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(54) ONTOLOGY DRIVEN DICTIONARY GENERATION AND AMBIGUITY RESOLUTION FOR NATURAL LANGUAGE PROCESSING

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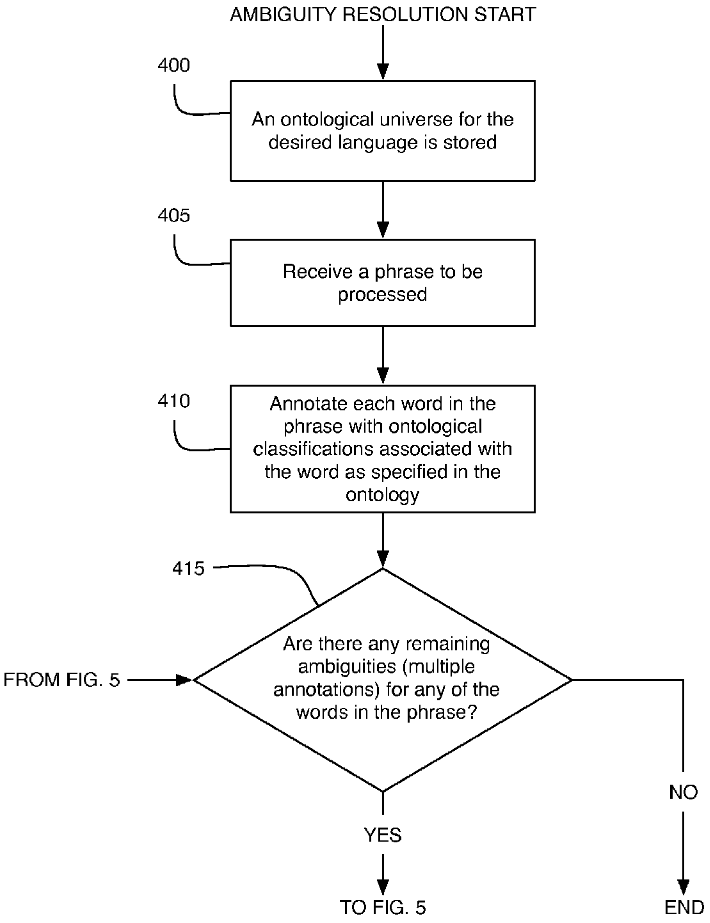
(57) ABSTRACT

A computer implemented method and system for natural language processing ambiguity resolution includes storing an ontology specifying a set of grammatical rules. A phrase comprising at least one current word to be processed is retrieved. A current word from the phrase is annotated with possible ontological classes according to the ontology. Any ontological rules associated with the possible ontological classes are retrieved. Ontological classes are eliminated based on the ontological rules. A surviving possible ontological class is determined to be an accurate ontological class for the current word. In another aspect of this disclosure, an ontology is stored in computer memory, the ontology having multiple ontological classifications, and word instances, each word instance associated with at least one of the ontological classifications. All word instances belonging to the selected ontological classification are retrieved.


AMBIGUITY RESOLUTION START
400
An ontological universe for the desired language is stored
405
Receive a phrase to be processed
410
Annotate each word in the phrase with ontological classifications associated with the word as specified in the ontology
415
Are there any remaining ambiguities (multiple annotations) for any of the words in the phrase?
FROM FIG. 5
NO
YES
TO FIG. 5
END

