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Using Markedness Principle for Abstraction of Dependency Relations of Natural Languages

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Abstract
Background/Objectives: There is no attempt to investigate the relationships between dependency and markedness even though the syntactic roles in language are decided by dependency relations and markers. The main objective of this study was to understand markedness beyond syntactical tables and propose a syntax graph with various syntax structures to verify the relationship between dependence of proposed markers. Methods/Statistical analysis: The methodology involved enquiry into the origin and development of dependency relations, starting from their definition, abstraction, and usage in syntactic structures through graphical presentations. Findings: This study revealed that dependency relations denoted by the markers can be classified into two types of dependencies according to their syntactic functions: implicit and explicit. Eventually, this markedness can be presented through syntax graphs of various syntactic structures to validate the functions of the markers and dependency relations. Improvements/Applications: This paper presents a reasonable method to define dependency relations based on the markedness and the valence theory of the predicate. This approach provides a systematic view to define dependency relations for natural language processing. The implementation of syntax graphs is a future research project.

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Keywords: Markedness, dependency relations, natural language processing (NLP), syntactic analysis, subcategorization, syntax graph

1. Introduction

Natural Language Processing (NLP) is now treated synonymously with AI applications such as Deep Learning (DL) and Machine Learning (ML). NLP has thus been understood as a concept beyond linguistic intelligence. The linguistic approaches are not sufficient to demonstrate potential impact and progressive accomplishment in the development of NLP applications. There is no dearth of research on NLP related issues such as language modeling and syntactic/semantic analysis in order to understand the written texts and spoken dialogs (Kim, 2020a, Nadkarni et al., 2011). Recently, a revolutionary approach prompted by Deep Learning (DL) provided a breakthrough insight in NLP and achieved significant innovations (Lopez and Kalita, 2017, Ethayarajh, 2019, Wang et al., 2019, Brown et al., 2020).

Several innovative language models based on transformer and attention mechanism such as BERT and GPT-3 demonstrate remarkable performance of NLP applications like question answering, sentiment analysis, conversational chatbots, machine translation, and text summarization (Wang et al., 2019, Brown et al., 2020, Vaswani et al., 2017, Dale, 2021). DL

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approach to NLP generally uses vector semantics based on a probability distribution over sequences of words (Turney and Pantel, 2010, Gamallo, 2021). However, although vector semantics provides practical efficiency and demonstrate surprising performance, the substantive issues inherent in natural languages remain in understanding linguistic competence and performance. Natural languages are a part of production system holding native syntactic/semantic structures, unlike random probabilistic structures. This fact implicates that language models should stand on linguistic features of natural languages rather than random stochastic events.

In other words, NLP should be able to exploit the linguistic properties of natural languages to realize linguistic capability like human language perception. One such property is markedness widely applied for the analysis of linguistic phenomena. Markedness is concerned with the characterization of the distinctive features that represent the presence of specific linguistic attentions. There are studies that have made significant efforts to explore the intrinsic properties of syntactic/semantic structures of markedness. For instance, markedness has been studied multi-dimensionally: the syntactic level marker is used to denote certain syntactic/semantic roles while conventionally markedness had been focusing on the description of the linguistic features. Likewise, markedness is now better understood as the binder or constructor of constituents.

Since the markedness can distinguish linguistic features, the capability of markedness to identify syntactic features has also been used in various grammar formalisms as a core conception of natural languages. Several grammar formalisms such as Lexical Functional Grammar (LFG), Feature-based unification grammar, Head-driven Phrase Structure Grammar (HPSG) have been proposed to describe syntactic/semantic structures (Kim, 2020b, Shieber, 2003). In the agglutinative languages such as Korean, the constituents' linguistic role is explicitly represented by the marker called the particles. Although there are many linguistic perspectives about the markedness, the markers play a crucial role in binding the constituents and the specification for the syntactic/semantic roles in a sentence. Therefore, the markedness is first-class citizen to provide the foundational basis for linguistic analysis.

