Intelligent Question Answering with Natural Language Understanding and Network-based Advanced Reasoning

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Abstract - This paper presents NaLURI (Natural Language Understanding and Reasoning for Intelligence), a working question answering system whose technique is based on full-discourse natural language understanding and a novel approach of reasoning for semantic network that couples with two advanced reasoning features namely relaxation of constraint and explanation on failure.

Keywords - Intelligent System, Natural Language Understanding, Question-Answering, Network-based Advanced Reasoning

I. INTRODUCTION

Google and other search engines alike have served mankind well, and the same goes for question answering systems that have been reliant on them. Some of the well known question answering systems that exploit the web search engines as an information retrieval tool are like Webclopedia [5], AnswerBus [21] and MULDER [9]. Such systems work very well given the size of the World Wide Web and consequently, many of the current researches are fixated on tackling the problem of question answering from the dimensions where the technique is based on the marriage of shallow natural language processing and information retrieval, and the information source using either TREC corpora or the World Wide Web. Undoubtedly, we acknowledged that open-domain question answering is a hard task because no restriction is imposed either on the question type or on the user's vocabulary. There are two reasons why these question answering systems are successful even in the face of openness in domain. First, the questions handled by these systems are limited to factual questions and they are the simplest in the hierarchy of questions [10]. Second, the systems cannot provide traceability for the origin of the answer, and justifications or explanations on why the answer is as such. Despite the practicality of being able to handle open domain questions, the modern-day question answering approach has resulted in great restrictions on the nature of question and response whereby the users are restricted to ask only factual questions, and the responses produced are merely extracted snippets and the validity cannot be verified.

The turn of the millennium has brought with it the wind of change to the community of question answering. Researchers in the field are slowly seeing a shift in approach, a shift towards the adoption of knowledge-base, higher level of natural language processing and advanced reasoning. This is clearly reflected through the response of participants from the Question Answering Roadmap workshop where majority of them felt that the lack of adoption of general natural language processing and reasoning was limiters to progress [11]. This has led to a new line of approach in question answering through the heavy use of knowledge base with understanding and reasoning [12]. This shift is also demonstrated through the proposed future directions of many researchers. [9], for example, has acknowledged through its future work section that their system's implementation lacks the use of syntactic and semantic information. By making more use of this information, they can actually improve their recall. In the future work of [3], they have considered including the ability to co-reference and also to enrich the semantic representations extracted from questions and documents. Another important future direction of theirs is to upgrade the nature of the answers to move beyond simple answer retrieval into full-blown answer synthesis. Last but not least, from the writings of [13], *"QA systems are expanding beyond information retrieval and information extraction, to become full-fledged, complex NLP applications..."*. In a way, these researchers do agree that a higher level of natural language understanding and reasoning is necessary to improve the quality of a question answering system. This shift has given birth to new researches and systems. Some examples are the work in biomedicine [22], system for weather forecast by [4], WEBCOOP [1][2] in tourism, AINI [14][15] in Medical, NaLURI [18][20] and START [6][7][8].

II. RELATED WORK

To achieve improvement upon the existing question answering facilities, we will need to approach the problem of restriction on the nature of question and response using natural language understanding and reasoning. A review on the existing systems based on understanding and reasoning namely START and WEBCOOP is performed to look for comparisons and rooms for improvements.

The review shows that START and WEBCOOP represent two very different efforts geared towards question answering based on natural language understanding and reasoning. Both START and WEBCOOP employ natural language understanding at the basic level. START follows the convention in understanding natural language and WEBCOOP uses a totally different practice. Natural language understanding in WEBCOOP is performed through pattern matching using hand-coded dedicated local grammars that are applicable only to properties of concepts in the domain ontology. In short, it is not a linguistic grammar like link grammar or principle-based grammar and is not applicable to general natural language information written in English. Rather, such grammar is domain-specific and will add on to the burden of scaling across multiple domains. Moreover, the meaning extracted using such grammar are stored in the form of indexed text in first-order logic and not some higher-level knowledge representation formalism. The natural language understanding in START is done using some linguistic-based parsers that focuses on grammatical information rather than domain-specific properties. This makes START easily scalable across multiple domains as demonstrated in its online question answering system. Because the information source is limited to sheer hand-coded annotations that represent the actual information, the parser is expected to be straightforward from the absence of the need to handle full semantic and discourse analysis. Thus, the parsing will not be able to scale to real-world information that has posed various hurdles to the field of natural language understanding since the very beginning. As for the reasoning mechanism in WEBCOOP, it can be considered as the true state-of-the-art and is the next move in the reasoning approach for intelligent responses. As for START, the system adopts a rule-based reasoning that deals with the literal matching of ternary expressions and rules. This approach is both effective and simple for first-order logic or ternary expressions but if we decide to employ other more powerful representation formalisms, different reasoning approach is required. Moreover, the representation formalism in START lacks the use of ontological and other domain information, which makes it impossible to introduce advanced reasoning features.

