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An exploratory study of deep parsing approaches to automated text analysis and grammaticality evaluation

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Abstract
Grammar-checking is a concept of interest in many natural language environments. It typically involves the evaluation of the grammaticality of transmitted messages, be it written or verbal. Automated grammaticality evaluation is the examination of natural language text for grammatical accuracy using computer software. The current study examined different deep parsing approaches adopted in computational linguistics for analysing the grammar of given texts. The study showed that the deep parsing approach proved to be quite precise in the outlining of grammatical rules.

Keywords: computational linguistics, automated text analysis, grammar analysis, grammaticality, deep parsing

1. Introduction

Automated grammaticality evaluation is the examination of natural language text for grammatical accuracy using computer software. Grammaticality evaluation can generally be divided into two broad categories which are: those that make use of precision or handcrafted grammar also known as the deep parsing technique; and those that make use of induced grammars also known as shallow parsing technique [1, 2, 3]. Both approaches are highly diversified and have attracted lots of research interest. The current study is focused on deep parsing techniques. The main idea of this paper is to explore the different deep parsing approaches employed in automated text analysis and grammaticality evaluation.

2. Advocacy for Deep Parsers

The deep parsers are the group of parsers that consider context at the document level, identifying entities in a structured manner and attaching semantic meaning to them [4, 5, 6, 2, 7]. Examples of deep parsers include MINIPAR and RASP [8, 9]. The deep generate some forms of categorical grammars that make use of well spelt out a set of linguistic rules [10, 11].

MacKinlay [2] after examining deep parsing techniques in several NLP operations, concluded that deep parsing is commonly implemented using handcrafted precision grammars, which encode the permissible structures of a language using vocabulary and a set of grammar rules stipulating how sentences can be constructed. These manually programmed handcrafted grammar rules were determined to be typically deterministic, fast and reliable [12].

Many studies including the work of Chomsky [13] and Fong *et al.* [14] have been strong advocates for the deep parsing approach to text analysis and grammaticality evaluation. These studies stressed that the clear outlining of linguistic rules cannot be substituted for by any other mechanism. It was established that grammaticality judgement presented a problem for probabilistic models since probabilities cannot be mapped directly to grammaticality and that the direct mapping was not possible because of the influence of sentence length and lexical frequency. Also, they went ahead to explain that the linguistic rules generated using Machine Learning (Probabilistic) approaches are difficult for humans to understand, and hence difficult to modify. Thus, they require that the system be retrained when performing a task that requires different corpora. Furthermore, because the induced grammar rules are closely associated with the annotated corpus domain, induced grammars are also usually domain-dependent [12].

3. Deep Parsing Using Handcrafted Grammar

Handcrafted grammars are grammars that are manually specified and evaluated by grammar engineers [15]. Handcrafted grammars are completely different from induced grammars. In contrast to requiring large scale treebanks, handcrafted grammars provide a single point of control for the handling of syntactic phenomena [2]. Owing to this single point of control, the grammar can be designed to handle even very rare and complex phenomenon or to even ignore particularly difficult ones, which is not possible with induced grammars. It is a very labour-intensive task to create a grammar of a language which has reasonable coverage and can create meaningful parse trees and semantics. There has nonetheless been a range of concerted efforts targeted at creating broad-coverage grammars for several languages, some of which are closely related in formalism.

3.1. Syntactic Formalisms

Blache *et al.* [16] explained clearly in his work that it was syntactic formalisms that made it possible to describe the question of grammaticality with precision. Handcrafted grammars are often designed to explicitly represent particular syntactic formalisms. Context-Free Grammar (CFG) for example is a commonly used method for formally specifying languages and is the basis for many handcrafted approaches. Transformational Grammar (TG) on the other hand attempt to enforce transformation rules that map given expressions unto more convenient representations [13]. Head-drive Phrase Structure Grammar (HPSG) is a theory of syntax in handcrafted grammars that would be elaborated upon later on in this paper. Theories within HPSG make up for the limitations of Context-Free Grammars [2]. Lexical-Functional Grammars (LFGs) have been developed for many languages as part of the ParGram project [17, 18]. Huang and He [19] equally employed the use of the LFGs for automated generation of reading comprehension assessment questions.

3.2. Robustness Techniques

The application of robustness techniques involving accepting less accurate or fragmented analyses of English grammar was discussed by Riezler *et al*. [20]. The work of Masuichi *et al*. [21] and Siegel and Bender [22] were very similar to that of Reizler *et al*. [20] but for its application in Japanese grammars named Jacy. In a similar light, the study of Muller and Kasper [23] looked at the grammar of German, GG, achieving 74-85% coverage over various test corpora [24]. The English Resource Grammar, ERG [25, 26] on the other hand is an HPSG that has achieved very high percentage coverage over Wikipedia.