Though the markers are used in the various levels to represent grammatical roles of words and phrase structures, this study focuses on syntactic level marker. The syntactic level marker (or simply marker) is a linguistic element to denote certain syntactic/semantic roles by the association of any two language constituents. The major constituent of the association is called governor or head, and the minor constituent is called dependent. This research investigates how markers denote or imply a certain syntactic/semantic role and how its linguistic interpretation of syntactic/semantic role is dependent on the relationship of two constituents in a sentence.

Such dependency relations between grammatical structures also provide the underlying foundation for representing the constituents' syntactic/semantic relationships (Kim, 2020a, Shieber, 2003, Mel'čuk, 2011, Debusmann, 2000). Dependencies in fact are a formal means of representing the syntactic structure of sentences and accepted as the staple approach for analyzing syntactic structures (Mel'čuk, 2011). The dependency relations that conceptualize linguistic relationships between constituents with the simple mechanism have been adopted in grammar formalism as the universal principle of natural languages. Nowadays, it is common to use dependency relations in natural language analysis. Many open tools and systems, such as Stanford CoreNLP, are widely available to provide the standard framework in the development of natural language applications (De Marneffe and Manning, 2008, Manning et al., 2014).

A modern phenomenon that deserves critical attention is the abstractions of dependency relations, the focus of the current study. It uses grammatical relations as they broadly support languages in their typological linguistic literature. Such an approach causes many variants and induces inconsistent analysis (Pyysalo et al., 2007). However, definite concepts about dependency relations need to be established for a coherent syntactic analysis. The relationships between dependency relations and markedness should also be investigated since the syntactic role of linguistic constituents are decided by the dependency relations and explicitly marked by the markers. But the conventional concepts of markedness have focused on the description of the distinctive features of linguistic elements. Hence, this study begins with the understanding of markedness and explains its categorization from diachronic perspectives of natural languages.

The remainder of this paper is structured as follows. Section 2 reviews the related previous work on the markedness principle from the diachronic perspectives of natural languages. The definition and categorization of the markedness are also presented in this section. This section also discusses a compact set of dependency relations as deduced from the markedness and describes the representations of dependency relations. Section 3 presents the methodology used in this study. Section 4 discusses and demonstrates the effectiveness of the marker-based analysis through syntax graphs of various types of sentences. Section 5 finally summarizes the contributions and puts forth the prospects for further work.

2. Literature Review

2.1 Markedness Principle of Natural Languages

There are various applications of markedness in various fields of linguistic studies such as phonology, morphology, semantics, and syntax. Markedness refers to the universal mechanism in natural languages, it provides the foundational basis for of linguistic analysis (Moravcsik and Wirth, 1986, Herbert, 2011, Yang, 2018). In linguistics, markedness is defined as the way words are changed or modified to give a special meaning. Outside of linguistics, markedness refers more generally to the meaning that the speaker intends. If someone meets you on the road and says "Hi, how are you?" you may or may not even answer the question. But if he asks, “How’s your father?" it is ‘marked’ and it carries the implication about your father. By making a “marked choice”, one is making a meaningful statement. Such as notion of markedness based on distinctive features such as meaning and intention has attracted attention in structural linguistics (Moravcsik and Wirth, 1986, Haspelmath, 2006).

Besides, there are also “unmarked choices” to give the normal meaning. For instance, the present tense is unmarked for English verbs: "walk" refers to the present tense but if “ed” is added, it indicates the past: "walked". Another example of markedness is the male-female gender distinction: male nouns are unmarked, while female ones are marked identified with "ess" and "ette" (e.g., "authoress", "poetess". The suffix ‘ette" is also “marked” for the diminutive, as in "cigarette".

Greenberg (1987) assigns the designations “marked” and “unmarked” to opposing structural entities that exhibit a consistently asymmetric relationship in term of distribution and/or syntagmatic structure and or paradigmatic complexity.