From the traits of both WEBCOOP and START, we can conclude that worthwhile efforts have been attempted that have actually led this approach of question answering to a higher level. For example, the advanced reasoning concepts of WEBCOOP and the use of dependency information between words for ternary expression by START are two important works that have been considered for use in this research. Nonetheless, their approaches towards natural language understanding only reach some level of the semantic analysis and not to the level of discourse analysis. Moreover, these systems store the output of natural language understanding using inexpressive representation formalisms that cannot fully exploit intrinsic properties like inheritance, generalization, etc and also, ontological information. Besides, due to the minimalist approach in the representation formalism where there is no need to handle ontological information, and to capture intrinsic properties, the reasoning approach is limited to merely rule-based and no advanced reasoning features are possible. Apparently, such approaches may be beneficial in terms of the processing time but the ease of scalability across domains and to real-life natural language text is questionable.

Hence, the solution to the problems of restriction on the nature of question and response is not as simple as including natural language understanding and reasoning. Further considerations have to be made with regards to the various levels of natural language understanding, choice of representation formalism and the reasoning technique with advanced features is important. A thorough consideration made during the design of the solution is important to make sure that during the course of solving one problem, additional unforeseen problems are not introduced.

III. NaLURI FRAMEWORK DESIGN

The design of the framework to solve the restriction on the nature of question and response must put into consideration three aspects namely full-discourse natural language understanding, powerful and expressive representation formalism like semantic network, and network-based reasoning that supports advanced reasoning. Firstly, the solution to the problems must adopt a natural language understanding approach that not only covers the necessary aspects of semantic analysis, but also to include the crucial aspects in discourse analysis. As a result, such approach will ensure that the question answering system can handle both questions and information from natural language text from any information source and domain. Secondly, with the solution based on powerful and expressive representation formalism like the semantic

network, facts produced by the full-discourse natural language understanding, including intrinsic properties between entities can be captured and expressed with the help of ontological information.

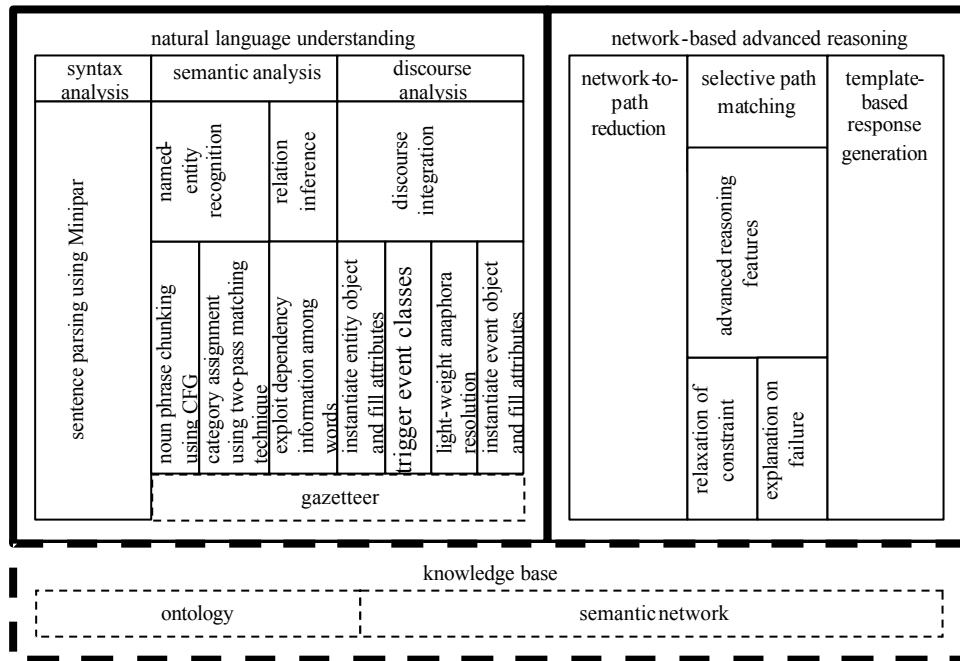analysis, an existing external module for sentence parsing called Minipar is used.