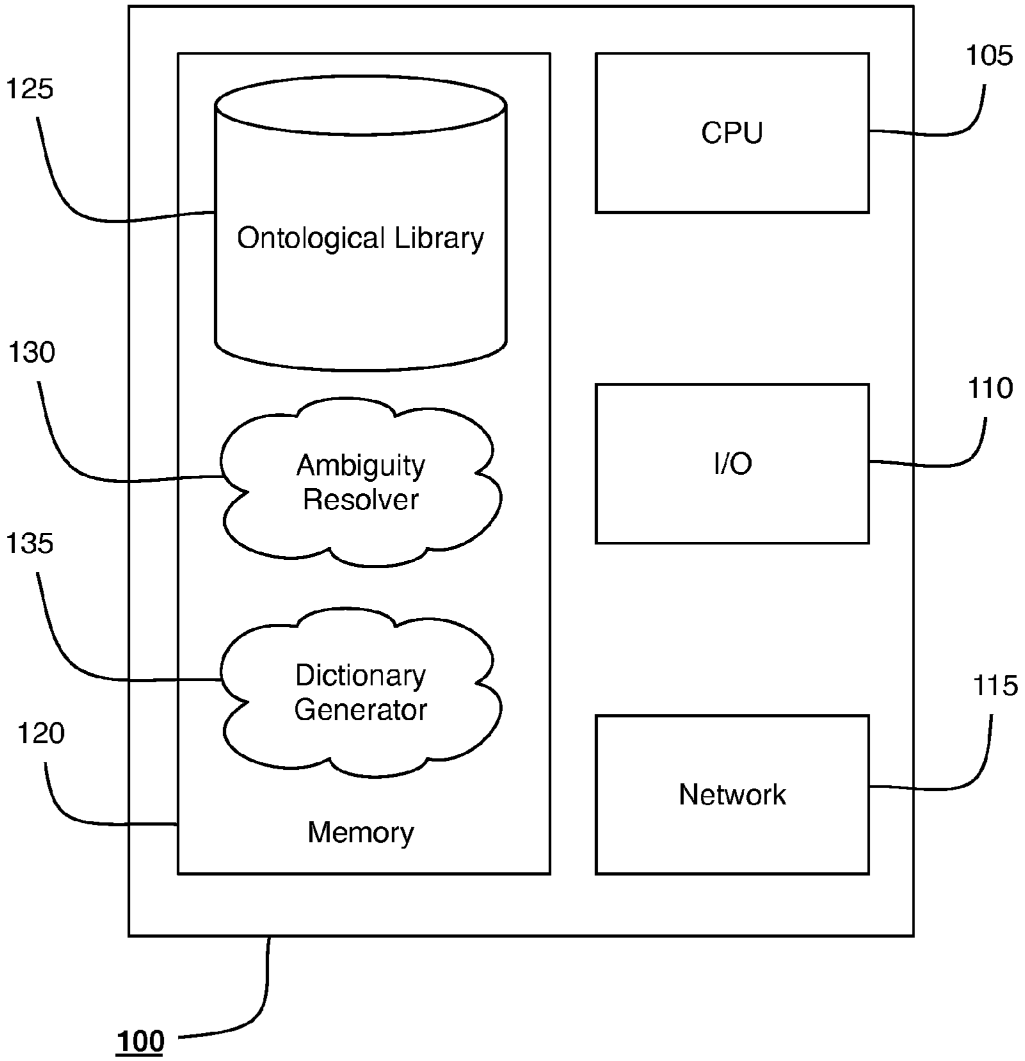

125
Ontological Library
130
Ambiguity
Resolver
135
Dictionary
Generator
120
Memory
105
CPU
110
I/O
115
Network
100

FIG. 1

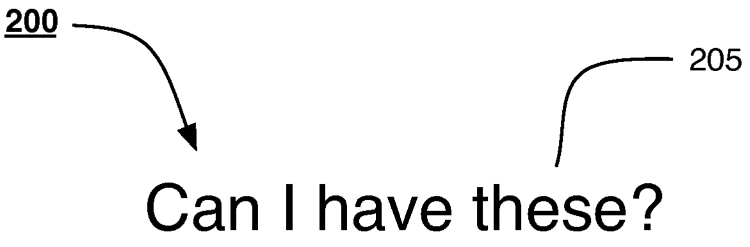


FIG. 2A

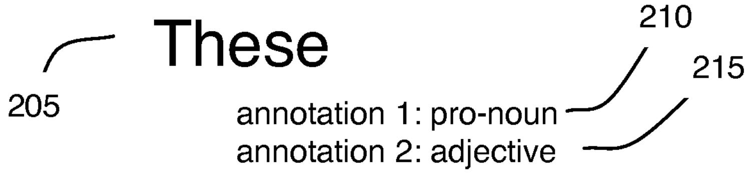


FIG. 2B