4. Grammar/Syntactic Formalisms

4.1. Transformational Grammars

Chomsky [13] proposed Transformational Grammar TG in response to his argument that Context-free Phrase Structure Grammar (CFPSG) cannot capture linguistically significant generalization of natural language syntactic properties. The TGs augment the CFPSGs with rules that map their syntactic structures unto other syntactic forms. Thus, for instance, to die could be transformed to ceases to live. However, following founded criticisms from Peters and Ritchie [27] as to the overly unrestricted nature of the TG, Chomsky developed the theory of Government and Binding, Principles and Parameters P&P, and Minimalism, which are more constrained versions of TGs [28]. TGs were literarily abandoned for over a decade after this period [29].

4.2. Feature-Based Grammars

Following the crisis with TGs came the Feature-based grammars, also known as information-based grammars, attribute-value grammars, constraint-based grammars or unification grammars [30, 31]. One of the crucial techniques, unification, employed by all feature-based approaches is the emphasis of unification grammar [29]. Among the feature-based grammars are the following formalisms: Functional Unification Grammar [31, 32]; Generalized Phrase Structure Grammar [33, 34]; Lexical-Functional Grammar [35]; Categorial Unification Grammar [36]; and Head-driven Phrase Structure Grammar [37, 38].

Representing the sets of features of grammar as one complex symbol using feature-based grammars has attracted a lot of research interests. Malchow [29] explained that there are three basic ways of structuring complex categories. These structures are Tree diagrams, also known as directed acyclic graphs (dags); Terms; and Matrices.

The following sentences demonstrate an example of constraint on Engish sentences as discussed by Müller [39]:

a. Joseph loves Mary
b. * I loves Mary

Where '*' connotes an error in sentence (b) owing to the violation of the constraint that the subject has to agree with the verb both in person and number.

4.2.1. Lexical-Functional Grammar (LFG)

Kaplan and Bresnan [17] discussed the lexical functional grammar (LFG) formalism, as a formal system for grammatical representation. LFG came into being as an attempt to solve the problems of the Transformational Grammar [35]. LFG is made up of standard context-free grammar (CFG) annotated with a functional structure that decides how the grammatical functions are assigned to the CFG rule [40]. The grammatical functions involved in the representation of lexical items and the CFG rules are the crucial components of the theory. These grammatical functions are classified into subcategorizable (governable) functions which are named SUBJ, OBJ, OBJ2, OBL, COMP, XCOMP, and others that are nonecategorizable namely ADJ and XADJ. Lexical items can only refer to the subcategorizable functions. The primary goal of the grammatical functions is that of mapping. The mapping between surface categorial structure and semantic predicate-argument structure.

4.2.2. Definite Clause Grammar (DCG)

The study of Reyle and Frey [40] clearly explained the Definite Clause Grammar (DCG) by its similarities and differences from the CFG. Similar to LFG, DCG is equally based on CFG. DCG is, however, the outcome of a translation of CFG into some form of expression known as Horn-clause in predicate logic. The expressions in Horn-clauses can easily be expressed as a program in PROLOG, thereby functioning similar a top-down parser. Reyle and Frey [40] however explained three main differences between DCG and CFG. Firstly is that of context-sensitivity, that is, with DCG, context-sensitive information can be tested for and transported by the arguments of the PROLOG functions that correspond to non-terminal categories. Secondly is the construction of tree-structures during the parsing process, in which case structures can be built in bits, leaving the parts that are yet to be specified as variables? The structure keeps being built and completed as it's parsed, with the freedom that the tree structure is not necessarily implemented in the exact order into the corresponding rules. Finally, additional functions or constraints on functions are inserted into the context-free rules.

4.2.3. Property Grammar (PG)

Property Grammar (PG) which is typically a fully constraint-based theory is a robust grammar formalism that can deal with a more or less grammatical sentence [41, 42]. Being a constraints based approach makes it possible for PG to process any kind of inputs. Also, it represents syntactic information in a decentralized manner, making it possible to combine them in different ways. It is a syntactic formalism that makes use of automatically derived parameters and empirically determined weights in calculating a grammaticality index. PG can be very efficient and robust. Constraints relaxation allows the system to select the best assignment, and not just the assignment satisfying the constraint system, thus permitting to deal with the more or less grammatical sentence.

