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Utilizing Prolog for Automatic Transformation of English Words

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Abstract
Artificial Intelligence is a branch of computer science that focuses on developing systems that emulate human intelligence to execute commands or tasks by applying the concept of automatic reasoning. Automatic reasoning is the ability of a system to draw logical conclusions, make decisions, and solve problems independently, without human intervention, based on provided information or rules. The complexity of grammatical rules in English often causes difficulties in understanding and remembering them, hindering mastery of correct English structures. To address these challenges, this research uses automatic reasoning as the primary foundation for developing automatic transformation systems for English words—specifically, transforming singular nouns into plural forms and adjectives into adverbs of manner. The objective of this research is to apply grammatical rules during word transformation in Prolog. Furthermore, this study tests the effectiveness and accuracy of the process by evaluating the success rate of correct transformations. The system's performance is assessed by comparing the transformed words to their correct plural forms and corresponding adverbs of manner, based on predefined grammatical rules. This research does not involve participants directly but evaluates the system's performance on a set of predefined words. The results demonstrate that the system successfully transformed all tested words with 100% accuracy, effectively altering their structure. This indicates that the system is both effective and reliable for use in English language learning. Additionally, the system's high accuracy in handling various morphological transformations makes it a valuable tool for improving English grammar and writing skills.
Keywords: artificial intelligence, automatic reasoning, Prolog, word transformation.

1. Introduction
Artificial intelligence is a field of computer science that focuses on developing systems that are able to imitate and complete tasks that require human intelligence (Zein, 2021). Artificial Intelligence can be defined as a computer system that imitates human abilities in completing tasks that require human intelligence (Suhanda, 2015). The main goal of artificial intelligence is to create computer systems that have the ability to complete tasks that require human thinking, analysis, decision making, and problem solving (Zein, 2021). Artificial intelligence has four main techniques: searching, learning, planning, and reasoning (Iskandar, et al., 2023), with the main scope in the fields of Machine Learning, Natural Language Processing, Knowledge Representation, Computer Vision, Robotic and Automated Reasoning (Saluky, 2018).

Automatic reasoning is one of the important pillars of reasoning techniques in artificial intelligence. Automatic reasoning is the ability of a computer system to analyze information, draw conclusions, and make decisions based on predetermined rules or logic. Another definition of automatic reasoning is a method for developing systems that are capable of solving problems using reasoning automatically based on certain logical rules (Russell & Norvig, 2010). The process of automatic reasoning involves knowledge representation which is a way to represent information or knowledge in a form that can be understood by a computer system with the aim of processing, storing, and retrieving information related to a particular problem. Automatic reasoning will extract, change, and manipulate the information contained in the knowledge representation and provide suggestions or solutions based on the information provided (Muttaqin, et al., 2023). Automatic reasoning allows the system to use the information and rules it has been

given to make conclusions or decisions independently. This allows the system to process information, identify patterns, and extract knowledge from the information it has.

Prolog is a logic programming language designed with the main aim of supporting automatic reasoning (Maulana, 2013). Prolog is an abbreviation of Programming in Logic which was developed in the early 1970s at the University of Marseilles, France, by Alain Colmerauer and Robert Kowalski (Noviana, Winarti, & Indriani, 2013). Prolog is one of the first logical programming languages that is well structured and has a strong logical base, so it is able to apply logical rules and carry out automatic reasoning to achieve certain goals (Pinet, 2022). The basis of Prolog is the representation of facts and rules in the form of predicate logic, where the system uses logical reasoning to evaluate the questions or statements asked. In a linguistic context, Prolog can be used to analyze and understand sentence structure in human languages. Currently, Prolog has become a very influential tool in the field of artificial intelligence, especially in knowledge-based systems (Permadi & Darmayanti, 2023), natural language processing (Weber, Minervini, Münchmeyer, Leser, & Rocktäschel, 2019) and grammar understanding (Alnajem, Mutawa, AlMeer, & AlQemlas, 2021; Reddy, 2011). The application of Prolog in a grammatical context can make a major contribution to the teaching and learning of grammar. With strong capabilities in automatic reasoning, Prolog can be a tool for identifying, explaining, and correcting language structures to facilitate better understanding and appropriate use of grammar in communication and learning contexts.