Figure 1. An outline of the solution framework

Thirdly, with the network-based representation formalism, alternative approaches for reasoning, other than rule-based, that can fully exploit the formalism's expressiveness can be adopted in the solution. Also, with the ontological commitment supported by the network-based representation formalism, the integration of advanced reasoning features can be done. Fig. 1 shows the design of the framework, which can be divided into two main parts namely natural language understanding mechanism and reasoning mechanism, and one supporting part which is knowledge base and gazetteer.

A. Natural Language Understanding

The design of the natural language understanding mechanism must take into considerations the various levels of analysis up to the discourse level [19]. Although there are existing concepts or techniques out there for various stages of analysis in natural language understanding but mostly, they are studied separately without care for compatibility in the case where these algorithms are required to be integrated for full natural language understanding. Hence, for this research, we have come out with a series of algorithms based on actual theories for various stages of analysis that were designed to work seamlessly together. In syntax

For the remaining stages of analysis, algorithms are developed, which can be entirely new or just innovative implementations of existing concepts. In semantic analysis, three algorithms were introduced; two cooperative algorithms for named-entity recognition and one algorithm based on existing concepts about ternary expression for relation inference. For named-entity recognition, context-free grammar is used for chunking noun phrases and a two-pass matching method for assigning categories to noun phrases. As for relation inference, it exploits four classes of dependency information between words to identify relations of interest. In discourse analysis, an entirely new four-stage method is developed to unify meanings of different sentences from the same discourse. One of the notable algorithms lies in the third stage for resolving anaphora. Also, note that both semantic and discourse analysis heavily utilize information from the gazetteer.

Named-entity recognition is implemented as two parts namely noun phrase chunking and category assignment. Noun phrase chunking algorithm is formalized as a context-free grammar such that a noun phrase is in the language of grammar G if it can be derived from it. As shown in Fig. 2, the grammar G constitutes of a tuple of four sets namely V, a finite set

of variables, *T*, a finite set of terminals, *R*, a finite set of rules and a start variable, $S \in V$. For example, based on the Minipar parse output in Fig. 3, *H = {Judge}*, N = *{U.S., William Pauley III}*, *A = {District}* and *D = {The}*.

The derivation sequence shown in Fig. 4 shows that the noun phrase *"The U.S. District Judge William Pauley II"* is indeed in the language of the grammar G.
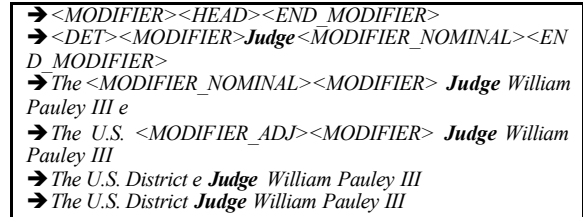
→ *<MODIFIER><HEAD><END_MODIFIER>*
→ *<DET><MODIFIER>Judge<MODIFIER_NOMINAL><END_MODIFIER>*
→ *The <MODIFIER_NOMINAL><MODIFIER> Judge William Pauley III e*
→ *The U.S. <MODIFIER_ADJ><MODIFIER> Judge William Pauley III*
→ *The U.S. District e Judge William Pauley III*
→ *The U.S. District Judge William Pauley III*

Figure 4. Derivation of the phrase *"The U.S. District Judge William Pauley III"* using a context-free grammar

G = (V, T, R, S)
where
V = { <NOUN_ PHRASE>, <MODIFIER>, <END_MODIFIER>, <HEAD>, <MODIFIER_NOMINAL >,
<MODIFIER_ADJ>, <DET>   }
T = H ∪ M
where   *M = {a set of all nouns, adjectives and determiners that modifies a head noun}*
H= {a set of all head nouns}
S = <NOUN_ PHRASE>
R:

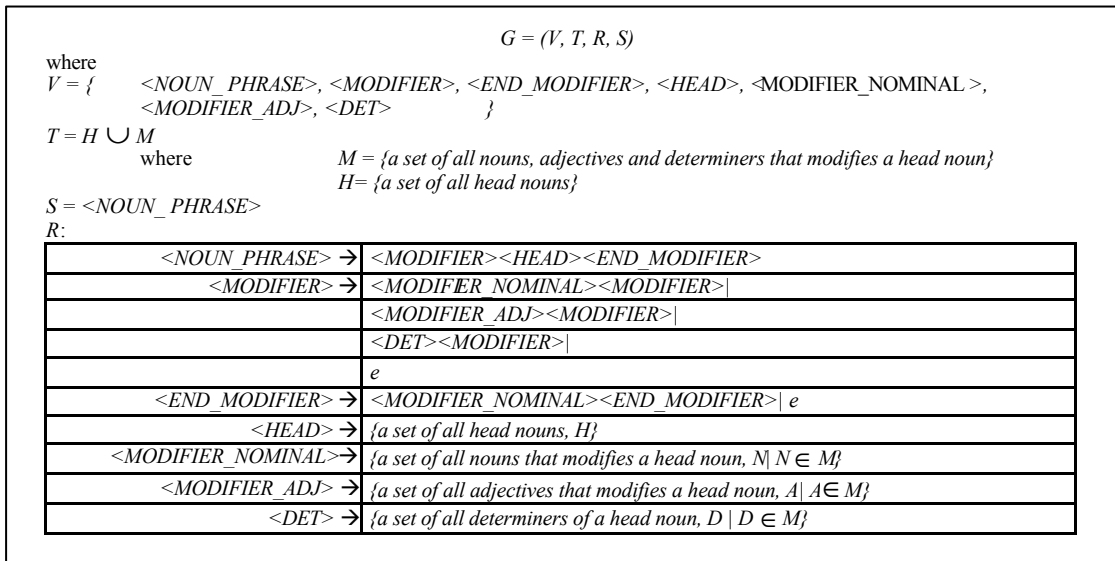|	
<NOUN_PHRASE> →	*<MODIFIER><HEAD><END_MODIFIER>*
<MODIFIER> →	*<MODIFIER_NOMINAL><MODIFIER>|*
	<MODIFIER_ADJ><MODIFIER>|
	<DET><MODIFIER>|
	e
<END_MODIFIER> →	*<MODIFIER_NOMINAL><END_MODIFIER>| e*
<HEAD> →	*{a set of all head nouns, H}*
<MODIFIER_NOMINAL>→	*{a set of all nouns that modifies a head noun, N| N ∈ M}*
<MODIFIER_ADJ> →	*{a set of all adjectives that modifies a head noun, A| A∈ M}*
<DET> →	*{a set of all determiners of a head noun, D	D ∈ M}*

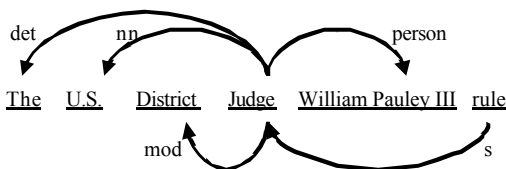Figure 2. Context-free grammar for noun phrase chunking

Figure 3. Dependency structure for the phrase *"The U.S. District Judge William Pauley III"*

The second part in named-entity recognition namely category assignment is carried out with the output of noun phrase chunking in a two-pass method using dependency information and a gazetteer. As the name implies, the two-pass method used for category assignment operates in two stages of matching with increasing complexity.

The process of assigning categories is shown in Fig. 5. The first pass attempts a direct match for any standalone names in the gazetteer without using any patterns and positive matches will usually prevail for single-word names concerning most dates and locations like *"Monday"* and *"California"* and rarely, certain person and organizations like *"Judge"* and *"Excite"*. Attention was given in the first pass to the matter of case distinction as there are cases where proper names coincide with normal words like the token *"deal"* as in agreement and the token *"Deal"*, a city in England.

A special feature employed in both passes in this category assignment technique is the use of aliases for names to cater new matching possibilities without creating redundancies. For example, some might refer to *"Hewlett-Packard"* by its name while others recognize the company through its short-form *"HP"*. Either way, this new technique allows entries in gazetteer to refer to the same entity with different names without compromising anything.

If there are not any direct matches for a noun phrase, then the second pass will be executed and usually, names of companies and person like *"Microsoft Corp."* and *"Andrew Garcia"*, consisting of two words will require the second pass for a positive match. Unlike the first pass, the second pass works on both standalone names and triggering words with mandatory fulfillment of corresponding patterns. As an example, if the company *"Excite Inc."* appears alone without the *"Inc."* label, the token will have a direct match without any need to proceed to the more complicated pattern match. If the company name appears as *"Excite Inc."*, then there will not be any exact names or aliases for a direct match. For such cases, the token would be broken down in an attempt to achieve any partial matches namely *"Excite"* and *"Inc."*. The first token *"Excite"* would trigger a partial match in the second row of the sample gazetteer in Table 1 and the corresponding pattern is retrieved. The *{TOKEN}* variable in the pattern is instantiated with the part *"Excite"* to produce *"Excite(\sIncorporated|\sInc[\.]?)?"* and using a several lines of regular expressions, the original token *"Excite Inc."* is used to match against the instantiated pattern and would produce a positive pattern match.

