Knowledge is described in (Hrvatska enciklopedija, 2021) as a system and logical outline of facts and generalizations about objective reality that are accepted and permanently retained in consciousness; a set of facts, information, and skills acquired through training or experience for theoretical or practical understanding and problem solving. People express their knowledge in natural languages in various ways, for example, in writing, orally, using a figure, etc.

This research aims to store knowledge expressed in texts in the knowledge base so that it can give answers to the questions asked, based on stored knowledge. In other words, the main motivation is to develop a question-answering (QA) system over a relational database that allows to input any text or knowledge expressed in text in any language. To achieve this, it is necessary to study how to write text expressed in natural language into a relational database. In addition, it is necessary to perform an analysis of each type of word in a given language and to define the rules by which it is possible to enter text or sentences in natural language into a relational database. It is also necessary to define a metamodel for each word type, which will later form the basis of the relational knowledge base metamodel. We are currently limited to Croatian and English, but it is possible to do the same for other languages.

Since analyses of nouns, adjectives and verbs have been made so far, further analysis is made for the closed word classes adverbs and prepositions. It included the study on how they could be written in a formalized form (FNOK record) which has so far proved suitable for entry into a relational knowledge base on which interrogation could be conducted.

4 Methodology

The basic concepts of the NOK method are nodes (which can be ordinary or process) and links with a single role. Two ordinary nodes, two process nodes or one ordinary and one process node are connected with a link. Each link between the nodes has only one role. The link between 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 (Asenbrener Katic et al., 2021). By using the NOK method, FNOK is created.

According to the general rules described in (Pavlic et al., 2013), (Asenbrener Katic et al., 2021), (Asenbrener Katic et al., 2018), can be briefly summarised:

- A word in a sentence in natural language corresponds to a node in the FNOK record. More precisely, the verb in a sentence in natural language corresponds to a process node in FNOK. Every other word type corresponds to an ordinary node (or simply: node).
- Transformation of a sentence in natural language into its formalized FNOK record is preceded by analysis of that sentence. The first step is to find verbs in it, because verbs are most common process nodes and they belong to the highest level of hierarchy. Other nodes belong to lower levels of hierarchy.
- Open bracket marks descending to lower levels of hierarchy, while closed bracket marks return to the previous level.
- Question or a question word is in front of each node in the hierarchy and indicates a role that links a node on a lower level with a node on a

higher level, i.e. node on a lower level is an answer to the asked question.

- Question (Role) is marked by quotation marks and a question mark ("?"). Some of the questions that can be asked are: "who?", "what?", "when?", "how?", "where?", "how much?", "how many?" etc., depending on the word type. Questions asked with roles are usually from the group of wh-questions.
- 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.

5 Research Results

The rules for converting adverbs and prepositions into FNOK records are presented in this chapter.

5.1. Adverbs

In Croatian, adverbs are a closed word classes that are most often added to verbs to express the circumstances of an action (place, time, manner, cause, purpose, and quantity or amount). Adverbs can also be added to adjectives (e.g. pretty good), adverbs (e.g. a little earlier) and nouns (e.g. many leaflets) (Tezak & Babic, 2005).

Table 1. gives a description of the types of adverbs (Tezak & Babic, 2005), (Silic & PranjkoVIC, 2005) in Croatian with an explanation in English.

Table 1. Description of the types of adverbs in Croatian with an explanation in English.

Types of adverbs in Croatian		Croatian	English
Vremenski prilozni (Adverbs of time)	Kada? (When?)	danas, večeras, noćas, jučer, sinoć, preksinoć, danas, sutra, preksutra, ljetos, proljetos, jesenas, zimus, proljeti, ljeti, jeseni, zimi, lani, preklani, obdan, obnoć, odmah, smjesta, sada, tada, onda, ikada, bilo kada, nikada, nekada, ponekad, katkad, uvijek, svagda, često, rijetko, rano, kasno, prije, poslije, potom, nedavno, skoro, uskoro, napokon, ...)	today, tonight, yesterday, last night, the day before yesterday, today, tomorrow, the day after tomorrow, last summer, last spring, last autumn, last winter, in spring, in summer, in autumn, in winter, last year, two years ago, during the day, during the night, immediately, promptly, now, then, ever, anytime, never, once, sometimes, always, often, rarely, early, late, before, after, recently, almost, soon, finally, ...
	Otkada? (Since when?)	od sad, otad, oduvijek, odavna, odmalena...	from now on, since then, always, long ago, from an early age, ...
	Dokada? (Until when?)	dosad, dotad, dogodine, do večer ...	so far, until then, until next year, until tonight ...
Mjесni prilozni (Adverbs of place)	Gdje? (Where?)	ovdje, tu, ondje, negdje, igdje, nigdje, ponedje, gore, dolje, unutra, vani, sprijeda, straga, ...	here, there, somewhere, anywhere, nowhere, up, down, inside, outside, in front, behind, ...
	Kamo? (Where to?)	ovamo, onamo, tamo, nekamo, nikamo, ikamo, naprijed, natrag ...	here, there, somewhere, nowhere, forward, backward
	Kuda? (Where?, Which way?)	ovuda, onuda, tuda, nikuda, nekuda, ikuda, kojekuda ...	This way, that way, nowhere, somewhere, anywhere, ...