These structural entities are represented by natural languages that contain formal symbolic systems with specific underlying rules and structures to represent abstract concepts. In natural languages, the linguistic constituents constructing a sentence such as words, phrases, and clauses expose or mark their linguistic roles in the surface structure implicitly or explicitly. This markedness mechanism is essential to specify the syntactic/semantic roles of the constituents of a sentence. The markedness is the universal mechanism observed in most natural languages (Moravcsik and Wirth, 1986, Herbert, 2011, Grano and Davis, 2018). To exemplify, sentences in a natural language are constructed from the linear binding of words or constituents by means of its unique grammar rules. For example, while the set of concept words shown in (1.a) cannot form a valid sentence, the linear binding of (1.b) by the grammar rules is a legitimate sentence.

1. a. {hall, Harry, her, Juliet, main, piano, play, sister, talk}

   b. Juliet *talked* to her sister about Harry who *played* the piano at the main hall.

In the construction of a sentence, the grammar system uses two substances to assign linguistic roles to the constituents. One is the lexical level markers that usually represent the linguistic properties of words used in the sentence - TALKED and PLAYED of (1.b). The lexical level markers generally represent semantic features of words rather than syntactic structural properties of the linguistic constituents. The other is the syntactic level markers that explicitly imply certain linguistic functions of grammatical structures – TO, ABOUT, and WHO of (1.b). The grammar system uses some pieces of linguistic elements to connect or associate two constituents in the linear binding. The syntactic level markers generally play a key role in defining complex linguistic structures by associating two constituents.

2.2 Categorization of Markedness

In natural languages, two types of the markedness are recognized: the explicit markers that imply syntactic/semantic roles such as shown in prepositional phrases; and implicit markers related to the subcategorization of the predicate. The explicit markers are a kind of syntactic tag imposed upon additional linguistic functions, and, as a kind of a binder, connecting the 'dependent' to the 'governor' in a surface structure. The explicit markers are also the principal element to construct complex sentences by expanding the primary linguistic functions of the constituents. For instance:

2. a. Patrick who worked at Google proposes a new project to develop NLP applications.

   b. When we arrived at the conference, we could find a group discussing KGs.

The explicit markers such as WHO, TO-inf, WHEN, and ING-xcomp shown in (2) are used as a syntactic tag that indicates additional linguistic functions of phrases and clauses. At the same time, the markers play the role of binding the marked constituents to the governors.

There are two types of explicit markers in natural languages. An open clausal complement (xcomp) of a verb or an adjective is a predicative or clausal complement without its own subject. The reference of the subject is necessarily determined by an argument external to the xcomp (normally by the object of the next higher clause, if there is one, or else by the subject of the next higher clause). This is often referred to as obligatory control. These clauses tend to be non-finite in many languages, but they can be finite. TO-inf and ING-xcomp of (2) are a typical example of xcomp. A clausal complement (ccomp) of a verb or adjective is a dependent clause that is a core constituent. That is, it functions as an object of the verb, adjective, or clausal adverbial. For example, WHO in (2.a) is a clausal complement.

Implicit Markers, on the other hand, require all constituents in a sentence to expose the linguistic function. Due to this principle, languages that use unmarked constituents and face the problem of assigning the linguistic function resolve their issues by using the word order. That is, the words that have relative positions in the predicate, play a role of implicit markers with the linguistic functions. The subject, direct object, and indirect object are the few typical positions in a sentence with the implicit marker. In general, the implicit markers are related to the subcategorization of the predicate (Roland, 2001).

Table 1. Categorization of Markers

Type	Category	Example
Explicit Markers	genitive (gen)	John's, …
	preposition (prep)	in, of, at, about, …
	conjunction (ccomp)	that, what, when, who, …
	coordinator (conjunction)	and, or, …
	verbid (xcomp)	to_verb, verb_ing, verb_ed, …
	auxiliary verb (aux)	will, can, must, …
	passive voice (pass)	be, is, was, …
	negation (neg)	not, never, …
Implicit markers	subcategorization (sc)	He knows Madonna, …
	empty category (ec)	big tree, happy family, …

Table 1 exhibits the English language markers that determine the syntactic functions and roles of the constituents. The dependency relations widely used for analyzing syntactic structures can be perceived from the perspective of the markedness.