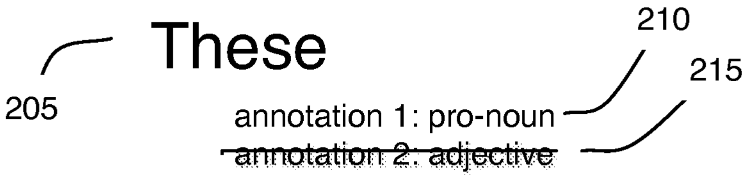


FIG. 2C

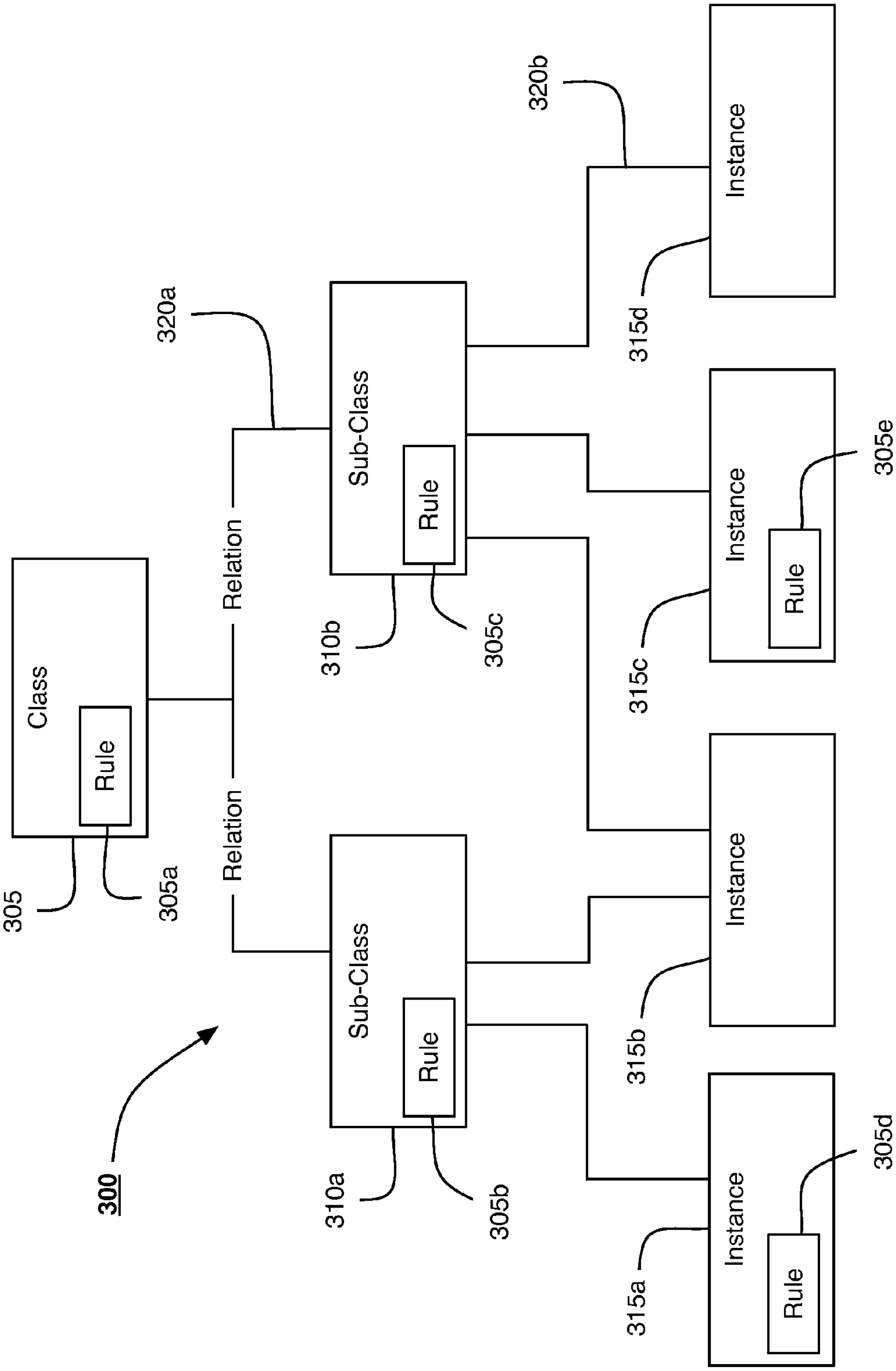

300
Class
Rule
305
305a
Relation
Relation
Sub-Class
Rule
310a
305b
Sub-Class
Rule
310b
305c
320a
320b
Instance
Rule
315a
305d
Instance
315b
Instance
Rule
315c
305e
Instance
315d