When learning English, students often experience many problems in understanding English. Research conducted by Tambunsaribu & Galingging (2021) shows that 66% of respondents stated that the most difficult English language material was grammar. Grammar is a language rule that occupies the main position or is the highest priority in language learning (Fitria, 2022; Fitria, 2020). Grammar can also be defined as learning related to word structure in the formation and combination of words to form sentences in a language. In simple terms, grammar can be defined as a language system that refers to the rules of English grammar. There are three main things to consider when studying grammar, namely grammar as rules, grammar as form, and grammar as a source (Rachmawati, 2022). Mastery of grammar is a measure of a person's skill and mastery of a language. One of the important elements in grammar is parts of speech, which can be interpreted as a grouping of words in English that are divided into several categories based on their role and function in the sentence structure. Parts of speech are divided into 9 types, two of which are Noun and Adverb (Fitria, 2022).

Nouns can be interpreted as words or names of objects that refer to people, animals, events, places, and ideas (Clark, 2017). In English, nouns can be singular (singular) or plural (plural). Singular is used to refer to one object or entity, while plural is used to refer to more than one object or entity. Usually, to change a noun from singular to plural, this is done by adding the letter '*s*' or '*es*' at the end of the noun and there are also several special rules for adapting to the last letter of the noun. An adverb is a word that can explain or describe a verb. Adverbs can be formed from an adjective and followed by the ending *–ly*. Adverbs can modify verbs or verb phrases. Adverbs in sentence structure can provide information related to manner, time, place, frequency, or certainty (Juliarta & Wirawan, 2021). Adverbs consist of several types, one of which is the adverb of manner, which can be interpreted as an adverb that is used to explain how an incident/occurrence can occur. The general rule for forming adverbs of manner is to add the suffix '*-ly*' to the adjective, which provides an additional pattern in the formation of adverbs in English. Several special rules for the Noun and Adverb categories add to the diversity of word formation patterns in English. There are many categories of words and rules that need to be considered in grammar, making students often trapped in understanding and remembering these rules, which can ultimately hinder their ability to master correct and standard English structures.

In an effort to overcome the difficulties faced in learning English regarding grammar rules, this research was conducted to find effective solutions. This research aims to explore the potential of Prolog for automatic reasoning to develop a system capable of transforming words into plural and adverb forms based on grammar rules. Prolog was chosen for its strength in rule-based logic, pattern matching, and automatic inference, making it ideal for grammar transformations and enabling automatic transformations without complex coding. The results of this research are expected to help overcome common difficulties and improve understanding in learning English grammar.

2. Methods

Fig. 1 shows the research flow. Following is the description of each step in this research flow.

2.1. Literature Study

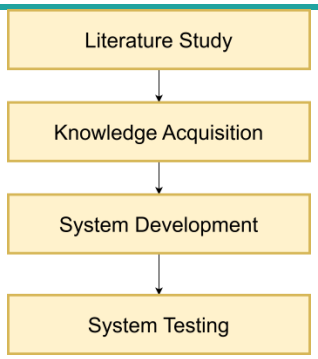

Fig. 1. Research flow.

Table 1
Representation of knowledge of grammar rules.

No.	Grammar Rules	Representation in Prolog
1	Words ending in the letter 'y', the plural form adds the affix 'ies'.	morph(Start, X, Y) :- append(Start, ['y'], X), append(Start, ['i', 'e', 's'], Y).
2	Words ending in the letters 'o, s, x, z, h', the plural form adds the suffix 'es'.	morph(_, X, Y) :- last(X, Z), member(Z,['o','s','x','z','h']), append(X, ['e','s'] , Y).
3	Words ending in the letter 'fe', the plural form adds the suffix 'ves'.	morph(_, X, Y) :- append(Start, ['f', 'e'], X), append(Start, ['v', 'e', 's'], Y).
4	For words ending in letters other than the previous rule, the plural form is added with the suffix 's'.	morph(_, X, Y) :- append(X, ['s'], Y).
5	Words ending in the letter 'll', the form of the adverb of manner is added with the suffix 'y'.	noun(_, X, Y) :- append(_, ['l','l'], X), append(X, ['y'], Y).
6	Words ending in the letter 'l', the adverb of manner is added with the suffix 'ly'.	noun (_, X, Y) :- append(_, ['l'], X), append(X, ['l','y'], Y).
7	For words ending in letters other than the previous rule, the form of the adverb of manner is added with the suffix 'ly'.	noun(_, X, Y) :- append(X, ['l','y'], Y).