	Otkuda? Odakle? (Where from?)	odavde, otud, odatle, odonud, niotkuda, odozgo, odozdo, odostraga, izdaleka, izvana, izbliza ...	from here, from there, from nowhere, from above, from below, from behind, from afar, from outside, up close ...
	Dokle? Dokud? (Until where?)	donekle, dovle, dotle, donle	to some extent, to that extent
Načinski priloz (Adverbs of manner)	Kako?, Kojim načinom? (How?)	ovako, tako, onako, nikako, nekako, ikako, kojekako, svakojako, kriomice, potajice, poimence, iznenada, odjednom, jedva, svejedno, ...	like this, like that, no way, somehow, secretly, namely, suddenly, barely, anyway
	Adverbs of manner in Croatian are also derived from adjectives	From descriptive adjectives in any degree (three states) of comparison: positive, comparative and superlative: blago, blaže, najblaže, brzo, daleko, dalje, jako, lako, lijepo, teško, teže, najteže, tiho, veselo, zlo, žestoko, ... (for example, Dijete se igra (kako?) veselo.)	mild, milder, mildest, fast, far, further, strong, easy, beautiful, hard, harder, hardest, quiet, merry, evil, fierce, ... (for example, Child plays (how?) merry).
		From relative adjectives (finishing with -ski in Croatian): bratski, gospodarski, hrvatski, ljudski, slavenski, školski, vojnički, etc. (for example, Govorimo (kako?) hrvatski.)	fraternal, economic, Croatian, human, Slavic, etc. (for example, We speak (how?) Croatian.)
Uzročni priloz (Adverbs of cause)	Zašto?, Zbog čega? (Why?)	zato, stoga	because
Količinski priloz (Adverbs of quantity)	Koliko? (How much? How many?)	ovoliko, toliko, onoliko, nekoliko, malo, premalo, više, previše, prekovise, najviše, ponajviše, manje, najmanje, ponajmanje, dosta, odveć, opet, još, sasvim, potpuno, previše	so much, so many, a few, a little, too little, more, too much, too many, less, least, enough, again, still, quite, completely
	Koliko puta? (How many times?)	jedanput, dvaput, triput, stoput	Once, twice, three times, a hundred times
Posljedični priloz (Adverbs of consequence)	S kojom posljedicom? S kojim ishodom? (With what consequence? With what outcome?)	uzalud, uzaman, utaman	in vain

There are a number of adverbs that do not answer the above questions. They are attached not only to verbs, but also to other types of words and even to the whole sentence, and they state:

- Reliability, truthfulness of what the article refers to: *naravno, pouzdano, neosporno, neprijeporno, nesumnjivo* (of course, reliably, indisputably, unquestionably, undoubtedly)
- More or less likely, the probability of what it refers to: *sigurno, zasigurno, jamačno, vjerojatno* (certainly, surely, guaranteed, probably)
- Doubt of what the article refers to: *navodno, tobože, naizgled* (allegedly, supposedly, apparently)
- Unexpectedness of what the adverb refers to: *ipak* (however)

- Limitation of what the adverb refers to: *jedan, jedino* (one, only)

- ...

In English, adverbs are the words most often attached to verbs, indicating the circumstances of the verb's action (place, time, manner, quantity, and cause). The adverb comes after the verb it modifies (Bozic, 2006).

Types of adverbs are (Bozic, 2006):

1. adverbs of place: *here, there, down, ...*
2. adverbs of time: *yesterday, today, now, tonight, often, always...*
3. adverbs of manner: *softly, slowly, quickly, carefully, ...*
4. adverbs of frequency/amount: *enough, quite, very, too much, too little, ...*
5. adverbs of purpose: *so, since, thus, because, ...*

Sometimes adverbs can modify adjectives to strengthen or weaken them. Also, some types of adverbs can modify other adverbs by changing their degree or accuracy. Adverbs are converted to FNOK in two ways.