To illustrate the use of aliases and triggering words in the second pass, consider the company name *"Oracle Corp."*. In second pass, the name would be broken down into *"Oracle"* and *"Corp."* and by referring to the same table above, the first token *"Oracle"* does not exists . But does this mean that *"Oracle Corp."* cannot be identified as a company? Through the use of triggering word *"Corporation"* and its alias *"Corp."*, the second token *"Corp."* would have a positive partial match and the noun phrase *"Oracle Corp."* will be categorized as a company even though we have no *"Oracle"* in our gazetteer. As for person names, they are identified in the same manner. When a partial match is triggered using the first name, a validating pattern is used to ensure that the trailing last name is in a valid form.

TABLE I. Sample gazetteer entries for company names

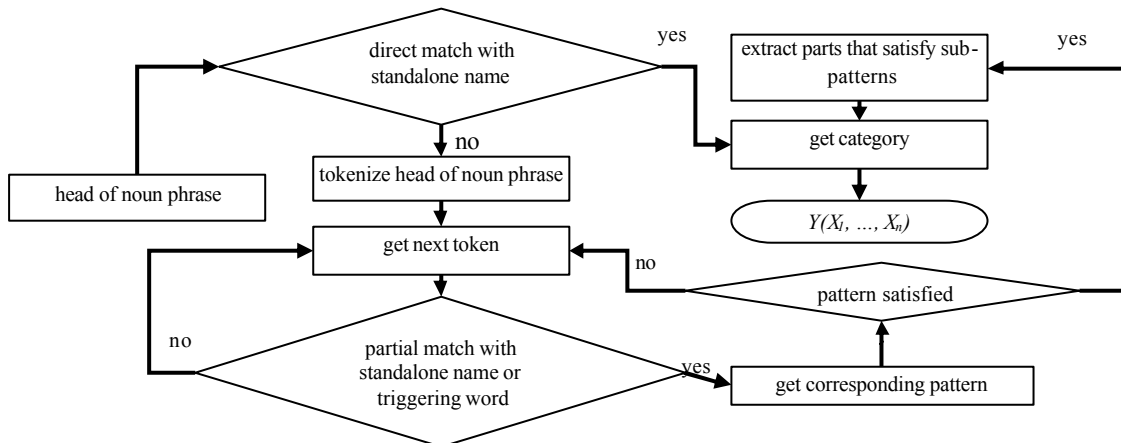| Name	Pattern	Type	Alias
Microsoft	({TOKEN}(\sCorporation\sCorp[\.]?)?)	specific	
Excite	({TOKEN}(\sIncorporated\sInc[\.]?)?)	specific	
Hewlett-Packard	({TOKEN}(\sCompany\sCo[\.]?)?)	specific	HP
Corporation	(([A-Z][\w\d'&\-\.]+\s)+{TOKEN})	generic	Corp.

Figure 5. Flowchart of the two-pass method

Regular expression was chosen for its strength and expressiveness to handle variations in patterns. For example, the pattern *(\sIncorporated|\sInc[\.]?)* will enable the recognition of the variants of *"Excite Inc."* like *"Excite Incorporated"* or *"Excite Inc"*[1]. After the positive match, the token would be assigned with the corresponding category of the partial match, *"company"*.

As the task of identifying individuals of entity objects and their attributes are performed by the named-entity recognition component of natural language understanding, instantiating event objects and their attributes are done through relation inference, the final task in semantic analysis. There are four types of relations based on dependency information exploited by relation inference module to identify all possible event objects. The relations are possession, appositive, subject-verb-object and prepositional phrase. This idea of extracting ternary relations using grammatical relationship has been applied by many systems like

START but what differs here is how the output is being further utilized.