4.2.4. Categorial Grammar (CG)
Categorial Grammar (CG) is one of the oldest lexicalized grammar formalisms [43, 36]. In CG, all grammatical expressions are unique based on a syntactic type that identifies them as either a function from arguments of one type to results of another or as arguments [44]. The types or categories employed in this case differ from the semantic type of the linguistic expression itself only in the inclusion of information about language-specific linear order. They are closely related in every other way.

Using two standard tools for studying models of grammar namely formal language theory and learnability theory, Carroll [43] explored the linguistic theory of CG with the final result that categorial grammars generate context-free languages. Bar-Hillel, Gaifman and Shamir [45] further explained that CGs are also weakly equivalent to context-free phrase-structure grammars (CFPSG). The initial extensions of CG were combinatory, inserting functional operations on adjacent categories into the CG core. This extension leads to the Combinatory Categorial Grammar CCG formalism [46]. CCG has remained very actively employed in linguistic research. It is actively used in parsing wide-coverage statistical models.

4.2.5. Generalized Phrase Structure Grammar (GPSG)
The generalised phrase structure grammar (GPSG) formalism was initially developed in the late 1970s by Gazdar and a number of other contributors [33, 34, 37]. A core focus of GPSG is to show that the syntax of natural languages can be described by context-free grammars, using suitable conventions focused on making the writing of such grammars easier for syntacticians. It made use of rules (met-rules) that generate context-free grammar productions. GPSG, also, augments syntactic descriptions by using semantic annotations applicable for the computation of the comprised meaning of a sentence from the derived syntactic tree. Following a series of other studies, however, Gazdar and many other syntacticians, have since argued that CFGs cannot adequately describe natural languages.

Like other feature-based grammars, GPSG is in part a reaction against transformational theories of syntax, developing notations in GPSG that are claimed to make transformations redundant. Many of the syntactic innovations of GPSG were subsequently incorporated into head-driven phrase structure grammar.

4.2.6. Head-driven Phrase Structure Grammar (HPSG)
Considering the different linguistic categories such as noun phrases and verb phrases; it is observed that the noun plays a very important role in the noun phrase, just as the verb does in the verb phrase. The noun in the noun phrase determines the characteristics of the phrase (such as its plurality). The same is true of verbs in verb phrases and prepositions in prepositional phrases. This concept is referred to as ‘headedness’ in linguistics and is the basis of the Head-driven Phrase Structure Grammar HPSG [2, 47]. Similarly, a number of studies have focused on the use of linguistically motivated grammar-based parsing, employing the PET parser [48] and the HPSG broad-coverage German Grammar (GG) and the English Resource Grammar (ERG) grammars [49, 23, 24, 50]. The works of Douglas [51], Menzel and Schroder [52] and Heinecke, Kunze *et al*. [53] equally applied linguistically motivated rule-sets, employing constraint-relaxation robustness technique for grammar-based language checking.

5. Grammaticality Evaluation
Grammaticality evaluation systems are usually used in text-editors, Computer-Aided Language Learning (CALL) or Machine Assisted Language Learning (MALL) systems [54, 55]. Irrespective of employing either the shallow or deep parsing techniques in the development of GES, most existing GES are typically ungraded, evaluating grammaticality in a binary (all or nothing) fashion. Thus, existing GES does not assign specific graded scores to the grammaticality of evaluated texts. They, therefore, for instance, do not provide Second Language (L2) learners with a graded-scale for measuring progress made in the learning process. Existing works, therefore, do not provide graded feedback on the grammaticality of the evaluated texts; a feature which is invaluable for L2 learners and automated essay scoring. The works of Aregbesola, Ganiyu *et al*. [56, 57, 58] were focused on a vector space approach towards addressing the issue of assigning specific percentage scores to the grammar of a text. The proposition was based on the concept of grammaticality gradience, which emphasised expressing the degree to which a sentence belongs to (or departs from) the grammar of a language [59]. Grammaticality has been adjudged to be inherently graded and not absolute [60].

6. Conclusion
This paper examined different deep parsing techniques employed in the lexical analysis and grammaticality evaluation. The Context-Free Grammar (CFG), Transformational Grammar (TG), Lexical Functional Grammar (LFG), and Head-drive Phrase Structure Grammar (HPSG) were discussed among others. The HPSG and the LFG are among the most advanced formalisms currently employed in several systems for parsing. Robustness Techniques were equally discussed, providing a means of accepting less accurate or fragmented analyses of the grammar of a given language. Finally, the concept of graded grammaticality evaluation in deep parsing systems was explored. It is hoped that more work will be done on the graded grammaticality evaluation concept as it is believed to have the potential to advance some other areas such as automated essay scoring and computer-aided language learning.

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