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Understanding and Executing a Declarative Sentence Involving a Forms-of-Be Verb

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***Abstract*—An important criterion for any artificial intelligence program is its capability to communicate with the external world. One common form of communication is by the use of a natural language, specifically English. When provided a sentence, it is important for the program to understand the intention of the given sentence, which is a significant first step for a program to perform logical reasoning. In this paper, we discuss two components of the grammar that affects the understanding of a sentence: role and control. These two components represent the knowledge that teaches how to use the language to express a thought. We describe in detail what needs to be learned for each of these components for three major grammar terms: noun phrase, declarative sentence, and forms-of-be verb. We then show how to use them to create a declarative thought corresponding to a given declarative sentence that uses a forms-of-be verb. Finally, we show what needs to be learned by the program so that the declarative thought can be understood precisely based on the exact subject and predicate in the given sentence. Object-Oriented paradigm is used to analyze the problem and design the solution to attack the problem.**

***Keywords*—semantics, grammar, natural language processing, artificial intelligence**

I. Introduction

There are several major criteria for any artificial intelligence program. One of them is its ability to communicate with the external world using a natural language, specifically English. In order to communicate successfully, one requirement is the program's ability to comprehend the intention of the given sentence. We divide the problem into three sub-problems. The first sub-problem is to learn the grammar of the English language and how to use it to express thoughts. The second sub-problem involves parsing an input English sentence using the learned grammar to produce an internal thought. The last sub-problem is to understand the intention of the internal thought produced by the parsing process.

There is a substantial amount of research being done in the field of natural language processing. Some of the major challenges and barriers facing research in the field are presented in [1]. Most research tries to overcome these challenges using logic based [2-3] or functional programming [4-5] languages. For every verb introduced, a new function for that verb needs to be written into the system. Carrying out the intention of the verb may be implicit to the execution of the functions. However, it is unclear how to locate the starting point of the reasoning process where the understanding of the sentence occurs. Some researchers are interested in the production of parts-of-speech tags when given a sentence [6-7]. Recently, we have developed a sub-system to learn the grammar terms (parts-of-speech) of the English language [8]. It is a part of the communication agent of the learning program in the project: A Learning Program System (ALPS) [9] whose goal is to learn all knowledge. The initial focus of ALPS has been on the development of the memory agent of a multi-agent artificial intelligence [10] program to store knowledge and the relationships among them. Basic capabilities, such as creating a new category, adding objects, attributes, properties, hierarchy and definition to a category have been provided. All these have been accomplished through special purpose interfaces that request the appropriate information. This approach requires us to develop interfaces for new kinds of knowledge. Using the natural language processing approach to comprehend the intention of the user can replace many interfaces by a single interface. The grammar sub-system first learns a subset of the English grammar, and then uses the grammar to parse sentences. A key idea introduced is the role of a grammar term, which defines the intention of the term. The roles of the various grammar terms in a particular sentence allow the program to understand the exact purpose of the sentence. They serve as the bridge between the grammar knowledge world and the knowledge world that the sentence is trying to express. An appropriate role has been correctly identified for every part of the sentence for our parsing algorithm in [8]. However, in order to fully understand the details of the sentence so as to carry out its intention, the detailed content of each individual role needs to be organized in a meaningful way. We call this organization effort by a role a satisfaction of the role. For those grammar terms that have multiple satisfied sub-roles, there are two tasks that need to be accomplished. The first task is to decide which role should be used to carry out this satisfaction process, and we introduce the idea of control to accomplish this. The second task is to figure out what knowledge is needed in order to correctly satisfy the content of the role. We describe in this paper the necessary knowledge needed for the roles of three major grammar terms: noun phrase, declarative sentence, and the forms-of-be linking verb. In addition, we focus on the understanding of a declarative sentence that uses a forms-of-be linking verb. This involves distinguishing the many possible declarations that the given sentence can convey.

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The knowledge required for the understanding of a declarative sentence that uses an action verb can be found in [11].