FIG. 3

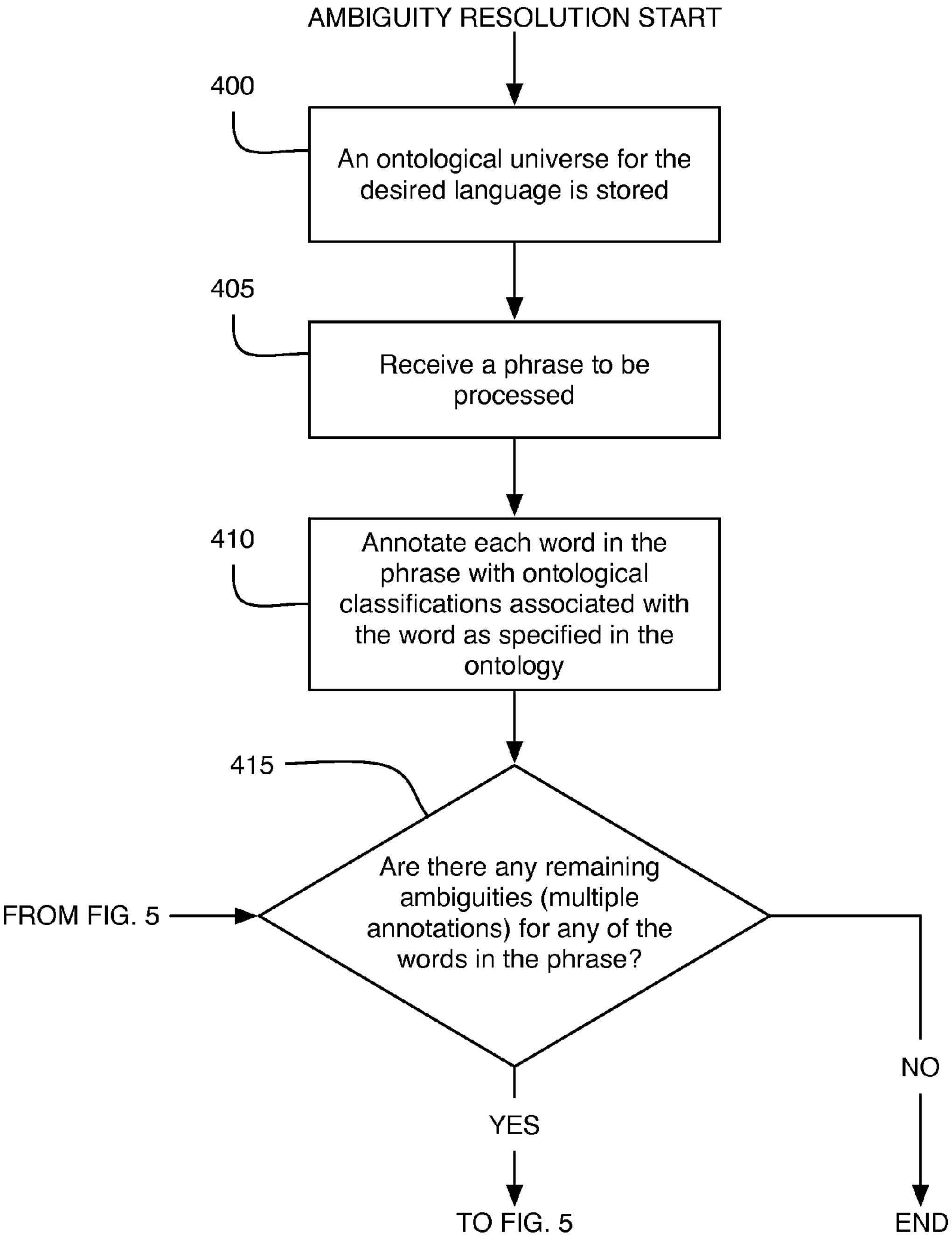

AMBIGUITY RESOLUTION START
400
An ontological universe for the desired language is stored
405
Receive a phrase to be processed
410
Annotate each word in the phrase with ontological classifications associated with the word as specified in the ontology
415
Are there any remaining ambiguities (multiple annotations) for any of the words in the phrase?
FROM FIG. 5
YES
TO FIG. 5
NO
END

FIG. 4

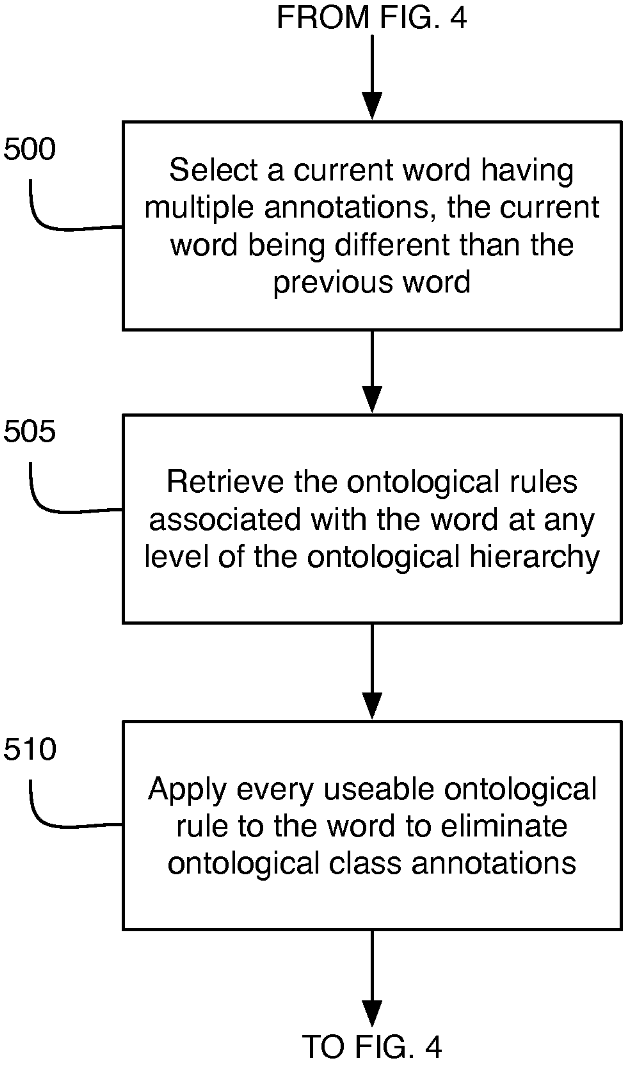

FROM FIG. 4
500
Select a current word having multiple annotations, the current word being different than the previous word
505
Retrieve the ontological rules associated with the word at any level of the ontological hierarchy
510
Apply every useable ontological rule to the word to eliminate ontological class annotations
TO FIG. 4