Possession uses the genitive case, an adjectival form of a noun, to show some sort of relationship between itself and what it describes. In a general sense, genitive relationships may be thought of as one thing belonging to, being created from or otherwise deriving from some other thing. Some varieties of possession relations include relationship as in *"Janet's husband"*, subjectivity as in *"my leaving"*, objectivity as in *"the archduke's murder"*, inalienable possession as in *"my height"*, *"his existence"* and *"her long fingers"* and alienable possession as in *"his jacket"* and *"my drink"*. Based on the dependency diagram in Fig. 6, a possessive relation exists between *"defendant's"* and *"right"* denoted by the *"gen"* link. It can be validly inferred that *"defendant has right"* but not vice versa.
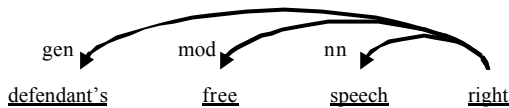

Figure 6. Dependency structure of a possessive relation

An appositive is a noun, noun phrase or noun clause which follows a noun or pronoun and renames or describes the noun or pronoun. A simple appositive is an epithet like Alexander the Great. Appositives are often set off by commas. An appositive is denoted through the use of the *"appo"* link and in the example *"Andrew Garcia, a former employee"* in Fig. 7, an appositive relation can be inferred between *"Andrew Garcia"* and *"a former employee"*.
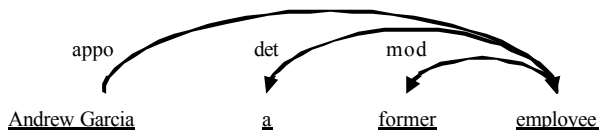

Figure 7. Dependency structure of an appositive relation

Next, the most important dependency among words that form the basic structure of an English sentence is subject-verb-object relation, as illustrated in Fig. 8. The entities and actions encoded in this relation provide the basic information that the complete sentence is trying to deliver. This type of relation is represented in the output of Minipar using the *"s"* and *"obj"* links.
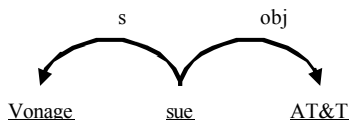

Figure 8. Dependency structure of a subject-verb-object relation

In subject-verb-object relation, conjunctions in either subject or object may exist. Please refer to Fig. 9 for the example. *Google"* and *"Electronic Frontier Foundation"* are connected through the *"conj"* link and the subject relation between "*Google"* and *"file"* can be distributed over the conjunctive link to enable us to infer that *"Electronic Frontier Foundation file amicus brief"*.

Figure 9. Dependency structure of a conjunctive relation

A preposition is a word that establishes a relationship between what is called its object (usually a noun phrase) and some other parts of sentences. The preposition and its object make up a prepositional phrase, which can be used to modify noun phrases and verb phrases in the manner of adjectives and adverbs. For example, in the sentence *"The appeals court rule on Wednesday"* in Fig. 10, the prepositional phrase *"on Wednesday"* is used to modify the verb *"rule"*.
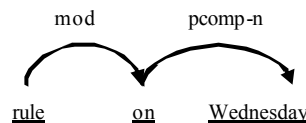

Figure 10. Dependency structure of prepositional relation

The first step instantiates plausible entity objects and fills their attributes using the information produced by named-entity recognition in the form of $Y(X_1,...,X_n)$. The appropriate class is instantiated based on the category indicator Y and the attributes for the new instance can be obtained from the attribute string $X_1,...X_n$. For example, *"company(org_name(X, AT&T))"* can be used to instantiate the class *"company"* to obtain *company(a1)* and fill its attributes using *"org_name(X,AT&T)"* to produce *"org_name(a1,AT&T)"*. The second step involves the use of verbs and prepositions returned by the relation inference phase to trigger possible event classes. These triggering verbs and prepositions together with the related patterns and maps are available in the gazetteer. To illustrate, consider the example verb *"side with"* which will be triggered by the name *"side with"* in the sample gazetteer in Table 2. Then, the associated category, pattern and map are returned for use in the next step. The pattern and map are extremely useful not only for plugging in the values of attributes for event

objects, but also for performing anaphora resolution. The third step implements light-weight anaphora resolution using the previously available information namely the tagged named-entities and contextual constraints in the form of pattern from the gazetteer.

TABLE II. Sample gazetteer entries for *"side with"* and *"file against"*

Name	Category	Pattern	Map
side with	resolution	{COURT}<RELATION> {PERSON|ORGANIZATION}	{OCCUR_AT} <RELATION> {PREVAILING_PARTY}
file against	legal_proce eding	{PERSON|ORGANIZATION} <RELATION> {PERSON|ORGANIZATION}	{PLAINTIFF} <RELATION> {DEFENDANT}

The algorithm resolves the anaphora to the nearest prior named-entity that satisfies the pattern as specified in the gazetteer. Consider the sentence *"A federal court has sided with AT_T over a complex patent lawsuit it filed against Microsoft."* and its corresponding list of named-entities below in Table 3. Initially, the anaphora *"it"* and other unknown entities are tagged as *"variable"*. The left column contains the offset of the entities in terms of discourse offset and local offset and *"it"* occurs at discourse offset 0 and local offset 13. The theory adopted by the anaphora resolver is to look back for the first named-entity whose class matches that of the pattern. In the case of anaphora *"it"*, the candidate antecedents are located in offsets before *"0.13"*, that is *"variable(desc(X,complex patent lawsuit))"*, *"company(org_desc(X,_),org_name(X,AT&T))"* and *"court(court_type(X,_),org_desc(X,federal),org_name(X,federal court))"*.