5.1.1. Adverbs attached to verbs

Since when analysing sentences, the first step is to look for verbs that have the role of a process node in FNOK and are at the top of the hierarchy, the question of the relationship between adverbs and verbs arises. The following rule is defined.

Rule 1. If adverbs are attached to verbs, then in FNOK they are hierarchically dependent on verbs, i.e. they are subordinate to verbs in the hierarchy. It can briefly be written like this:

$V, Adv \rightarrow V$ ("role?" *Adv*), where *Adv* stands for adverb, *V* stands for verb and *role?* stands for a wh-question.

Note: When more than one adverb is associated with the verb in a sentence, they are analyzed individually, each in relation to the verb. The order of adverbs and corresponding questions in FNOK is taken from the sentence:

$V, Adv\ 1, \dots, Adv\ n \rightarrow V$ ("role 1?" *Adv 1*, ..., "role n?" *Adv n*) where *Adv 1*, ..., *Adv n* stand for different adverbs, *V* stands for verb and *role 1?*, ..., *role n?* stand for different wh-questions.

Examples are given first in Croatian, then the same sentence in English:

- Medvjedi jedu *pohlepno*. → jedu ("tko?" medvjedi, "kako?" *pohlepno*)
- The bears eat *greedily*. → eat ("who?" bears ("art?" the), "how?" *greedily*)
- Marko *danas brzo* vozi auto. → vozi ("tko?" Marko, "što?" auto, "kada?" *danas*, "kako?" *brzo*)
- Mark drives a car *quickly today*. → drives ("who?" Mark, "what?" car ("art?" a), "when?" *today*, "how?" *quickly*)

5.1.2. Adverbs attached to other word types (other than verbs)

When adverbs are attached to adjectives or other adverbs, they are translated in FNOK as hierarchically dependent on the adjectives, nouns, or adverbs they modify. The rule is:

Rule 2. Adverbs attached to other word types (adjectives or other adverbs, but not verbs), are translated in FNOK as hierarchically dependent on the adjectives, nouns, or adverbs they modify. It can be written in this form:

$Adv, X \rightarrow X$ ("role?" *Adv*), where *Adv* stands for adverb, *X* stands for adjective, noun or adverb modified by the adverb, and *role?* stands for a wh-question.

More complex examples can be reduced to this basic rule.

Example:

- Ti izgledaš *jako dobro*. → izgledaš ("tko?" ti, "kako?" *dobro* ("kako?" *jako*))
- You look absolutely fabulous! → look ("who?" you, "how?" fabulous ("how?" absolutely))
- Marija svira violinu *izuzetno dobro*. → ("tko?" Marija, "što?" violinu, "kako?" *dobro* ("kako?" *izuzetno*))
- Mary plays the violin *extremely well*. → plays ("who?" Mary, "what?" violin ("art?" the), "how?" *well* ("how?" *extremely*))
- Marko danas *vrlo brzo* vozi auto. → vozi ("tko?" Marko, "što?" auto, "kada?" *danas*, "kako?" *brzo* ("koliko?" *vrlo*))
- Mark drives a car *very quickly* today. → drives ("who?" Mark, "what?" car ("art?" a), "when?" *today*, "how?" *quickly* ("how?" *very*))

5.2. Prepositions

In Croatian, prepositions are a closed word classes used to indicate the relations between beings, things, and phenomena, and they affect the case of the word they stand next to. They are most often associated with nouns and noun pronouns but can also refer to open word classes (adjectives, adjective pronouns and numbers) (Tezak & Babic, 2005), (Silic & Pranjkovic, 2005). Prepositions cannot stand alone in sentences.

In English, prepositions are a type of words that indicate the relationships between objects, beings, and phenomena. They cannot stand alone and are always connected with nouns (Biblioteka Strani Jezici, 2009). Prepositions are combined with other types of words to form prepositional phrases, which usually have a similar form: a preposition followed by determiners, and one or two adjectives followed by nouns or pronouns. This whole phrase has a modifying role, acting as an adjective or adverb that locates something in time and space, modifies a noun, or tells when, where, or under what conditions something happened (Greenbaum & Quirk, 2006).

The following rule is defined for the conversion of prepositions into FNOK.

