The Semantic Web Needs Anaphora Resolution

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1. Abstract

This paper will address the importance of using anaphora resolution in the creation of knowledge databases or ontologies for the Semantic Web. The current debate existing between promoters of the Semantic Web [1] and NLP oriented practitioners of the web like the creators of the START QA system [6;13]: the former believe that by simply establishing a standard in the format of the information to be published on the web they will allow natural language communication, i.e. question/answering, to ensue. On the contrary, practitioners of the web find it totally misleading and insufficient in itself: they assume that natural language facilities must come first. This debate is reminiscent of a similar debate existing between people working in the NLP paradigm who have witnessed an increasing gap dividing on the one side, Knowledge Representation oriented researchers – usually engineers, their implementations being some variant of expert systems; on the other side, NLP oriented computational linguists who have continued working within the domain of a syntactic-semantic approach, not disregarding the relevance of knowledge of the world, but trying to reduce its impact on the overall architecture of a Text/Speech Understanding System.

2. Semantic Web and RDF

The Semantic Web is an extension of the World Wide Web that facilitates the exchange of machine-readable information [1]. At the heart of the Semantic Web is a technology known as the Resource Description Framework (RDF) [2], a portable XML-based representation of semantic networks or labeled directed graphs. RDF serves as the lingua franca of the Semantic Web, making it possible for programs to exchange ontologically encoded information, such as authorship, annotations, topic labels, content and customer satisfaction ratings, etc. over the Internet using a standard format.

The basic RDF data model consists of a series of nodes in a graph, which represent objects, and arcs connecting nodes, which represent relationships between objects. An arc (also called a predicate) in conjunction with the two nodes it connects is collectively termed a statement in RDF parlance and is the unit of information in the RDF model. Furthermore, nodes and predicates are named by uniform resource identifiers (URIs), which in conjunction with the XML Namespace standard [3], allow object identifiers to be globally unique. These standards also allow predicate vocabularies to be defined, which give standard names to relationships such as "has name", "published by", etc.

RDF is the lingua franca of the Semantic Web, providing a standardized data model for allowing interchange of metadata across the Internet. In short, it is a portable representation of a semantic network, a labeled directed graph. The basic unit of information in RDF is the statement, consisting of a triple of subject (a resource), predicate (an arc in the graph), and object (another resource or a literal).In its original form, RDF was meant for consumption by computers, not humans.

Most of the Web's content today is designed for humans to read, not for computer programs to manipulate meaningfully. Computers can adeptly parse Web pages for layout and routine processing—here a header, there a link to another page—but in general, computers have no reliable way to process the semantics, as [1] assumes. The authors continue by noting that the task is complicated,

> For the semantic web to function, computers must have access to structured collections of information and sets of inference rules that they can use to conduct automated reasoning. Artificial-intelligence researchers have studied such systems since long before the Web was developed. Knowledge representation, as this technology is often called, is currently in a state comparable to that of hypertext before the advent of the Web: it is clearly a good idea, and some very nice demonstrations exist, but it has not yet changed the world. It contains the seeds of important applications, but to realize its full potential it must be linked into a single global system.
> … The challenge of the Semantic Web, therefore, is to provide a language that expresses both data and rules for reasoning about the data and that allows rules from any existing knowledge-representation system to be exported onto the Web. Adding logic to the Web—the means to use rules to make inferences, choose courses

> of action and answer questions—is the task before the Semantic Web community at the moment. A mixture of mathematical and engineering decisions complicate this task.

Their conclusions are a mixture of hope and lack of realism: agents should be endowed with NLP capabilities which are far beyond current technology,

> The real power of the Semantic Web will be realized when people create many programs that collect Web content from diverse sources, process the information and exchange the results with other programs. The effectiveness of such software agents will increase exponentially as more machine-readable Web content and automated services (including other agents) become available.