The rest of the paper is organized as follows. Section 2 gives a short description of the English grammar learned and briefly describes our parsing algorithm. Section 3 describes in details our solution to satisfy the role for the noun, the noun phrase, and the forms-of-be linking verb. Section 4 looks at how to generate the correct thought given a declarative sentence that uses a forms-of-be verb. Section 5 discusses how this thought is then understood by the system based on the many possible declarations that can be inferred from the actual knowledge referred to in the given sentence. Section 6 concludes our paper with a discussion and a look at future work.

II. THE ENGLIGH GRAMMAR

The learning of the English grammar is done in an incremental manner in ALPS. Our program first learns a subset of the English grammar, and then uses it to parse and understand English sentences. In the future, it will also use the learned grammar to generate an English sentence when given a thought. Our program first learns the various grammar terms in English: such as sentence, complete subject, verb, noun phrase, and preposition. There are four major components introduced in [8] for each grammar term: structure, role, kind, and rule. Not all components are required for every grammar term, which means that a specific grammar term may be defined by a combination of some of these components. The structure of a grammar term may be either a sequence or an alternative, which defines exactly the grammatical format of the term and the type of knowledge that it contains. The role of a grammar term defines the intention of the term. They serve as the bridge between the grammar knowledge world and the knowledge world that a sentence is trying to express. A term may have multiple kinds, which are subsets that may share the same structure but must have different roles. For example, a declarative sentence is one kind of the sentence grammar term. Finally, a rule specifies a condition that must be satisfied. Rules may be applied directly to the grammar term or to one of its structures. The control is a recently added fifth component that helps define a grammar term, and it will be discussed throughout this paper.

Our parsing algorithm consists of a syntactic stage followed by a semantic stage. The syntactic stage deals with the analysis of the individual words in the sentence, stemming words into its root form and passes the re-constructed sentence to the semantic stage. The semantic stage deals with recognizing all the subparts of a given sentence, identifying the knowledge referenced in that sentence and producing an appropriate thought associated with the sentence. The semantic stage is based on a high-level template parser that makes use of the individual structures' unique internal parsers. It is a depth-first top-down parser whose execution consists of processing in two major manners: top-down and bottom-up. The top-down processing starts parsing using the structure of the highest grammar term, the sentence; and works its way down to lower-level terms. It is responsible for recognizing the terms of the sentence, and identifying the knowledge mentioned in the sentence. After recognizing a term of the sentence by the knowledge involved, the algorithm verifies that the appropriate rules unique to the grammar term or its structure are satisfied. Based on the recognized grammar term with all its identified sub-roles, the top-down parsing process finishes by choosing the associated role of the term and including that role in the parse result. As a result, the purpose of the grammar term has been correctly identified. However, in order to understand and carry out the detailed purpose, the content of the role needs to be organized. Processing in the bottom-up manner satisfies the role by organizing all the identified sub-roles appropriately, and the organized role is returned to a higher-level term.

There are two possible cases in satisfying a role. First, when parsing a grammar term that has an alternative structure, since the parsing is completed by only one alternative, the grammar term can have at most one satisfied sub-role. If the alternative is at the lowest level, the role is satisfied by the knowledge identified in the sentence, e.g., the knowledge representing 'John' or 'buy'. Otherwise, this role can easily be satisfied by the knowledge stored in the role of the involved alternative. On the other hand, after parsing a grammar term that has a sequence structure, the role of each term in the sequence has been satisfied, so there are several sub-roles available to satisfy the role associated with the grammar term. For this case, there are two tasks involved. The first task is to identify the correct sub-role to carry out the satisfaction process. We introduce the idea of control to identify the correct sub-role to carry out the duty of satisfying a role. The second task is on how to carry out the process once the correct role has been identified. It has to prepare its content in such a way that the intention can be understood and executed easily by the appropriate knowledge object. By the time the sentence grammar term finishes parsing, the result is a thought that reflects what the sentence wants to express, and the identified knowledge is stored as the appropriate parts of this thought.