2.3 Syntactic description of language

For a syntactic description of natural languages, diverse grammar formalisms such as Systemic Functional Grammar, Lexical Functional Grammar (LPG), Head-driven Phrase Structure Grammar (HPSG) are proposed (Shieber, 2003, Matthiessen and Halliday, 2009). The grammar formalisms have their unique foundational principles such as unification and feature structure to represent the complex syntactic/semantic structures and explain the composition of

linguistic structures (Boas and Dux, 2017). Novel insights are also presented for syntax rather than phrase structures (Shieber, 2003, Mel'cuk, 1988). Hence, in the context of dependency relations as the primary base in NLP (De Marneffe and Manning, 2008, Manning et al., 2014), there has been much effort to develop a set of universal dependency relations. Though the development of the concerted set of dependency relations remains incomplete.

The tree structure is also commonly used to represent syntactic structures (Sachan et al., 2020). However, graph structures flexibly represent complex structures and support good performance (Mulang et al., 2017). Such graphic representation needs to be explored for a more realistic representation of dependency relations than dependency trees as there is a dearth of such representations in the previous writings. The section on 'Discussion' attempts to fill this literature gap by proposing a set of dependency relations and discuss their properties and roles in the context of syntactic structures.

2.4 Abstraction and Representation of Dependency Relations

The abstraction of dependency relations considers the inherent characteristics of syntactic/semantic relations diachronically, without trying to model the contemporary linguistic structures precisely. There are a few basic principles used for dependency relations such as uniqueness, non-crossing, and acyclic property (Mel'čuk, 2011, Mel'cuk, 1988). However, dependency relations remain a directed, binary relation between governor and dependent. This implies that dependency relations can be recognized and categorized by the linguistic properties of markers. Further, the dependency relations presented in a sentence are embodied by the markers implicitly or explicitly. In other words, dependency relations are cohesive principles to generate linguistic structures, and the markers are the proxy to realize dependency relations in sentences.

Though sentences are generated by linear association of linguistic constituents according to their dependency relationships, these dependency relationships are realized with the markers in surface structures. These markers offer important evidence to define dependency relations. The dependency relations are also inductively derived from relationships between constituents in the surface structure and classified into syntactic dependency, semantic dependency, and morphological dependency (Mel'čuk, 2011, Mel'cuk, 1988).

This is evident from the fact that several grammar formalisms have been used to analyze syntactic structures of NLP. The dependency relations have also received an increasing amount of attention to developing practical natural language understanding (NLU) applications (De Marneffe and Manning, 2008, Manning et al., 2014). Many open tools and systems such as Stanford CoreNLP are widely available to provide the universal development environment (De Marneffe and Manning, 2008). A few of these dependency relations used in NLU applications are broadly taken across many typological linguistic works of literature. Since natural languages are constantly changed and evolved, this kind of abstraction from the corpus would suffer from extracting universal dependency relations innate in natural languages. Thus, some definite criteria that can reflect universal linguistic properties are required in the abstraction of dependency relations (Grano and Davis, 2018).

3. Methodology

This study revolves around the abstraction of dependency relations, development of a compact set of dependency relations and devise principles and rules to define dependency relations. The methodology therefore adopted involved enquiry into the origin and development of dependency relations, starting from their definition, abstraction, and usage in syntactic structures through graphical presentations. Since the syntactic structures are decided by the dependency relations and their syntactic functions are explicitly represented by markers, the markedness principle was given adequate attention in this study. From the analysis of the diverse syntactic structures, two types of markers emerged: explicit markers denoting syntactic functions and implicit markers related to subcategorization.

This paper thus attempts a pioneering study by using the markedness principle, one of the universal properties of natural languages, to analyze dependency relations from the point of view of linguistic consistency. This facilitated the investigation of categorization and syntactic

properties of markers. A new syntactic structure representation called syntax graph was presented to validate the effectiveness of the marker-based syntactic analysis.