Our central idea for bridging this gap between the core Semantic Web data model and natural language revolves around the suggestion offered by the authors of the START system, i.e. the application of the natural language annotations technology they employed by Start. In essence, they propose to “tag” fragments of RDF with language to facilitate access. In fact, annotation support has already been explored in the context of the Semantic Web. Projects such as Annotea [4] and CREAM [5] are developing frameworks for creating and exchanging RDF-encoded annotations between Semantic Web clients. RDF also forms the basis of Haystack’s data model [6], meaning that annotations created from within the Haystack environment are usable by other RDF-enabled software packages. Furthermore, natural language technology enables users to query information stores using everyday language without resorting to specialized and often unintuitive query languages.
We believe that natural language annotations are not only an intuitive and helpful extension to the Semantic Web, but will also assist in the deployment and adoption of the Semantic Web itself. As the authors comment, the primary barrier to the success of the Semantic Web is a classic chicken-and-egg problem: people will not spend extra time marking up their data unless they perceive a value for their efforts, and metadata will not be useful until a “critical mass” has been achieved. Although researchers have been focusing on ontology editors to reduce barriers to entry, such initiatives are not sufficient to overcome the hurdles.

3. Large-scale Syntactic-Semantic Indexing

Although full syntactic and semantic analysis of open-domain natural language text is beyond current technology, we believe that it is possible to augment RDF’s manual-annotation-based approach with automatically built annotations by extracting a limited subset of relations from unstructured text; in short, shallow/partial text understanding on the level of semantic relations, an extended label including Predicate-Argument Structures and other syntactically and semantically derivable head modifiers and adjuncts. This approach is promising because it attempts to address the well-known shortcomings of standard “bag-of-words” information retrieval/extractioin techniques without requiring manual intervention: it develops current NLP technologies which make heavy use of statistically and FSA based approaches to syntactic parsing.
To this end, we have developed GETARUNS [10], a prototype question answering system based on matching semantic relations derived from the question with those derived from the corpus (for START see Lin, 2001, 2003). These relations are simplified versions of RDF’s ternary expressions (see also Katz, 1997), but can be generated automatically and indexed on a large scale.
Currently, START’s system answers millions of natural language questions about places (e.g., cities, countries, lakes, coordinates, weather, maps, demographics, political and economic systems), movies (e.g., titles, actors, directors), people (e.g., birth dates, biographies), dictionary definitions, and much, much more. Because START performs sophisticated syntactic and semantic processing of questions to pinpoint the exact information need of a user, questions can be answered with remarkable precision. The authors report that in the period from January, 2001 to March, 2002, Start and Omnibase replied to over 326 thousand queries from users all over the world. Of those, 67% were answered successfully by our system (59% of the questions answered were handled by Omnibase) [7]. Table 1. here below shows the ternary structure induced for a sample of typical questions in START:

Table 1: Some sample questions that can be handled by an object–property–value model of Web data.

Question	Object	Property	Value
Who wrote the music for Star Wars?	Star Wars	composer	John Williams
Who invented dynamite?	dynamite	inventor	Alfred Nobel

How big is Costa Rica?	Costa Rica	area	51,100 sq. km
How many people live in Kiribati?	Kiribati	population	94,149
What languages are spoken in Guernsey?	Guernsey	languages	English, French
Show me paintings by Monet	Monet	works	[images]

4. Ternary Expressions as Predicate-Argument Structures

As a result, researchers like Lin, Katz and Litkowski have started to work in the direction of using NLP to populate a database of RDFs, thus creating the premises for the automatic creation of ontologies to be used in the SW. People have come to believe that the problem of NLP might be reduced to that of creating ternary expressions; in turn the problem of ontologies has also been reduced to that of having ternary expressions available. This reduction is in our opinion absolutely misleading and not to further: we want to make it clear that in no way RDFs and ternary expressions may constitute a formal tool sufficient to express the complexity of natural language texts.

RDFs are assertions about the things (people, Webpages and whatever) they predicate about by asserting that they have certain properties with certain values. If we may agree with the fact that this is natural way of dealing with data handled by computers most frequently, it also a fact that this is not equivalent as being equally useful for natural language. The misconception seems to be deeply embedded in the nature of RDFs as a whole: they are directly comparable to attribute-value pairs and DAGs which are also the formalism used by most recent linguistic unification-based grammars. From the logical and semantic point of view RDFs also resemble very closely first order predicate logic constructs: but we must remember that FOPL is as such insufficient to describe natural language texts.