We will present the details on how the control chooses the proper role, how the chosen role carries out the satisfaction process, and present what needs to be learned to accomplish these tasks. Specifically, we describe in detail the roles for noun phrase, declarative sentence, and the forms-of-be linking verb. The noun phrase is associated with the usage role while its meaning depends on where it is used. The declarative sentence has the role of declaration, meaning it declares a statement about a knowledge object. One form of a declarative sentence uses the forms-of-be linking verb: 'is', 'am', and 'are'. The forms-of-be verb is associated with the define role which is used to define a knowledge object as a state of being, an aspect of a knowledge object, or a relationship. We will describe in detail how the define role understands the intention of the sentence. Another form of a declarative sentence makes use of an action verb.

III. SATISFYING THE USAGE ROLES

The satisfaction of the usage role is the most complicated case in our program. This role is used by the grammar terms noun and noun phrase. In English, a noun phrase consists of a sequence of grammar terms and may contain multiple nouns. It starts with an optional determiner, followed by a compulsory noun, sometimes known as the head noun, and finally a number of optional prepositional phrases. Each prepositional phrase consists of a preposition followed by a noun. Thus, “John”, “a dog”, and “the king of Spain” are all acceptable noun phrases. There are two components of the usage role: its purpose and structure. The purpose states the function of the term used within a higher-level term, and the structure reflects how the referred to knowledge can be identified.

The usage role of a term serves a different purpose depending on its position in the structure of its higher-level grammar term. For each noun, its position determines its purpose within a noun phrase; and similarly for noun phrases within a sentence. In a noun phrase, the compulsory noun is given the usage role with the purpose of a simple subject. The noun in any optional prepositional phrase is also a usage role but has the purpose of the object of the preposition. In a simple declarative sentence, the noun phrase that appears before the verb is known as the complete subject and serves the purpose of subject. For noun phrases that appear after the verb, its purpose depends on the type of verb used. If the verb is a linking verb, then the following noun phrase is part of the subject complement. The purpose of this noun phrase is to serve as the predicate of the sentence. If the verb is an action verb, then the compulsory noun phrase that follows is a part of the object complement. This noun phrase serves the purpose of the direct object of the sentence. Within the object complement, an optional noun phrase may precede the direct object, which serves as the indirect object.

The structure of the usage role is used to identify the exact knowledge object referred to by a noun or a noun phrase. We classify five different kinds of structures, each implemented by its own class. They are whole-object, constant, aspect-of-an-object, relationship, and additional-information. The whole-object structure is used for the following two situations. The first situation is for proper nouns represented by simple knowledge objects, such as ‘John Smith’, ‘USA’ and ‘the Pacific Ocean’. The second situation involves an optional determiner followed by a category name, e.g., ‘3 apples’, ‘a house’, and ‘2 cars’. The grammar term determiner includes the alternatives article and cardinal number. An article can be ‘a’, ‘an’, or ‘the’, and the value for all of them is one. A cardinal number is currently learned to be recognized by the natural number data type. As a result, it can only recognize actual numerical numbers. To recognize and understand cardinals such as one, five, twenty, and thirty, the program needs to learn the spelling and rules for numbers. The second structure of usage role is the constant structure. It is used for storing a simple numeric constant, which does not have a subsequent category name, such as ‘2’. It is also used for concept values such as ‘3 meters’, ‘10 grams’, and ‘4 yards 1 foot 2 inches’. These two structures are used for noun and any noun phrase that does not contain a prepositional phrase.