In this step, searching for information from various sources such as literature, journals, articles, books and other relevant sources was conducted. The aim is to understand grammar rules, especially changing words into plural forms and adverbs of manner.

Grammar rules obtained from literature studies will be represented as knowledge in the Prolog system. This knowledge acquisition process involves gathering and formalizing the necessary grammar rules for word transformation. The representation of grammar rule knowledge is crucial because it enables the system to understand and automatically apply the necessary grammar rules. This process includes writing the rules into the structure of the Prolog language so that they can be comprehended and utilized by the system. The implementation of reasoning in Prolog is achieved by defining these rules as logical statements that can be accessed to produce the appropriate transformations. A representation of the grammar rules used in the system can be seen in Table 1.

2.2. Knowledge Acquisition

Formulate grammar rules found in literature studies into logical rules so that they can be understood and implemented by Prolog. This process aims to ensure the consistency of the grammar rule structure with its application in the Prolog language.

2.3. System Development

The system development was carried out using the SWI-Prolog version 9.0.4 tool, involving the application of grammar logic rules that had previously been formulated in the knowledge acquisition stage into a system that can change words into plural forms and adverbs of manner automatically. The system developed has two procedures for carrying out word transformation: the plural procedure and the adverb of manner procedure. Each procedure is designed to call the corresponding grammar rules necessary for

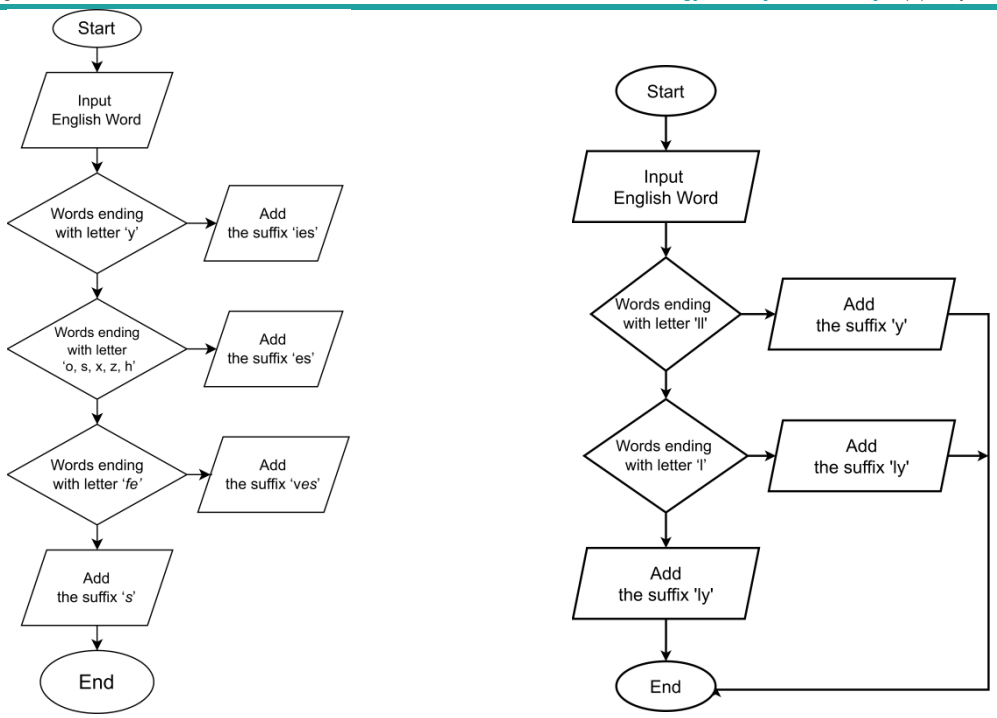

Fig. 2. Research flow: (a) Plural procedure and (b) Adverb of manner procedure.

the specific word transformation being performed. The procedure will call the grammar rules that correspond to the word transformation that will be carried out.

Transforming words into plural forms involves 4 rules, which have been previously represented in Table 1. The flow of the plural procedure can be seen in Fig. 2.a. These rules are essential for accurately transforming singular nouns into their plural forms. The transformation of words into the form of adverbs of manner has 3 rules, also represented in Table 1, with the procedure flow for adverbs of manner illustrated in Fig. 2.b. The reasoning model in Prolog utilizes these rules to make logical inferences about the word transformations, ensuring accurate output based on the defined grammar structures.