Ternary expressions(T-expressions), <subject relation object>.

Certain other parameters (adjectives, possessive nouns, prepositional phrases, etc.) are used to create additional T-expressions in which prepositions and several special words may serve as relations. For instance, the following simple sentence

(1) Bill surprised Hillary with his answer

will produce two T-expressions:

(2) <<Bill surprise Hillary> with answer>
<answer related-to Bill>

In Litkowski's system the key step in their question-answering prototype was the analysis of the parse trees to extract semantic relation triples and populate the databases used to answer the question. A semantic relation triple consists of a discourse entity, a semantic relation which characterizes the entity's role in the sentence, and a governing word to which the entity stands in the semantic relation. The semantic relations in which entities participate are intended to capture the semantic roles of the entities, as generally understood in linguistics. This includes such roles as agent, theme, location, manner, modifier, purpose, and time. Surrogate place holders included are "SUBJ," "OBJ", "TIME," "NUM," "ADJMOD," and the prepositions heading prepositional phrases. The governing word was generally the word in the sentence that the discourse entity stood in relation to. For "SUBJ," "OBJ," and "TIME," this was generally the main verb of the sentence. For prepositions, the governing word was generally the noun or verb that the prepositional phrase modified. For the adjectives and numbers, the governing word was generally the noun that was modified.

4.1 Ternary Expressions are better than the BOWs approach, but…

People working advocating the supremacy of the Tes approach were reacting against the Bag of Words approach of IR/IE in which words were wrongly regarded to be entertaining a meaningful relation simply on the basis of topological criteria: normally the distance criteria or the more or less proximity between the words to be related. Intervening words might have already been discarded from the input text on the basis of stopword filtering. Stopwords list include all grammatical close type words of the language considered useless for the main purpose of IR/IE practitioners seen that they cannot be used to denote concepts. Stopwords constitute what is usually regarded the noisy part of the channel in information theory. However, it is just because the redundancy of the information channel is guaranteed by the presence of grammatical words that the message gets appropriately computed by the subject of the

communication process, i.e. human beings. Besides, entropy is not to be computed in terms of number of words or letters of the alphabet, but in number of semantic and syntactic relation entertained by open class words (nouns, verbs, adjectives, adverbials) basically by virtue of closed class words. Redundancy should then be computed on the basis of the ambiguity intervening when enumerating those relations, a very hard task to accomplish which has never been attemped yet, at least to my knowledge.
What people working with TEs noted was just the problem of encoding relations appropriated, at least some of these relations. The IR/IE BOWs approach suffers (at least) from Reversible Arguments Problem (Katz & Lin)
- What do frogs eat? vs What eats frogs?
The verb "eat" entertains asymmetrical relations with its SUBJect and its OBJect: in one case we talk of the "eater", the SUBJect and in another case of the "eatee", the OBJect. Other similar problems occur with TEs when the two elements of the relation have the same head, as in:
-The president of Russia visited the president of China. Who visited the president?
The question will not be properly answered in lack of some clarification dialogue intervening, but the corresponding TEs should have more structure to be able to represent the internal relations of the two presidents. The asymmetry of relation in transitive constructions involving verbs of accomplishments and achievements (or simply world-changing events) is however further complicated by a number of structural problems which are typically found in most languages of the world, the first one and most common being Passive constructions:
i.John killed Tom.
ii.Tom was killed by a man.
Who killed the man?
Answer to the question would be answered by "John" in case the information available was represented by sentence in i., but it would be answered by "Tom" in case the information available was represented by sentence ii. Obviously this would happen only in lack of sufficient NLP elaboration: a too shallow approach would not be able to capture presence of a passive structure. We are here referring to "Chunking"-based approaches those in which the object of computation is constituted by the creation of Noun Phrases and no attempt is made to compute clause-level structure.
There is a certain number of other similar structure in texts which must be regarded as inducing into the same type of miscomputation: i.e. taking the surface order of NPs as indicating the deep intended meaning. In all of the following constructions the surface subject is on the contrary the deep object thus the Affected Theme or argument that suffers the effects of the action expressed by the governing verb rather than the Agent:

Inchoatized structures; Ergativized structures; Impersonal structures

Other important and typical structures which constitute problematic cases for a surface chunks based TEs approach to text computation are the following ones in which one of the arguments is missing and Control should be applied by a governing NP, they are called in one deifnition Open Predicative structures and they are

Relative clauses; Fronted Adjectival adjunct clauses; Infinitive clauses; Fronted Participial clauses,; Gerundive Clauses; Elliptical Clauses; Coordinate constructions

In addition to that there is one further problem and is definable as the Factuality Prejudice: by collecting keywords and TEs people apply a Factuality Presupposition to the text they are mining: they believe that all terms being recovered by the search represent real facts. This is however not true and the problem is related to the possibility to detect in texts the presence of such semantic indicators as those listed here below:

Negation; Quantification; Opaque contexts (wish, want); Future, Subjunctive Mode; Modality; Conditionals

Finally there is a discourse related problem and is the **Anaphora Resolution** problem which is the hardest to be tackled by NLP: it is a fact that anaphoric relations are the building blocks of cohesiveness and coherence in texts. Whenever an anaphoric link is missed one relation will be assigned to a wrong referring expression thus presumably jeopardising the possibility to answer a related question appropriately.

5. GETARUNS Complete and Shallow

Consider now a simple sentence like the following:

· John went into a restaurant

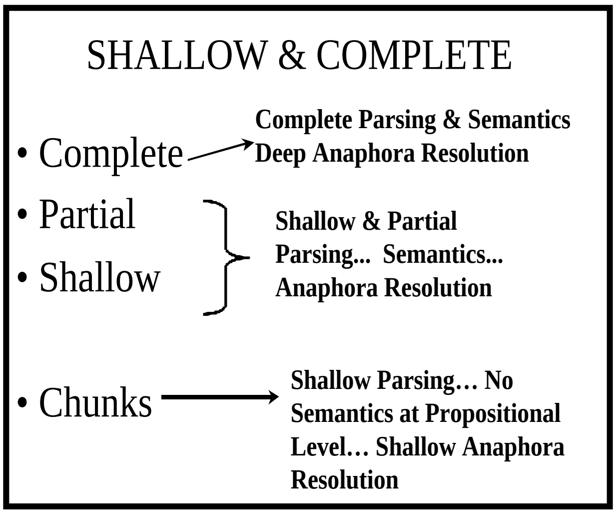
This might be represented by TEs as follows:

<John go restaurant>

<GO <SUBJ John>, <OBLrestaurant>>

GETARUNS represents the same sentence in different manners according to whether it is operating in Complete or in Shallow or Chunks modality. In turn the operating modality is determined by its ability to compute the current text: in case of failure the system will switch automatically from Complete to Partial/Shallow modality; and in case of failure again it will switch to Chunks modality.

Fig.1 GETARUNS system Shallow and Complete



The system will produce the following representations:
loc(infon2, id1, [arg:main_tloc, arg:tr(f1_r01)])
loc(infon3, id2, [arg:main_sloc, arg:restaurant])
ind(infon4, id3)
fact(infon5, inst_of, [ind:id3, class:man], 1, univ, univ)
fact(infon6, name, [john, id3], 1, univ, univ)
ind(infon7, id4)
fact(infon8, isa, [ind:id4, class:restaurant], 1, id1, id2)
fact(infon9, inst_of, [ind:id4, class:place], 1, univ, univ)
fact(id5, go, [agent:id3, locat:id4], 1, tes(f1_r01), id2)
fact(infon12, isa, [arg:id5, arg:ev], 1, tes(f1_r01), id2)
fact(infon13, isa, [arg:id6, arg:tloc], 1, tes(f1_r01), id2)
fact(infon14, past, [arg:id6], 1, tes(f1_r01), id2)
fact(infon15, time, [arg:id5, arg:id6], 1, tes(f1_r01), id2)