4. Discussion

This debate between singular-plural compatibility across morphological and semantic markedness is less relevant to the present study. The study focuses more on categorization and types of dependency relations according to their purpose in surface structure. Two types of dependency relations: government-dependency and attachment-restriction surfaced during this study. The government-dependency was found generally mandatory in relation to subcategorization and markedness while the attachment-restriction was optional in relation to connecting some modifying constituent to the governor. For example, the relations (MAN) – (PRESENTED) – (PAPER) in (3) are the type of government-dependency, while the relations (MAN)-(ENGLAND), (PAPER)-(BLOCKCHAIN) and (PRESENTED-US) are the attachment-restriction dependency.

(3) A man from England presented a paper about the blockchain to us.

The dependency relation is a structural relationship physically expressed in the surface sentence which makes is difficult to identify the semantic feature that is usually determined according to syntactic/semantic properties of three arguments: governor, dependent, and marker. This may be understood by looking at the properties of dependencies relations and their association. The marker is a linguistic element to denote certain syntactic/semantic roles by the association of two constituents. The major constituent of the association is called governor or head, and the minor constituent is called dependent. The conventional syntactic analysis is apt to ignore the role of the marker, however, the marker plays a proactive role in associating constituents for complex syntactic structures.

In sentence (3), the syntactic/semantic property of the relationship (MAN, ENGLAND) is decided by the marker FROM. This implies that the marker as a master of the phrasal structure represents a new syntactic/semantic role of ENGLAND. In other words, the marker FROM dominates ENGLAND and acts as the representative of phrasal structure. The same interpretation confirms why (TO, US), not (TO, WE), is correct. Thus, the marker is governor and proxy representing the syntactic/semantic function of its associated constituent. The representation of dependency relations such as the dependency tree generally uses an arrow from the governor to dependent. USD analysis of (3) shows dependencies like (MAN → ENGLAND) and (MAN ← PRESENTED). It causes unreasonable representations uniformly regarding dependency relations as government-dependency. From the point of view of man, England is an optional acquired semantic element, and from the point of view of England, man is a target element to grant its semantic features. In this case, it is unreasonable to say that man dominates England.

In another example (4) containing typical preposition marker OF, the semantic feature of dependency relation between (4.a MEMBER – PARLIAMENT) and (4.b DRESS – SILK) cannot be uniquely defined. This implies that the dependency relation should be understood from the perspective of the valence structure.

(4) a. John was elected member of Parliament.

b. She designed a dress of silk for her mother.

Table 2. Dependency Relations and Related Markers

Type	Dependency Relations			Related Markers		
government/	mark	expl		sc	ec	conj
dependency	subj	iobj	dobj			
attachment/	bin	link	pp	ccomp	xcomp	prep
restriction	amod	advmod	poss	ec	gen	
	aux	pass	neg	aux	pass	neg

Table 2 exhibits the compact set of dependency relations based on the markedness of syntactic functions in surface structure. It shows:

- *mark*: dominant relation by the marker.
- *link*: loosely coupled relation between clauses to describe the causal or contextual relationship.
- *bind*: the relationship between the governor and phrasal dependent to impose a semantic restriction.
- *pp*: relation by a prepositional phrase.

This shows how the dependency relations are substantially conceptualized to represent the core syntactic structure of a sentence. This is evident of the fact that two types of dependency relations should be considered in the representation of dependencies, particularly in the attachment-restriction of dependency relations, the representation should be directed from the core component to the optional constituent.

Henceforth, it is possible to subdivide relations according to their specific syntactic features similar to Universal Stanford dependencies (USD) (De Marneffe and Manning, 2008, Manning et al., 2014). This also enables to understand properties and representations of dependency relations. In that case, the marker denotes a certain syntactic/semantic role by the association between governor and dependent. It becomes necessary to explore the relationship between marker itself and its associated constituent to understand how syntactic function is realized in a sentence.