The next two structures of the usage role (aspect-of-an-object and relationship) deal with a relationship between knowledge objects. A common way for the English language to express the knowledge that corresponds to an aspect of an object is by using a noun phrase where the simple subject is followed by the preposition ‘of’ and then by the object of the preposition: such as “the queen of England”, “the weight of John”, and “the average of the radii of the circles”. Currently, only the preposition ‘of’ has been taught to have the aspect-of-an-object structure. Every instance of this structure has two logical knowledge objects: aspect and object. In order to bridge an aspect-of-an-object structure with the grammar, the system needs to learn the link between these two logical objects and the usage roles of a noun phrase. This means teaching this role structure to associate aspect with the simple subject and object with the object of the preposition. By using this learned knowledge, the role structure can be satisfied correctly, and the complete meaning of the noun phrase can be recognized. The next structure of a usage role is the relationship structure. It is used for situations such as “the boy across the street”, “the book under the table”, and noun phrases that use other location prepositions. The two logical knowledge objects of the relationship structure are the object-of-interest and the reference-object. The object-of-interest is learned to associate with the simple subject and the reference-object with the object of the preposition.

Finally, the last structure of a usage role is the additional-information. It is used to provide the sentence with supplementary information. Many prepositions are currently learned to have this structure, e.g., ‘to’, ‘from’ and ‘for’. Besides the preposition used, the other important local logical knowledge object is the purpose. The purpose is learned to associate with the object of the preposition. As in other noun phrases that involve prepositional phrases, there may be a sequence of additional-information prepositional phrases, each independent of one another such as in “John buys 8 apples from Mary for 2 dollars.”

Now, we will describe how to use the two components of a usage role, its purpose and structure, to satisfy the roles of a noun and a noun phrase. First, we describe how the usage role of a noun is satisfied. Its structure is either a whole-object or a constant. A whole-object corresponds to knowledge whose name has been learned, and thus can be searched successfully when parsed. On the other hand, constants are recognized by either data types or concepts and those knowledge objects are only created when parsed. Next, we describe how the usage role is satisfied for a noun phrase. At the time of satisfying the role for a noun phrase, several satisfied sub-roles may be available. In order to recognize which structure the given noun phrase should have, the noun phrase uses the control knowledge to locate the correct role structure. For the noun phrase, the control knowledge is given by the sequence: preposition, noun. This means that if there is a prepositional phrase, the correct structure will be dictated by the preposition used in the noun phrase; otherwise it is dictated by the compulsory noun. If the structure is dictated by the noun, then it has already been satisfied correctly by the noun at a lower level. On the other hand, if the structure is dictated by a preposition, an object of the structure associated with that preposition is created with its content organized accordingly. Recall that each preposition has learned to have a specific structure. For example, if the preposition is ‘of’, an aspect-of-an-object structure is created, and the knowledge identified as the simple subject and the object of the preposition can be organized in the structure as the aspect and the object, respectively.

To show how a noun phrase is satisfied, suppose the noun phrase “the weight of John” is the complete subject of a given declarative sentence. As the phrase is being parsed, the term 'weight' is recognized by the concept knowledge. This will create a whole-object structure, which is satisfied by storing the concept knowledge weight as the simple subject of the noun phrase. Following this, the next term parsed is the preposition 'of'. Since this preposition is taught to be a usage role with an aspect-of-an-object structure, such a structure is created. However, this structure cannot be satisfied yet because not all the necessary component knowledge has been parsed. Next, 'John' is recognized as an object of a category. Another usage role with whole-object structure is created and satisfied, but this usage role is stored as the object of the preposition of the noun phrase. Now that each grammar term in the noun phrase sequence has been parsed, the top-down stage of the parsing of the noun phrase is completed and the role for the noun phrase will be satisfied. Since the noun phrase contains multiple roles, the control is used to determine which role and its structure will be used to satisfy the usage role of the entire noun phrase. For the noun phrase, the first control object is the preposition. Therefore, an aspect-of-an-object structure is created in this example. It is now possible to satisfy this structure, since all the required components are available. Satisfying this structure involves using the bridge knowledge that matches the grammar knowledge of the usage role with the logical knowledge for the structure. For the aspect-of-an-object structure, the bridge links simple subject to aspect and object of the preposition to object. Using this bridge, the knowledge identified as the simple subject and the object of the preposition are stored in the structure as the aspect and object, respectively. In addition to satisfying the structure of the noun phrase, its purpose also needs to be identified. Since this noun phrase is the complete subject of the sentence, it assumes the role of the subject of the sentence. The process of satisfying usage roles for other structures is accomplished in a similar manner.