FIG. 5

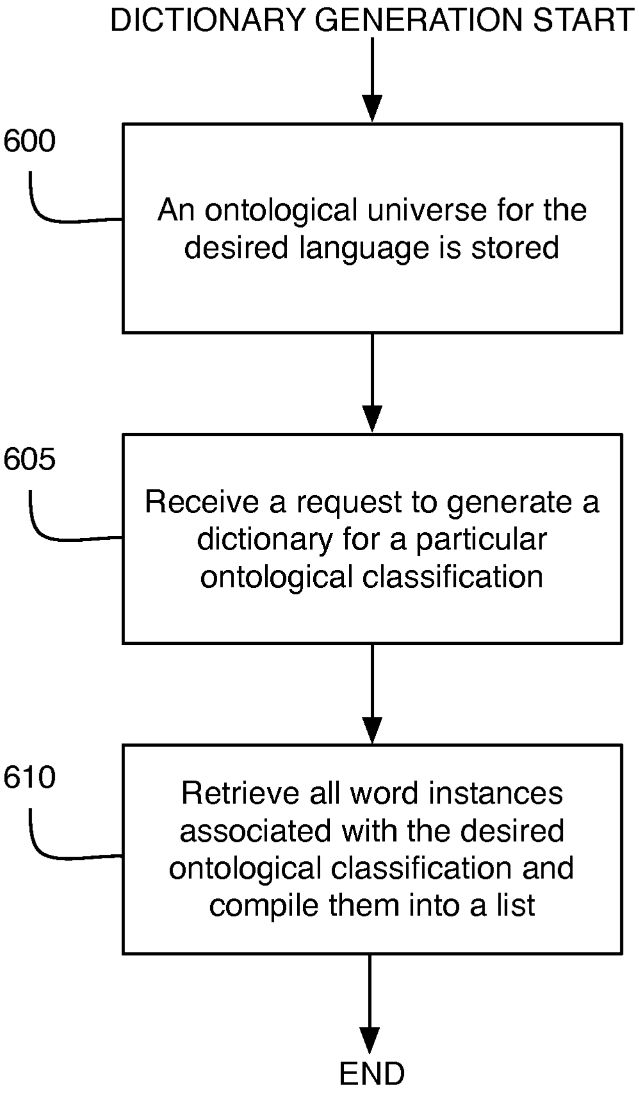

DICTIONARY GENERATION START
600
An ontological universe for the desired language is stored
605
Receive a request to generate a dictionary for a particular ontological classification
610
Retrieve all word instances associated with the desired ontological classification and compile them into a list
END

FIG. 6

ONTOLOGY DRIVEN DICTIONARY GENERATION AND AMBIGUITY RESOLUTION FOR NATURAL LANGUAGE PROCESSING

BACKGROUND

[0001] 1. Field

[0002] This disclosure relates generally to data processing of linguistic data, and, more particularly, to ontology-driven natural language processing.

[0003] 2. Background

[0004] Natural language processing utilizes software to analyze and understand human languages. Understanding a human language requires knowing what a word or phrase stands for, and how to link concepts together in meaningful ways. One method in which this is accomplished is dictionary-based annotation. Dictionaries are prepared with lists of words, including common parts of speech, such as nouns, verbs, conjunctions, etc. The dictionaries are then used to annotate each word in a phrase to be processed. Subsequently, post-processing must be done to eliminate redundant annotations by utilizing grammatical rules. Because of the large number of possible grammatical rules in a language, hundreds or thousands of rules may need to be applied to each word.

BRIEF SUMMARY

[0005] In one aspect of this disclosure, a computer implemented system and method is disclosed for natural language processing ambiguity resolution. The system and method comprise storing, in computer memory, an ontology specifying a set of grammatical rules. Using the computer processor, a phrase comprising at least one current word to be processed is retrieved. A current word from the phrase is annotated with possible ontological classes to which the current word belongs according to the ontology. Using the processor, any ontological rules associated with the possible ontological classes to which the current word belongs are retrieved. Possible ontological classes are eliminated based on the ontological rules. A surviving possible ontological class is determined to be an accurate ontological class for the current word.