TABLE III. Sample named-entities and offsets information for anaphora resolution

legal_proceeding(e1)			
attributes of event objects	defendant(e1,e3)		
		company(e3)	
	entity objects	attributes of entity objects	org_name(e3,Microsoft)
	plaintiff(e1,e2)		
		company(e2)	
	entity objects	attributes of entity objects	org_name(e2,AT&T)

Using offset information alone is not enough as this would mean *"variable(desc(X,complex patent lawsuit))"* is the antecedent. This light-weight anaphora resolution also takes into consideration the context in which the anaphora exists in a simple subject-verb-object relation or prepositional phrase. In the case of *"it"*, it exists in a subject-verb-object relation *"it file against Microsoft"* where the position *"it"* assumes must be an active performer of some task specified through the verb.

This constraint is duly specified in the pattern associated with each verb and by the referring back to the sample entries of the gazetteer above, the pattern associated with *"file against"* states that the subject *"it"* must assume the role of a person or organization. This constraint eliminates the two candidates *"variable(desc(X,complex patent lawsuit))"* and *"court(court_type(X,_),org_desc(X,federal),org_name(X,federal court))"*, leaving the one possible antecedent for *"it"*,*"company(org_desc(X,_),org_ name(X,AT&T))"*.

The fourth and final step in discourse analysis is the instantiation of event objects and filling their attributes with entity objects. Initially, the verbs or prepositions that trigger event categories in the second step are used to instantiate event objects. For example, *"file against"* triggers the *"legal_proceeding"* category and thus a new instance *legal_proceeding(e1)* is created. Because many different verbs in the same discourse can trigger similar events, such verbs will all point to the same event object instead of creating multiple objects of the same event class. This is followed by the use of maps to relate entity objects to attributes of the newly created event objects. Using the same example, *"{federal court}<sided with>{AT&T}"* employs the map *"{OCCUR_AT}<RELATION>{PREVAILING_ PARTY}"* to fill two attributes namely *"occur_at"* and *"prevailing_party"* with entity object *company(e2)* for AT&T and *company(e3)* for Microsoft respectively.

Table IV. Logical representations of event and entity objects

0.12	variable(desc(X,complex patent lawsuit))
0.13	variable(desc(X,it))
0.16	company(org_desc(X,_),org_name(X,Microsoft))
0.3	court(court_type(X,_),org_desc(X,federal),org_name(X,federal court))
0.7	company(org_desc(X,_),org_name(X,AT&T))
1.14	variable(desc(X,evidence))
1.18	variable(desc(X,AT&T concealed information))
1.23	government(org_desc(X,_),org_name(X,U.S. Patent Office))
1.24	variable(desc(X,when))
1.29	variable(desc(X,its speech compression))
1.3	judge(per_fname(X, William),per_lname(X, Pauley III),profession(X, Judge))
1.9	date(day_of_month(X,9),day_of_week(X,Monday),month(X,Februa ry),year(X,2004))

The final output is in logic form and will be integrated into the existing semantic network. The final output for the phrase *"AT&T file against Microsoft"* is shown above in Table 4 and the corresponding semantic network is depicted in Figure 11 below. Objects like *"e2"*, *"e3"* and *"e1"* are by default related to their class *"company"* for the first two and *"legal_proceeding"* for the latter using the edge *"is"*. As for attributes like *org_name(e3,Microsoft),*

org_name(e2,AT&T), defendant(e1,e3) and *plaintiff(e1,e2)*, their predicates are used as edges to connect the first argument to the second argument.
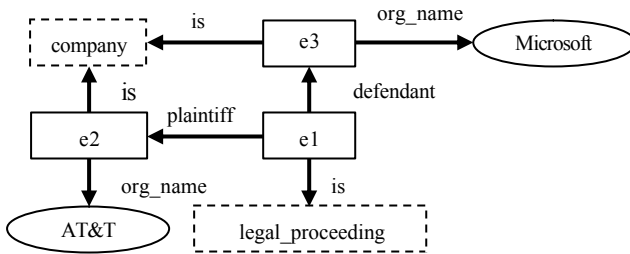

Figure 11 . Semantic network for *"AT&T file against Microsoft"*

B. Network-based Advanced Reasoning

For the design of the reasoning mechanism, there are three top-level algorithms namely network-to-path reduction, selective path matching and template-based response generation. More about this novel reasoning approach is available in [17].