IV. THE DECLARATION AND DEFINE ROLES

The purpose of a sentence is to express different kinds of thoughts: to make a declaration, to ask a question, or to issue a command. Therefore, the role of a sentence is taught to be a thought. There are several different kinds of thought roles, each corresponding to a different kind of sentence. A declarative sentence is taught to have the declaration role, an interrogative sentence has the question role, and an imperative sentence has the command role. To respond to a thought after understanding its purpose, the program may carry out the intent of a declaration, respond to the query of a question, or execute the order of a command.

When the system is given an English sentence, the parsing algorithm will use the learned grammar, beginning with the sentence grammar term, to parse the sentence. For each successfully parsed grammar term or structure, its associated role will be identified and called to satisfy the detail contents. For example, all relevant knowledge involving the complete subject is satisfied by the subject role. The satisfaction of the roles is accomplished in a bottom-up manner. By the time all the components of the sequence structure for a sentence have been completed, all the sub-roles have been satisfied individually and all that remains is the role at the highest level, the role of the sentence. Now, suppose a given sentence ends with the punctuation '?'. The rule attached to the sentence will decide that it is an interrogative sentence with the question thought. If our given sentence ends with the punctuation '.', then the rule determines that it is a declarative sentence. All the roles that have been collected are stored in a language declaration thought. This thought maps the roles with the corresponding knowledge found in the sentence. For example, when the sentence "Mary is a teacher." is parsed, the resulting language declaration thought maps subject to Mary and predicate to teacher.

At this point, all the roles in the language declaration thought have been satisfied except the declaration role associated with the entire sentence. Since there are several satisfied sub-roles such as the subject, the verb, and the predicate roles, the control tells our program which role to carry out the satisfaction process of a declaration thought. The control for a declarative sentence is taught to be the verb. Now suppose the verb in the sentence is an action verb, the identified and chosen verb role is the act role. The knowledge learned by the act role, and how act role uses these learned knowledge to recognize all the potential effects of a sentence can be found in [11]. On the other hand, if the English sentence uses a forms-of-be verb, the chosen verb role to satisfy the declaration thought is the define role. Satisfying the define role is similar to the process of satisfying usage roles. The define role has two local logical knowledge objects: the object-of-interest and the definition. Its purpose is to use the definition to define the object-of-interest. In English, the subject represents the object-of-interest, and the definition is provided by the predicate. We teach the define role these correspondences so that it can be satisfied correctly to create the final declaration thought. The final declaration thought uses the knowledge from the define role and the language declaration thought to link the local logical knowledge objects with the knowledge found in the sentence. This completely satisfied final declaration thought is the result of the parsing algorithm. Continuing with the language declaration thought produced from the sentence "Mary is a teacher." and using the define role, the final declaration thought links the object-of-interest with Mary and the definition with teacher. Fig. 1 outlines the process of parsing a declarative sentence to produce a final declaration thought, when the verb is a forms-of-be verb.

Figure 1. The process of parsing a sentence to produce a final thought.