[0006] In another aspect of this disclosure, a computer-implemented system and method is disclosed for generating a dictionary from a selected ontological classification for use in natural language processing. A request to generate a dictionary from a selected ontological classification is received using a computer processor. All word instances belonging to the selected ontological classification are retrieved using the computer processor and compiled into a list.

[0007] The foregoing has outlined rather generally the features and technical advantages of one or more embodiments of this disclosure in order that the following detailed description may be better understood. Additional features and advantages of this disclosure will be described hereinafter, which may form the subject of the claims of this application.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] This disclosure is further described in the detailed description that follows, with reference to the drawings, in which:

[0009] FIG. **1** is a high level representation of an illustrative natural language processing ambiguity resolution and an ontology-based dictionary generator system;

[0010] FIG. **2**A illustrates the effects of natural language processing ambiguity resolution on an example ambiguous word;

[0011] FIG. **2**B continues to illustrate the effects of natural language processing ambiguity resolution on the example ambiguous word of FIG. **2**A;

[0012] FIG. **2**C continues to illustrate the effects of natural language processing ambiguity resolution on the example ambiguous word of FIG. **2**A;

[0013] FIG. **3** illustrates a representative ontological library;

[0014] FIG. **4** illustrates a preferred sequence of steps for natural language processing ambiguity resolution;

[0015] FIG. **5** illustrates a continuing sequence of steps from FIG. **4** for processing ambiguity resolution; and

[0016] FIG. **6** illustrates a preferred sequence of steps for ontology-based dictionary generation.

DETAILED DESCRIPTION

[0017] This application discloses a computer-implemented system and method for natural language processing ambiguity resolution and generating an ontology-based dictionary. The natural language processing ambiguity resolution system and method utilizes a language ontology instead of simplistic word dictionaries to understand language. Language ontologies are known in the art, but will be briefly discussed here for the sake of clarity (and with more detail in FIG. **3** below). The ontology creates a hierarchy representing the structure of the language. Broad concepts in the language may be represented as Ontological Classes, which may be subdivided further into Ontological Sub-Classes. For example, a major Ontological Class like "words" may be divided into Sub-Classes like "nouns," "verbs," "adjectives," etc., which may be further divided into further Sub-Classes, such as "pronouns," "single-word verbs," "multi-word verbs," etc. The entire structure of the language may thus be represented by the ontology. Ontological Classes may be related by Ontological Relations. For example, an Ontological Sub-Class of "nouns" called "pronouns" may be related to the former as inclusive within the "nouns" class. Similarly, features or characteristics of the Ontological Classes may be stored in the ontological model as Ontological Attributes. Ontological Rules may be associated with Ontological Classes, Relations and Instances (i.e., specific words) in accordance with actual grammatical rules used by the represented language.

[0018] The use of an ontology conveys a benefit to natural language processing ambiguity resolution. Because the structure of the language is represented by the ontology, it is unnecessary for the system to apply every possible grammatical rule to the ambiguous word. Instead, only the rules associated with the possible Ontological Classes, Relations, etc. need be retrieved and applied to the word to resolve its grammatical ambiguity, greatly reducing the processing time necessary to resolve word ambiguity. The language ontology may also be used to generate conventional dictionaries by, for example, retrieving every word instance directly associated with a selected Ontological Class, and compiling it into a list.

[0019] FIG. **1** is a high level representation of an illustrative natural language processing ambiguity resolution and an ontology-based dictionary generator system **100**. The natural language processing ambiguity resolution and an ontology-based dictionary generator system **100** preferably includes a central processing unit ("CPU") **105**, memory **120**, network device **115** and input/output device **110**. The CPU **105**

receives and executes program instructions. Memory **120** may be provided for both long term and short-term memory (i.e., random access memory and hard disk storage), and provide data storage for the CPU **105**. Network device **115** may provide connectivity to a network, which may be, for example, an intranet, extranet or the Internet. Input/output device **110** may provide accessibility for human operators, including devices such as keyboards, mice, displays, touch screens, etc.

[0020] Software processes ambiguity resolver **130** and the dictionary generator **135** may be stored in memory **120** and are executable by the CPU **105** to operate on the natural language processing ambiguity resolution and ontology-based dictionary generator system **100**, facilitating or executing the actual processes of resolving word ambiguity and generating word dictionaries from ontological libraries. The ambiguity resolver **130** and the dictionary generator **135** may be separate software processes, or they may be implemented within the same software process. The ontological library **125** may be stored as a data structure in memory **120** (or in other storage accessible by the system **100**), and include an ontological universe for one or more desired languages.