The idea behind the reasoning mechanism is based on the notion of complexity-reduction whereby a problem of answer discovery that begins with two networks namely query network and semantic network, is later collapsed into two sets of paths by the network-to-path reduction algorithm. From there on, the task of finding the answer is scaled down to the selective matching of the nodes in the paths of both sets, which is performed by the selective path matching algorithm. Also, integrated with the selective path matching are two advanced reasoning features namely relaxation of constraint and explanation on failure to enhance the reasoning process. Lastly, once the desired answer is discovered or during failure, the desired explanation is synthesize, a proper unambiguous response in English is generated using template-based response generation.

IV. EVALUATION

The evaluation of question answering systems has been largely reliant on the TREC corpus and it works relatively well with non-dynamic responses. It gets more difficult to evaluate NaLURI as there is no baseline or comparable systems in the field of news on Cyberlaw cases. Furthermore, due to the dynamic nature of the responses, there is no right or wrong answer as there are always responses to justify the absence of an answer. Besides, developing a set of test questions is easier said than done because unlike the open-domain evaluations, where test questions can be mined from question logs like Encarta, no question sets are at the disposal for domain-oriented evaluations. The predicament remains in the preparation of question sets of different domain for evaluation without giving rise to

any fairness issue. People will tend to be very skeptical with the use of different question sets in one evaluation that compares an array of systems. Question like, "*I find that the questions used for evaluating XXX are more difficult that those used for evaluating YYY. This will certainly make YYY better"* will usually arise.

Hence, in line with this research, a refined black-box approach through observation and classification with a scoring mechanism is produced. This black-box approach is based on the work of [23], [24] and [25] to enable assessment and comparison of heterogeneous question answering systems. We further refine this approach by proposing a response classification scheme and a scoring mechanism. To demonstrate this approach, we have selected three question answering systems that represent different level of response generation complexity namely AnswerBus, START and NaLURI. The evaluation details are beyond the scope of this paper but more details can be obtained from [16] and [20].

V. CONCLUSIONS

This paper has presented a solution to the restrictions on the nature of question and response, and the resultant problems that ensue from the lack of ideal integration of natural language understanding and reasoning. Accordingly, a practical approach which combines full-discourse natural language understanding, powerful and expressive representation formalism like semantic network in the Cyberlaw domain, and network-based reasoning that supports advanced reasoning is proposed as solution. This practical introduction of understanding and reasoning into question answering has improved the overall quality of domain -oriented question answering systems in terms of the diversity of question supported and also quality of response. Users are allowed to ask questions beyond the use of wh-words and obtain responses that exhibit intelligence.

During the course of designing the solution framework, several contributions were accomplished:

- introduction of two cooperative algorithms for named-entity recognition namely a context-free grammar for noun phrase chunking and two-pass method for category assignment, and an entirely novel approach for discourse analysis using a four-stage discourse integration with light-weight anaphora resolution.
- introduction of a new network-based reasoning approach founded on three algorithms namely network-to-path reduction, selective path matching with advanced reasoning features, and template-based response generation.

The algorithmic contributions above are highly applicable for future researches in the field of intelligent and dynamic responses for question answering because of the modular nature of the algorithms and the proper documentations. But the most worthwhile contribution remains intangible. The practical integration of natural language understanding and reasoning into question answering attempted by this research, whose practicality was founded through a series of evaluation, will once and for all scrap away the idea that the introduction of these two elements into question answering will raise lots of practical issues. This will pave way for more future researches in this practical approach towards question answering based on natural language understanding and reasoning.

In terms of the reasoning capability of NaLURI, we plan to strengthen the existing advanced reasoning and response generation capabilities by implementing additional features like generating intensional responses when the number of direct responses is very large or too small and also look for more advanced natural language response generation techniques to replace the current template-based approach.

The most challenging of all future work would be the research on the automated development and maintenance of the ontology and the gazetteer. This work will bring the dream of having question answering systems based on natural language understanding and reasoning portable across multiple domains a step closer to reality. This work will not be achieved easily due to the need to call for a whole new research to study the overall requirements and together with it, an accompanying dissertation.

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