V. Understanding and Executing a Sentece Using a Forms-of-Be Verb

The final sub-problem in comprehending a declarative sentence using a forms-of-be verb as the main verb is to understand the final declaration thought produced by the parsing algorithm as described in the previous section. Grammatically, the forms-of-be verb is used to link the predicate to the subject. Semantically, the system already knows that the intention of the given declarative sentence is to use the definition to define the object-of-interest. However, a definition here is very ambiguous. For instance, the following two sentences both link the predicate to the subject at the grammatical level: "Gorillas are primates." and "Steve is a doctor." Yet, on the semantic level, the first sentence defines the category of gorillas as a sub-category of primates, while the occupation of the object Steve is defined to be a doctor in the second sentence. So, how can two grammatically identical sentences be understood differently? We solve this problem by recognizing that there are many kinds of definitions. For example, one kind of definition is to define an unknown as a kind of knowledge, e.g., "Country is a category." So if the object-of-interest is unknown to the system, and the definition is a recognized kind of knowledge, then the declarative sentence is to define the unknown as that kind of knowledge. Similarly, another kind of definition is to convey the idea that one category is a generalization of another category, e.g., "Apples are fruits." In such a definition, the general category is the definition, and the specialized category is the object-of-interest. So when we recognize both object-of-interest and definition are categories, we can infer that the declarative sentence is to define a generalization relationship between the two categories.

As a result, we use a pattern to distinguish the different kinds of definitions. A pattern consists of two classifications, which reflect the object-of-interest and definition, respectively. For each pattern, the meaning and appropriate action is provided to inform the system of the kind of definition this particular pattern represents. By finding the classification of the knowledge stored in the final declaration thought and using the knowledge the recognized pattern implies, the intention of a given declarative sentence can be understood. In ALPS, there are currently six types of classifications: kind, category, object, concept, concept value, and unknown. The kind classification represents internal bodies of knowledge that are recognized by the system, this includes category, object, idea, concept, etc. This classification is used to create a new instance of one of these bodies of knowledge. Concept represents the bodies of quantifiable knowledge that has units of measurement, such as height, weight, speed, and volume. A concept value is a constant value of a concept such as '7 grams'. Finally, unknowns classify those terms that are not recognized by ALPS where each term represent a new piece of knowledge.

Based on the implications of the learned patterns, the precise intention of the given declarative sentence can now be understood. Take the first example sentence that involves gorillas. Assume that both gorilla and primate have been learned as categories by the ALPS system, our system recognizes it as the pattern <category, category>. The action attached to this pattern creates a hierarchy relation with gorilla as a child of primate, which is determined to be the semantic meaning of the sentence. As for the other sentence "Steve is a doctor", assume that the knowledge base of the ALPS system contains Steve as an object of the human category, and doctor as a category taught as a sub-category of occupation. Our system will recognize this as the pattern <object, category>. For this pattern, the action associated with it is to create an attribute for the object that has category as its aspect value. In other words, doctor becomes an attribute value of the object Steve. However, an internal condition needs to be verified before this relationship can be formed. In order for Steve to have an attribute of doctor, the system needs to verify that the category human can have occupation as an aspect. The establishment of this relationship is discussed shortly when we present the possess role. Once it asserts that humans can have an occupation, the definition that the occupation of Steve is a doctor is logically possible. The verification of this condition ensures that Steve the human can be a doctor, but that Steve the cat cannot.

As mentioned earlier, we need to teach the system that humans can have an occupation. One method is to use the existing special interface of the learning program. Alternatively, this may be achieved conveniently by teaching the system the declarative sentence "Humans have occupations." Similar to the define role and its relation to the forms-of-be verb, the forms-of-have verb is taught to have the possess role. Given a sentence, the purpose of the possess role is to attach the predicate to the subject. In our example, the subject human (singular after stemming) can possess an occupation. Again, in order to distinguish the wide range of semantic meanings to possession, the possess role is taught to associate different patterns with different meanings. For this sentence, the pattern is <category, category>. However, unlike the define role, the meaning for this pattern is not to create a hierarchical relation, but rather to add the aspect of occupation to the human category. A current list of patterns with their meanings for both the define role and the possess role are detailed in Table 1. This list is by no means complete and can be expanded as new patterns are introduced. Finally, we note that all these meanings were originally taught by a human teacher instead of pre-programmed.