This first representation is inspired by Situation Semantics where reality is represented in Situations which are collections of Facts: in turn facts are made up of Infons which information units characterised as follows:

Infon(Index,
Relation(Property),
List of Arguments - with Semantic Roles,
Polarity - 1 affirmative, 0 negation,
Temporal Location Index,
Spatial Location Index)

In addition Arguments have each a semantic identifier which is unique in the Discourse Model and is used to individuate the entity uniquely. Also propositional facts have semantic identifiers assigned thus constituting second level ontological objects. They may be "quantified" over by temporal representations but also by discourse level operators, like subordinating conjunctions. Negation on the contrary is expressed in each fact.

So in case of failure at the Complete level, the system will switch to Partial and the representation will be deprived of its temporal and spatial location information as follows:
ind(infon4, id3)
fact(infon5, inst_of, [ind:id3, class:man], 1, univ, univ)
fact(infon6, name, [john, id3], 1, univ, univ)
ind(infon7, id4)
fact(infon8, isa, [ind:id4, class:restaurant], 1, id1, id2)
fact(infon9, inst_of, [ind:id4, class:place], 1, univ, univ)
fact(id5, go, [agent:id3, locat:id4], 1, univ, id2)

Finally, the Shallow and the Chunks modality will limit the DM representation to entities, as follows:
ind(infon4, id3)
fact(infon5, inst_of, [ind:id3, class:man], 1, univ, univ)
fact(infon6, name, [john, id3], 1, univ, univ)
ind(infon7, id4)
fact(infon8, isa, [ind:id4, class:restaurant], 1, id1, id2)
fact(infon9, inst_of, [ind:id4, class:place], 1, univ, univ)

In addition, all system modalities will build separately a less abstract representation which is intended to capture the real words being used in the linguistic descriptions: this representation is exploited in Summarization and in the generation of canned-type answer. Suppose we have a sentence as the following one:

"This unit has been manufactured to assure your personal safety, but improper use can result in potential electrical shock or fire hazards."

which has been taken from one of the texts we have used for our Evaluation Test reported below, the representation at the concrete level is as follows: it is constituted by a set of referring expressions with an index, a semantic identifier (the same of the the DM) and a Grammatical Function,
refs(r0007, id5, subj, unit, [this, unit])
refs(r0008, id8, mod, electrical_shock, [electrical, shock, electrical_shock])
refs(r0009, id4, obj, safety, [your, personal, safety])
refs(r0010, id6, subj, use, [improper, use])

Multiwords are decomposed and appear twice in the final representation. Then there is the list of relations,
refs(r0011, id7, obl, fire, [in, potential, electrical_shock, or, fire])
refs(r0012, 4-4, id6, subj, [can, result], [improper, use])
refs(r0013, 4-4, id7, obl, [can, result], [in, potential, electrical_shock, or, fire])
refs(r0016, 4-1, id5, subj, [has, been, manufactured], [this, unit])
refs(r0017, 4-1, id9, vcomp, [has, been, manufactured], [to, assure, your, personal, safety])
refs(r0015, 4-2, id9, obj, [to,assure], [your,personal,safety])

6. The Experiment

We downloaded the only freely available corpus annotated with anaphoric relations, i.e. Wolverhampton's Manual Corpus made available by Prof. Ruslan Mitkov on his website. The corpus contains text from Manuals at the following address, http://clg.wlv.ac.uk/resources/corpus.html

Text Type	Referring Exps	Coreferring Exps	Total Words
AIWA	1629	716	6818
ACCESS	1862	513	9381
PANASONIC	1263	537	4829
HINARI	673	292	2878
URBAN	453	81	2222
WINHELP	672	206	2935
CDROM	1944	279	10568
Totals	8496	2624	39631