2.4. System Testing

Using different words in English with various variations of grammar rules used to change words into plural forms and adverbs of manner. This is done to check the accuracy and reliability of the system in handling various variations of grammar rules. The data used in this research consists of individual words specifically selected for transformation into their plural forms and corresponding adverbs of manner. The input words are provided in their standard singular form, which the system will transform into either their plural form or their corresponding adverbs of manner. Since the data is limited to these forms, no preprocessing steps were required, allowing the system to directly perform the transformations from singular nouns to plural forms and adjectives to adverbs of manner.

3. Results and Discussion

System testing was carried out using various English words to ensure whether the system could transform words into plural forms and adverbs of manner. The first rule test was carried out using 3 English words ending in the letter 'l'. The test results show that the system can transform words into plural forms automatically based on the first rule. The test results can be seen in Fig. 3.a.

The second rule test was carried out using 5 English words ending in the letters "o, s, x, z, h". The test results show that the system can transform words into their plural form automatically based on the second rule. The test results can be seen in Fig. 3.b. The third rule test was carried out using 3 English words ending in the letter 'fe'. The test results show that the system can transform words into plural forms automatically based on the third rule. The test results can be seen in Fig. 3.c. The fourth rule was tested using 3 English words ending in letters other than the previous rule. The test results show that the system can transform words into plural forms automatically based on the fourth rule. The test results can be seen in Fig. 3.d. The fifth rule test was carried out using 2 English words ending in the letter 'll'. The test results