Once the final declaration thought has been understood completely, its intention can be carried out, when needed, by simply calling the existing functions with arguments set appropriately. However, there are some limitations to the executing capabilities of the define role. For example, when defining a new kind, only categories and ideas can be properly created; while other kinds of knowledge are not created currently. There are several reasons for that. The first reason is that the existing learning program requires a large amount of information to create knowledge objects of those kinds. The second reason is that the name of the sub-kind is needed in order to create the correct type of objects to preserve polymorphic behavior in an Object-Oriented solution. To further complicate the situation, each sub-kind may require different initial component knowledge. For example, consider learning the two concepts: mass and force. When teaching mass, a fundamental concept, the following information is needed: its type, name, an initial unit of measurement, any

TABLE I. LEARNED PATTERNS AND THEIR MEANINGS FOR THE DEFINE AND POSSESS ROLES.

Pattern	Meaning	Example
Define Role		
<unknown, kind>	Creates a new kind (category, idea, etc)	Countries are a category.
<unknown, category>	Creates an object of the category	Canada is a country.
<category, category>	Creates a hierarchy relationship	Apples are fruits.
<object, category>	Adds an attribute	John is a doctor.
<concept, concept value>	Adds a concept attribute	The height of Mt. Everest is 8,850 m.
Possess Role		
<category, concept>	Adds an attribute	Vehicles have weight.
<category, category>	Adds an aspect	Humans have emotions.
<object, category>	Adds a possession	John has 3 computers.
<object, concept value>	Adds a possession	John has 7 dollars.

shorthand notation, and which system the unit belongs to such as the metric system. On the other hand, for learning force, a concept derived from other concepts, the formula of the product of mass and acceleration is needed. This amount of information is unlikely to be provided in one sentence and will generally require a discourse to gather the appropriate amount of knowledge before creating the correct knowledge object. Alternatively, the system could be set up to incrementally add to the definition of a knowledge object rather than requiring all the details up front.

VI. DISCUSSION AND CONCLUSION

Of the five structures that have been discussed, the relationship structure is the only one that currently is unable to identify the knowledge referenced in the noun phrase. The reason is the ALPS program does not have the ability to identify knowledge based on its location relative to other knowledge objects; such as "the ball under the table". In addition, we are currently working on several related problems. For instance, although a preposition is taught to associate with one structure, some prepositions may be used for more than one structure, e.g., 'by'. With the phrase "by the bookshelf," a relationship structure should be created. On the other hand, the phrases "by Sunday" and "by himself" represent a time and a means; both should be represented by additional-information structures. A potential extension is to allow multiple structures for a preposition, but the problem now is to determine the correct structure when the preposition is used. Therefore, one possibility is to use the context of the sentence to determine the structure since using the preposition alone is not sufficient. Another problem we are working on is to use these learned language knowledge to produce a sentence reflecting a given internal thought, where examples on the creation of internal thoughts may be found in [11]. The sentence generation process is similar to the parsing processing. It uses the structures and rules of the grammar term to ensure a grammatically correct sentence, while the roles are for correlating the knowledge in the internal thought to the semantics of the various parts of the sentence.

An important requirement for an artificial intelligent system to communicate is its capability to understand the intention of a given sentence. The top-down stage of our parsing algorithm begins the process by associating the knowledge specified in the sentence with the appropriate grammar terms and their respective roles. In this paper, we show how the bottom-up stage of our parsing algorithm organizes the identified knowledge in order to understand the precise purpose of each role. The parser uses the control concept to choose the appropriate role to perform the organization effort. The overall intention of a given sentence is understood through multiple levels of organization. We have shown how a usage role, a role for nouns and noun phrases, can be organized using one of five structures and how the location of a usage role affects its purpose. For nouns, their location in a noun phrase determines how they will be used in the overall knowledge structure of the noun phrase. For noun phrases, their position in the statement defines their role in the overall intention of the sentence. At the sentence level, the role of the verb determines the interactions and relationships between the noun phrases. When the verb is a forms-of-be verb the define role uses patterns to distinguish among the multiple possible declarations and realize the precise intention of the given sentence. Finally, the intention can be carried out to update the knowledge base, if necessary.

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