4.1 Syntax Graph based on Dependency Relations

A new methodology was devised in this study to represent syntactical structures through graphs based on dependency relations often known as syntactic knowledge graphs. The objective was to investigate the markedness principle of natural languages and understand appropriate sets of dependency relations to construct syntactic graphs. The dependency relations have already been recognized as a unique methodology for syntactic/semantic analysis, this approach will further help to decipher the linguistic performance of NLP applications. Moreover, the use of syntactic graphs will also make it feasible to understand variations in dependencies and might help to reach a shared consensus on the issue of dependency relations. The syntax graphs can also describe more detailed linguistic information and can be established as knowledge graphs (KGs) (An, 2021, Mulang et al., 2017).

As a typical example of syntax graphs, Figure 1 visualizes syntactic relationships of (3). The dependency relations inherent in (3) can be easily recognized in Figure 1. Note that the prepositional markers FROM, TO, and ABOUT play the role of governor and establish attachment-restriction relationships with their target constituents. The unmarked relation (man, presented) and (presented, paper) can be resolved by the position markers related to the subcategorization of PRESENTED.

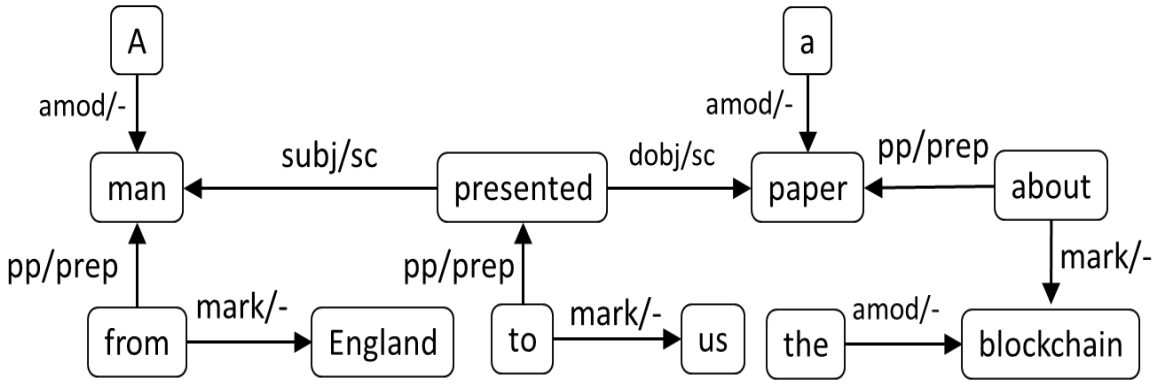

Figure 1. Syntax graph with prepositional dependencies

Figure 2 is a syntax graph of (1.b) that contains a clausal complement. HARRY is bound by WHO that dominates the predicate PLAYED. So, the syntactic relationship between HARRY and PLAYED is deductible.

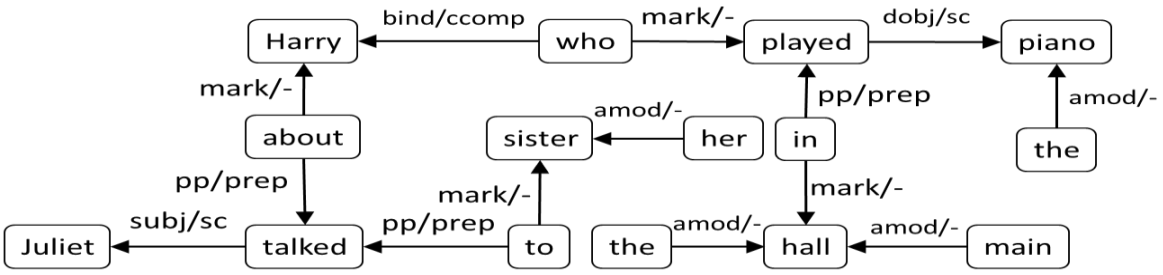

Figure 2. Syntax graph with clausal complement

Another merit of the syntax graph is to localize all syntactic relations for the constituent. As said earlier, every constituent should have its marker to represents dependency relation and syntactic/semantic linguistic functions. These markers are recognized at three linguistic levels viz., words, phrases, and clauses. The syntax graph might contain such linguistic levels as open complements constructed in the same manner. The syntax graph of the sentence (2.a) is represented as Figure 3. This is possible as the markers play a role of governor to their associated constituent.