Rule 3. In FNOK prepositions are hierarchically positioned below nouns, i.e. below the part of speech with which they are associated (noun, noun pronoun or open word classes (adjectives, adjective pronouns and numbers)). Each preposition belongs to the noun to which it refers. The noun is mentioned first, followed by the preposition. The question (role) for the preposition is taken from the noun, which is hierarchically superior to it. Briefly, the rule is:

$X, Prep, N \rightarrow X$ ("role1?" *N* ("role1?" *Prep*), where *Prep* stands for preposition, *X* stands for any kind of word and *role1?* stands for a wh-question.

Examples are given first in Croatian, then the same sentence in English:

- Knjiga je *na* stolu. → je ("što?" knjiga, "gdje?" stolu ("gdje?" *na*))

- The book is *on* the table. → is ("what?" book ("art?" the), "where?" table ("where?" on, "art?" the))
- Ja radim svoju domaću zadaću svaki dan *u* pet sati. → radim ("tko?" ja, "što?" zadaću ("čiju?" svoju, "kakvu?" domaću), "kada?" dan ("koji?" svaki), "koliko?" sati ("koliko?" u, "koliko?" pet))
- I do my homework every day *at* five o'clock. → do ("who?" I, "what?" homework ("whose?" my), "when?" day ("what?" every), "when?" o'clock ("when?" five ("when?" at)))
- Jack je *u* kući. → je ("tko?" Jack, "gdje?" kući ("gdje?" u))
- Jack is *in* the house. → is ("who?" Jack, "where?" house ("where?" in, "art?" the))

5.3. ER diagrams for Adverbs and Prepositions

Figure 1. and Figure 2. show entity-relationship (ER) diagrams for adverbs and prepositions, respectively. The ER diagrams are presented using the entity-relationship method in accordance with the Methodology for development of information systems (MIRIS).

In creating the ER diagram for adverbs, rules 1 and 2 were used, as well as general knowledge about adverbs in Croatian and English.

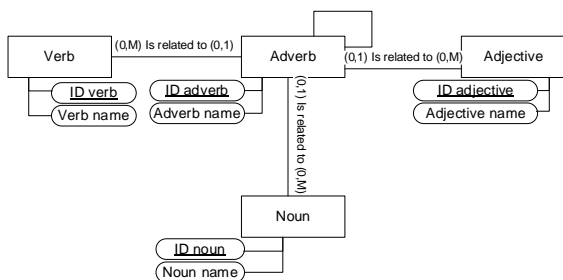


Figure 1. ER diagram for adverbs

In building the ER diagram for prepositions, rule 3 and general knowledge about prepositions in Croatian and English were used.

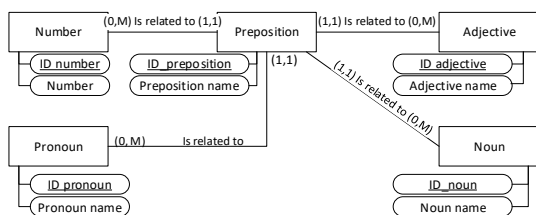


Figure 2. ER diagram for prepositions

Note: Not necessarily all, but at least one relationship between Preposition and other word types

(Noun, Pronoun, Adjective, Number) must be fulfilled.

Both models will be part of a metamodel of the language, that will show the relationships between all types of words and can be used to store natural language sentences to relational database. According to the ER diagrams, adverbs are related to verbs, adjectives, nouns and other adverbs, while prepositions are related to nouns, pronouns, adjectives and numbers.

5.4. Prototype testing

The rules presented in this paper were used in the development of the metamodel of the language and in the development of the prototype of a QA system over a relational database. The first tests, which focused on verbs, nouns, and noun phrases, were extended by new sentences that focused on adverbs and prepositions. The prototype was tested on 54 sentences and 120 questions in English and 53 sentences and 118 questions in Croatian. The sentences consisted of nouns, verbs, adjectives, prepositions and adverbs. The rules described in previous work (Asenbrener Katic et al., 2021), (Asenbrener Katic et al., 2018), (Pavlic et al., 2017) and in this paper were used to transform sentences into a FNOK record suitable for input to a relational database. For the given questions, the system offered 90,3% of correct answers in English and 90,4% of correct answers in Croatian language.

6 Conclusion

In this paper, an analysis of adverbs and prepositions in Croatian and English is presented, and rules are defined on how to write these two word types in a formalized FNOK record suitable for input into the knowledge database. The Node of knowledge method was used, as well as its formalisms FNOK, which have already shown that it is possible to enter nouns, verbs and adjectives of Croatian and English into the QA system.