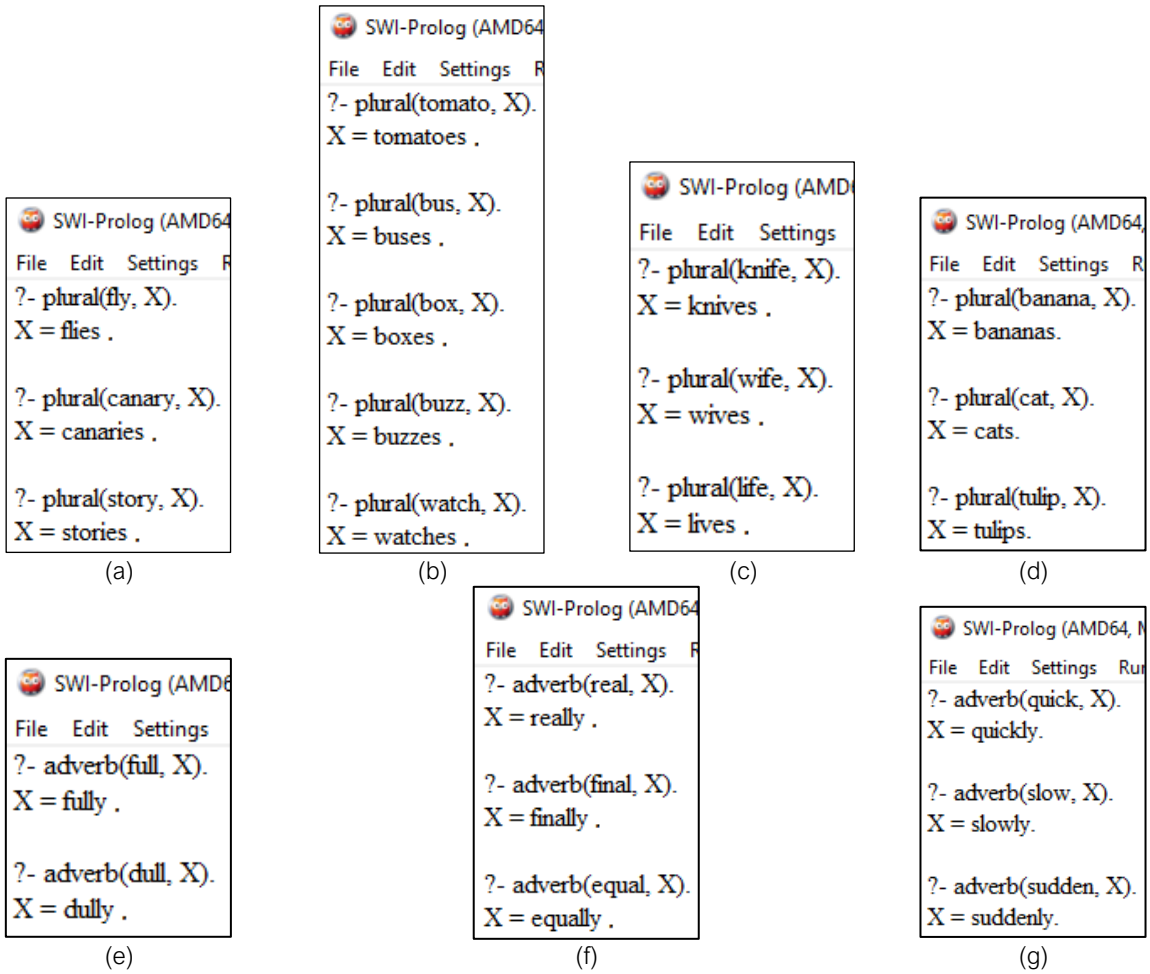

Fig. 3. Test results for the seven rules: (a) First rule, (b) Second rule, (c) Third rule, (d) Fourth rule, (e) Fifth rule, (f) Sixth rule, and (g) Seventh rule.

show that the system can transform words into adverbs of manner automatically based on the fifth rule. The test results can be seen in Fig. 3.e.

The sixth rule test was carried out using 3 English words ending in the letter 'l'. The test results show that the system can transform words into adverbs of manner automatically based on the sixth rule. The test results can be seen in Fig. 3.f. Testing the seventh rule is carried out using 3 English words that end in letters other than the previous rule. The test results show that the system can transform words into adverbs of manner automatically based on the seventh rule. The test results can be seen in Fig. 3.g.

This section presents research results and discussion regarding the system's ability to automatically transform English words into plural forms and adverbs of manner. The testing method used in this research involved employing various selected English words to evaluate the system's ability to transform singular nouns into plural forms and adjectives into adverbs. Each test was conducted with groups of words that had specific endings to examine particular grammatical rules. The success of the tests was measured by observing whether the system accurately produced the correct forms according to the rules.

The testing results show that the system developed can apply various morphological rules accurately, both in transforming words into plural forms and adverbs of manner. The system successfully handles words with different letter endings, such as 'l', 'o', 's', 'x', 'z', 'h', and 'fe', as well as other cases not covered in special rules. The testing results show that the system could transform all tested words with 100% accuracy, indicating that the system is effective and reliable for applications in English language learning. This indicates that the system has high accuracy in handling various types of morphological transformations.

This system offers greater flexibility and accuracy, especially in handling transformations on more complex endings. However, there are several limitations that need to be taken into account, such as the potential reduction in morphological accuracy in very rare endings or more complex cases. These limitations

can affect system effectiveness in certain contexts and must be addressed to improve overall system performance.

This system has broad potential applications, including in natural language processing, language learning applications, and writing tools. With its ability to automate language transformation, this system can provide significant benefits in a variety of practical contexts.

For future development, it is recommended to focus on improving accuracy in handling rarer or complex suffix cases, as well as adding features that can expand the scope of the system. This will allow the system to be a more comprehensive and effective tool in a variety of applications. Thus, this system can become a more solid solution for automatic language transformation and contribute to the advancement of language processing technology.

4. Conclusions

Based on the research results, it can be concluded that the implementation of grammar rules into Prolog language has proven successful in automatically transforming words in English into plural forms and adverbs of manner. The system that has been created is able to integrate the rules, which is one of the reasons grammar materials is considered difficult by students, so it can be a great opportunity to improve language learning. It is expected that the implementation of grammar rules in Prolog language can support the development of computational linguistic systems so that they can provide more efficient and interactive assistance for students in understanding and applying more complex grammar rules.

Suggestions for further research are to use a more in-depth method involving various grammar rules to solve various examples of cases that may occur in the process of word transformation in English. Moreover, there is room for improvement in the developed system by considering the recognition of more complex word patterns and integration with the latest artificial intelligence technology, such as machine learning, which can increase the system's ability to handle a wider variety of case examples.

5. CRediT Authorship Contribution Statement

Nida Muhliya Barkah: Conceptualization, Data curation, Formal Analysis, Project administration, Writing – original draft, Writing – review & editing, Resources, Software, Validation, Visualization, and Investigation. **Maria Ulfah Siregar:** Supervision, Writing – review & editing.

6. Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

7. Acknowledgments

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