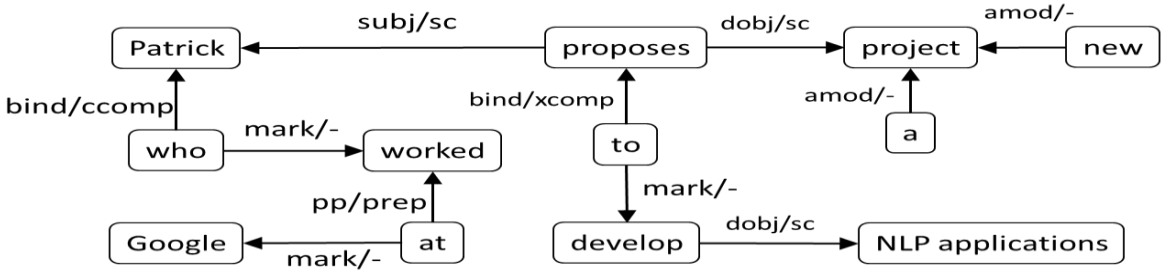

Figure 3. Syntax graph with open clausal complement

However, natural language systems need linguistic apparatus to manifest dependencies in the surface structures. The markedness principle thus proves to be an important universality of natural languages used to specify the syntactic/semantic function of the constituents of a surface structure. The dependency relations, on the other hand, provide the foundation for the linguistic approach toward NLP although language model approaches such as BERT and GPT-3 have drawn considerable attention and shown remarkable performance in NLP applications (Ethayarajh, 2019, Wang et al., 2019, Vaswani et al., 2017, Dale, 2021). Two approaches should maintain a cooperative and complementary relation to the realization of linguistic intelligence. This paper proposes a novel, compact set of dependency relations based on the markedness principle of natural languages. The dependency relations proposed in this paper can be effectively applied to syntactic analysis, especially, to construct a syntax graph rather than a dependency tree.

5. Conclusion

NLP has enabled linguistic intelligence as a key field of Artificial Intelligence. It has shown how the linguistic knowledge can accelerate the evolution of NLP and realize more natural application systems with enhanced language competence and performance. This study aimed at investigating the markedness principle for the abstraction of dependency relations. The dependency relations are foundational mechanism to provide syntactic/semantic knowledge. Nevertheless, the linguistic commitment of the set of dependency relations remains one of the bothering issues.

The study took off with a few premises. First, sentences have a linear binding of constituents in accordance with grammar rules. In the binding of these constituents, the markers are used as the connectors between governor and dependent. In other words, markers explicitly denote dependency relations in surface structure. Secondly, attention was drawn to diverse syntactic structures, highlighting two types of markers, explicit and implicit markers. This premise helped to explore and classify the dependency relations denoted by the markers into two types of dependencies based on their syntactic functions. Finally, this study also argued that the two markers play the role of a

governor to their associated constituent. The syntax graphs of various syntactic structures presented in this study validate these premises and are evidence of the functions of the markers and dependency relations.

The conclusion drawn of this study highlight that there are many linguistic perspectives about markedness and the dependency relations embodied in markedness. It is also revealed that markedness plays a role in the specification for the constituents of a sentence's syntactic/semantic roles. Specifically, the valency values and dependency relations are two cohesive principles to generate linguistic structures, and markedness is the apparatus to realize the grammatical functions of dependency relations in sentences. While the conventional concepts of markedness focus on describing the distinctive features of linguistic elements, markedness should be better understood as the bearer of dependency relations.

Lastly, it is recommended that these two approaches should be adopted to accomplish a cooperative and complementary relation to realize linguistic intelligence. This should be adopted as a novel, compact set of dependency relations based on the markedness principle of natural languages. Such a model of dependency relations can be effectively applied to syntactic analysis, especially to construct a syntax graph rather than a dependency tree. The syntax graph featured in this study exemplify how syntax graphs can be utilized to illustrate linguistic information in more detail and recognized as knowledge graphs, in comparison to syntax trees.

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