The paper defines two rules for adverbs and one for prepositions that allow natural language sentences containing these word types to be written in formalized form and entered into a relational database. Each rule is accompanied by several examples. ER diagram of adverbs and ER diagram of prepositions, which will be part of the language metamodel required for the development of the QA system, have been defined. The defined rules were implemented in a prototype QA system tested on 54 sentences and 120 questions in English and 53 sentences and 118 questions in Croatian. We achieved very good results (the system provided 90,3% correct answers in English and 90,4% correct answers in Croatian).

However, there are some limitations. This research is part of a larger research that will be expanded step by step. Accordingly, future research will include rules for pronouns and conjunctions, and the QA system tests will be expanded with more complex sentences and questions. Problems encountered in these tests will be the subject of further research. The language metamodel will need to be improved and developed for other word types, such as pronouns and conjunctions. It will be necessary to revise the algorithms used in the prototype and implement additional rules to improve the prototype. It is also planned to extend the research to other languages.

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References

- Asenbrener Katic, M., Candrlic, S., & Pavlic, M. (2018). Modeling of verbs using the node of knowledge conceptual framework. 2018 41st International Convention on Information and Communication Technology, Electronics and Microelectronics, MIPRO 2018 - Proceedings, 1022–1027. <https://doi.org/10.23919/MIPRO.2018.8400187>
- Asenbrener Katic, M., Candrlic, S., & Pavlic, M. (2021). Nouns in the Conceptual Framework “Node of Knowledge.” *Tehnicki Vjesnik - Technical Gazette*, 28(6), 2088–2093. <https://doi.org/10.17559/TV-20200731095329>
- Biblioteka Strani Jezici. (2009). *Engleska gramatika, English Grammar*. Knjigotisak d.o.o.
- Bozic, D. (2006). *Rječnik englesko-hrvatski, hrvatsko-engleski: s gramatikom*. Marijan tisak.
- Brachman, R., & Levesque, H. (2004). *Knowledge representation and reasoning*. The Morgan Kaufmann Series in Artificial Intelligence, Morgan Kaufmann.
- Cali, A., Gottlob, G., & Pieris, A. (2012). Towards more expressive ontology languages: The query answering problem. *Artificial Intelligence*, 87–128.
- Candrlic, S., Asenbrener Katic, M., & Jakupovic, A. (2020). Preliminary Multi-lingual Evaluation of a Question Answering System Based on the Node of Knowledge Method. *Lecture Notes in Networks and Systems*, San Francisco, SAD: Springer, 998–1009. https://doi.org/doi:10.1007/978-3-030-12388-8_69
- Candrlic, S., Asenbrener Katic, M., & Pavlic, M. (2019). A system for transformation of sentences from the enriched formalized Node of Knowledge record into relational database. *Expert Systems with Applications*, 115, 442–464. <https://doi.org/10.1016/j.eswa.2018.07.021>
- Devlin, J., Chang, M.-W., Lee, K., & Toutanova, K. (2019). BERT: Pre-training of deep bidirectional transformers for language understanding. *Proceedings of the 2019 Conference of the North*, 4171–4186.
- Dovedan Han, Z. (2021). *Progovorimo pythonski. Vlastita naklada*
- Gerhalter, K. (2021). Annotation Model: Criteria for Linguistic Categorization in the Database “Adjective-Adverb Interfaces in Romance.”
- Gomez-Perez, A., & Benjamins, V. R. (2002). *Knowledge Engineering and Knowledge Management, Ontologies and the SemanticWeb*. Proceedings of 13th International Conference, EKAW 2002.
- Gong, H., Bhat, S., & Viswanath, P. (2018). Embedding syntax and semantics of prepositions via tensor decomposition. *ArXiv Preprint ArXiv:1805.09389*.
- Greenbaum, S., & Quirk, R. (2006). *A Student’s Grammar of the English Language*. Longman.
- Hrvatska enciklopedija, mrežno izdanje. (2021). knowledge. *Leksikografski Zavod Miroslav Krleža, Pristupljeno 15. 6. 2022*. <<http://www.Enciklopedija.Hr/Natuknica.aspx?ID=67357>>.
- Jakupovic, A., Pavlic, M., & Dovedan Han, Z. (2014). Formalisation method for the text expressed knowledge. *Expert Systems with Applications*, 41(11), 5308–5322. <https://doi.org/10.1016/j.eswa.2014.03.006>
- Jakupovic, A., Pavlic, M., Mestrovic, A., & Jovanović, V. (2013). Comparison of the Nodes of Knowledge method with other graphical methods for knowledge representation. *Proceedings of the 36th International Convention /CIS/, MIPRO 2013*, 1276–1280.
- Liao, S.-H., Pei-Hui, C., & Pei-Yuan, H. (2012). Data mining techniques and applications – A decade review from 2000 to 2011. *Expert Systems with Applications* (39), 11303–11311.
- Liu, H.-C., You, J.-X., Li, Z., & Tian, G. (2017). Fuzzy Petri nets for knowledge representation and reasoning: A literature review. *Engineering Applications of Artificial Intelligence*, 60, 45–56. <https://doi.org/10.1016/J.ENGAPPAI.2017.01.012>
- Liu, Y., Ott, M., Goyal, N., Du, J., Joshi, M., Chen, D., Levy, O., Lewis, M., Zettlemoyer, L., &