[0021] FIGS. **2**A, **2**B and **2**C are high-level overviews of the process by which natural language processing ambiguity resolution may be executed on an example ambiguous word **205** contained in a to-be-resolved phrase **200**. In FIG. **2**A, a phrase to be processed **200** is received by the CPU **100**. Then, one of the words in the received phrase is selected for processing by the ambiguity resolver **130**. In this example, the word "these" **205** is selected. In FIG. **2**B, the selected word "these" **205** is then annotated with possible Ontological Classes and Sub-Classes of which "these" **205** is directly ontologically related (based on the ontological library **125**). In this example, a "pronoun" annotation **210** and "adjective" annotation **215** are used to annotate or otherwise mark the selected word "these" **205**. In the example shown in FIG. **2**C, the "adjective" annotation **215** is eliminated based on an Ontological Rule, associated with the "adjective" sub-class, that, for example, adjectives must be followed by nouns. When the ambiguity resolver **130** applies this rule to the phrase **200**, it determines that there is no "noun" word following the selected word "these" **205**. Therefore, based on the Ontological Rule, the ambiguity resolver **130** may determine that the selected word "these" **205** cannot be an adjective, eliminating it as depicted. With only one annotation remaining in this example, the ambiguity resolver **130** has determined that the selected word "these" **205** is a pronoun. Similarly, if there had been an adjacent word following the word "these" **205** in the phrase **200**, a determination of the classification of the adjacent word would be necessary to make a determination of whether the selected word "these" **205** is an adjective. If such a determination were made, then, based on the Ontological Rule, and the fact that the adjacent word is not a noun, a determination could be made by the ambiguity resolver **130** that the selected word "these" **205** is not an adjective, and therefore must be a pronoun.

[0022] FIG. **3** illustrates a representative (simplified) ontological library **300**. An actual ontological library **300** corresponding to a real language will necessarily be more complex and involved. The ontological library contains a class **305** (which may correspond to large categories of words, such as nouns, verbs, etc.), sub-classes **310***a* and **310***b* (which may correspond to more specific categories of words, such as pronouns, proper nouns, etc.) and instances **315***a*, **315***b*, **315***c* and **315***d* (which may correspond to specific instances of words belonging to the related respective class or sub-class. These classes are related via Ontological Relationships such as relationships **320***a* and **320***b*, designating, for example, that sub-class **310***b* belongs to class **305**, and instance **315***d* belongs to sub-class **310***d* (and in turn, class **305**). Certain classes, sub-classes or instances may have one or more Ontological Rules **305***a*, **305***b*, **305***c*, **305***d* and **305***e* associated with them. These may correspond to broad rules of grammar, usage-specific exceptions, norms of use, or any other rule of language that may be required to accurately represent the desired ontologically.

[0023] FIGS. **4** and **5** illustrate a preferred sequence of steps for natural language processing ambiguity resolution. An ontological library or universe **125** for one or more desired languages is received and stored, preferably in memory **120** of the natural language processing ambiguity resolution system **100** (step **400**). A phrase to be processed is received by CPU **105** of the natural language processing ambiguity resolution system **100** (step **405**). Each word in the phrase is annotated using the ambiguity resolver **130** with one or more ontological classifications to which the word belongs, as specified in the ontological library or universe **125** (step **410**). The ambiguity resolver **130** may then determine whether there are any remaining ambiguities for any of the words in the phrase (step **415**), an ambiguity being the presence of more than one ontological class annotation on a single word.

[0024] Referring to FIG. **5**, a word having an ambiguity is selected for processing by the ambiguity resolver **130** (step **500**). The current word may be different than a previously selected word to ensure the system **100** continuously moves on to processing a new word with new information. As ambiguity is resolved, some ontological rules that did not previously apply may then be applied. Ontological rules associated with the ontological annotations for the word are then retrieved from the ontological library **125** (step **505**). Rules are preferably retrieved from any level of the ontological hierarchy. For example, rules associated with the word itself, with the sub-class of which the word belongs, and rules associated with a greater class inclusive of the sub-class may all be retrieved for use in resolving ambiguity. Every useable ontological rule is utilized to eliminate ontological class annotations from the current word (step **510**). The system **100** may then return to FIG. **4** for continued processing. If no ambiguities remain (step **415**), then the process may end.

[0025] Some rules may not yet be useable because of ambiguity of surrounding words. For example, if an ontological rule states that an adjective must precede a noun, but the next word in the sentence has not yet been determined to be a noun, the ambiguity may be unresolveable until the system **100** processes the adjacent word. These ambiguities will be resolved in subsequent loops of the system **100**, since the process continues as long as there are unresolved ambiguities, and the process always selects a new word different than the previous word for processing. Naturally, the system may in some cases encounter unresolveable ambiguities. A count may be imposed on to trigger termination of the loop, and a generated notification of the problem may be sent to an administrator if the system **100** detects that it is trapped in an infinite loop with an unresolveable ambiguity.