- Stoyanov, V. (2019). RoBERTa: A robustly optimized BERT pretraining approach. ArXiv Preprint ArXiv:1907.11692.
- Neelakantan, A. R. (2017). Knowledge Representation and Reasoning with Deep Neural Networks. Doctoral Dissertations. 1114.
- Pavlic, M., Dovedan Han, Z., Jakupovic, A., Asenbrener Katic, M., & Candrljic, S. (2017). Adjective representation with the method Nodes of Knowledge. 2017 40th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO), 1221–1226. <https://doi.org/10.23919/MIPRO.2017.7973610>
- Pavlic, M., Jakupovic, A., & Mestrovic, A. (2013). Nodes of knowledge method for knowledge representation. *Informatologia*, 46(3), 206–214.
- Pawar, S., Thombre, S., Mittal, A., Ponkiya, G., & Bhattacharyya, P. (2021). Tapping BERT for Preposition Sense Disambiguation. ArXiv Preprint ArXiv:2111.13972.
- Pollin, C., Schneider, G., Gerhalter, K., & Hummel, M. (2018). Semantic Annotation in the Project “Open Access Database ‘Adjective-Adverb Interfaces’ in Romance.” Proceedings of the Workshop on Annotation in Digital Humanities. CEUR Workshop Proceedings, 41–46.
- Rauker Koch, M., Asenbrener Katic, M., & Pavlic, M. (2017). Fable representation in fnok and dnok formalisms using the nok conceptual framework. *Annals of DAAAM and Proceedings of the International DAAAM Symposium*. <https://doi.org/10.2507/28th.daaam.proceedings.061>
- Rauker Koch, M., Candrljic, S., & Asenbrener Katic, M. (2022). Automation of the conversion of natural language to formalized node of knowledge record. *Zbornik Veleučilišta u Rijeci*, 10(1), 57–71. <https://doi.org/10.31784/zvr.10.1.4>
- Rauker Koch, M., Pavlic, M., & Asenbrener Katic, M. (2015). Homonyms and Synonyms in NOK Method. *Procedia Engineering*, 100, 1055–1061. <https://doi.org/10.1016/j.proeng.2015.01.466>
- Rauker Koch, M., Pavlic, M., & Jakupovic, A. (2014). Application of the NOK method in sentence modelling. Proceedings of the 37th International Convention MIPRO 2014, 1426–1431.
- Silic, J., & Pranjekovic, I. (2005). Gramatika hrvatskoga jezika za gimnazije i visoka učilišta. Školska knjiga.
- Socher, R., Huval, B., Manning, C. D., & Ng, A. Y. (2012). Semantic compositionality through recursive matrix-vector spaces. Proceedings of the 2012 Joint Conference on Empirical Methods in Natural Language Processing and Computational Natural Language Learning, 1201–1211.
- Tezak, S., & Babic, S. (2005). Gramatika hrvatskoga jezika, Priručnik za osnovno jezično obrazovanje. Školska knjiga.
- Timko, Đ. O. (2018). Najproduktivniji modeli tvorbe priloga u hrvatskom i ukrajinskom jeziku. *Visnyk of Lviv University. Series Philology.*, 69, 102–110.
- Wiedemann, G., Remus, S., Chawla, A., & Biemann, C. (2019). Does BERT make anysense? interpretable word sense disambiguation with contextualized embeddings. ArXiv Preprint ArXiv:1909.10430.
- Zaheer, M., Guruganesh, G., Dubey, A., Ainslie, J., Alberti, C., Ontanon, S., Pham, P., Ravula, A., Wang, Q., Yang, L., & et al. (2020). Big bird: Transformers for longer sequences. ArXiv Preprint ArXiv:2007.14062.