[0026] FIG. **6** illustrates an illustrative sequence of steps for ontology-based dictionary generation. An ontological library or universe **125** may be stored in memory **120** of system **100** (step **600**). The system **100** may then receive a request to generate a dictionary for an ontological classification (step **605**). All word instances associated with the ontological classification may then be retrieved and compiled into a list by the dictionary generator **135** (step **610**).

[0027] Aspects of the present invention have been described with respect to block diagrams and/or flowchart illustrations of methods, apparatus (system), and computer program products according to embodiments of the invention. It will be understood that each block of the flowchart illustrations and/or block diagrams, and combinations of blocks in the flowchart illustrations and/or block diagrams, can be implemented by computer instructions. These computer instructions may be provided to a processor of a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

[0028] The aforementioned programs can be written in any combination of one or more programming languages, including low-level, high-level, object-oriented or non object-oriented languages, such as Java, Smalltalk, C, and C++. The program code may execute entirely on the user's computer, partly on the user's computer, as a stand-alone software package, partly on the user's computer and partly on a remote computer, or entirely on a remote computer or server. In the latter scenario, the remote computer may be connected to the user's computer through any type of network, including a local area network (LAN) or a wide area network (WAN), or the connection may be made to an external computer (for example, through the Internet using an Internet service provider). Alternatively, the functions of the aforementioned programs can be implemented in whole or in part by computer circuits and other hardware (not shown).

[0029] The foregoing description of various embodiments of the present invention has been presented for purposes of illustration and description. It is not intended to be exhaustive nor to limit the invention to the precise form disclosed. Many modifications and variations are possible. Such modifications and variations that may be apparent to a person skilled in the art of the invention are intended to be included within the scope of the invention as defined by the appended claims.

What is claimed is:

1. A computer implemented method for natural language processing ambiguity resolution, comprising:

storing, in computer memory, an ontology specifying a set of grammatical rules;

receiving, using the computer processor, a phrase comprising at least one current word to be processed;

annotating, using the computer processor, a current word from the phrase with ontological classes to which the current word belongs according to the ontology;

retrieving, using the processor, any ontological rules associated with the ontological classes to which the current word belongs;

eliminating, using the processor, ontological classes based on the ontological rules; and

determining, using the processor, a surviving ontological class to be an accurate ontological class for the current word.

2. The method of claim **1**, further comprising:

retrieving, using the processor, an ontological class of an adjacent word from the phrase, the adjacent word being adjacent to the current word;

comparing, using the processor, the ontological class of the adjacent word with a required ontological class according to the ontological rule of one of the ontological classes to which the current word belongs; and

eliminating the one of the ontological classes to which the current word belongs if the ontological class of the adjacent word does not match the required ontological class.

3. The method of claim **2**, further comprising:

repeating all steps for each word in the phrase until each word of the phrase is each annotated with only a single respective ontological class from the ontology.

4. The method of claim **1**, further comprising;

receiving, using the computer processor, a request to generate a dictionary from a selected ontological classification;

retrieving, using the computer processor, all word instances belonging to the selected ontological classification; and

compiling the retrieved word instances into a list.

5. A system for natural language processing ambiguity resolution, comprising:

a computer processor; and

computer memory, the computer memory storing an ontology specifying a set of grammatical rules, and a series of program instructions, wherein the program instructions are executable by the computer processor to:

receive, using the computer processor, a phrase comprising at least one current word to be processed,

annotate, using the computer processor, a current word from the phrase with ontological classes to which the current word belongs according to the ontology,

retrieving, using the processor, any ontological rules associated with the ontological classes to which the current word belongs,

eliminate, using the processor, possible ontological classes based on the ontological rules, and

determine, using the processor, a surviving possible ontological class to be an accurate ontological class for the current word.

6. The system of claim **5**, wherein the program instructions are further executable by the computer processor to:

retrieve, using the processor, an ontological class of an adjacent word from the phrase, the adjacent word being adjacent to the current word;

compare, using the processor, the ontological class of the adjacent word with a required ontological class according to the ontological rule of one of the ontological classes to which the current word belongs; and

eliminate the one of the ontological classes to which the current word belongs if the ontological class of the adjacent word does not match the required ontological class.

7. The system of claim **6**, wherein the program instructions are further executable by the computer processor to:

repeat all steps for each word in the phrase until each word of the phrase is each annotated with only a single respective ontological class from the ontology.

8. The system of claim **5**, wherein the program instructions are executable by the computer processor to:

receive, using the computer processor, a request to generate a dictionary from a selected ontological classification,

retrieve, using the computer processor, all word instances belonging to the selected ontological classification, and

compile the retrieved word instances into a list.

* * * * *