Table 2. General data of Worlverhampton's coreference annotated corpora

We reported in Tab. 2 the general data of the Coreference Corpus. As can be easily noted, there is no direct relationship existing between the number of referring expressions and the number of coreferring expressions. We assume that the higher the number of coreferring expressions in a text the higher is the cohesion achieved. Thus the text identified as CDROM has a very small number of coreferring expressions if compared to the total number of referring expressions. The proportion of referring expressions to words and of coreferring expressions to referring expressions is reported in percent value in table 3. where the most highly cohesive texts are highlighted in italics; highly non cohesive texts are highlighted in bold:

Text Type	Referring Exps % W	Coreferring Exps % RE
AIWA	23.89	*43.21*
ACCESS	19.84	27.01
PANASONIC	26.15	*42.51*
HINARI	23.38	29,22
URBAN	20.38	**17.88**
WINHELP	22.89	27.14
CDROM	18.39	**14.24**
Means	21.43	30.88

Table 3. Proportion of coreferential expressions to referring expressions

To compare our results with the SGML documents we created a Perl script that extracted all referring expressions and wrote the output into a separate file. The new representation of the SGML files looked now like a list of records each one denoted by an index a dash and the text of the referring expression. In case of complex referring expressions we had more than one index available and so we translated the complex referring expression into a couple or a triple of records each one denoted by its index.

The first comparison results were very disappointing. So we looked into the files and we found out that in general, there were mapping problems in the way in which complex referring expressions had been manually encoded. For instance, in such cases as the following ones,

Example 1.

· ASCII text

from the Royal National Institute for the Blind's helpsheets.

· SGML text

<COREF ID="1833"><COREF ID="1832">the Royal National Institute for the Blind's</COREF> helpsheets</COREF> .

· output records

1832- the Royal National Institute for the Blind-s_

1833- the Royal National Institute for the Blind-s_ helpsheets

· our output

1753 - the Royal National Institute

1754 - the Blind-s_ helpsheets

Example 2.

· ASCII text

many of the features available with the CombiBraille

· SGML text

<COREF ID="1747">many of the features available with <COREF ID="1748" TYPE="IDENT" REF="1664">the CombiBraille</COREF></COREF>

· output records

1747 - many of the features available with the CombiBraille

1664 - the CombiBraille

· our output

1666 - many of the features available

In both examples the governing referring expression is not captured becuase the choice of the annotators (or the program that helped in the annotation) has been dishomogeneous and misleading. Perhaps a better way to encode the internal modifying relation could have been the following one,

Example 3. SGML text
<COREF ID="1833"><COREF ID="1832">the Royal National Institute</COREF> for the Blind's helpsheets</COREF> .
Example 4. SGML text
<COREF ID="1747">many of the features available<COREF ID="1748" TYPE="IDENT" REF="1664"> with the CombiBraille</COREF></COREF>
In addition to these problems we found other more serious problems: modifiers of the nominal head were systematically left off in case they were quantifiers, as in
Example 4.
· ASCII text
Much of this document
· SGML text
Much of <COREF ID="1823" TYPE="IDENT" REF="0">this document</COREF>
Or in case a nominal head was modified by an an adjunct predicate relative clause this was treated as a single referring expression, as in
Example 5.
· ASCII text
every useful feature that I know about
· SGML text
<COREF ID="1789">every useful feature that I know about</COREF>
· our output
1702 - every useful feature
This treatment was not applied to complementizerless relative clauses predicate adjuncts, as in
Example 5.
· ASCII text
a normal terminal screen of the kind Linux supports
· SGML text
<COREF ID="481">a normal terminal screen</COREF> of the kind <COREF ID="482" TYPE="IDENT" REF="1">Linux</COREF> supports

where we see that the modifier “of the kind” is left off and the relative adjunct is thus cut off from its governing head “a normal terminal screen”.
In addition to this, the annotators chose not to treat as referring expression all section numbers, money amounts numbers, numbers related to software versions. Also email addresses and webpage addresses have been left off. Since they constitute regular referring expressions in our system we decided to include them in the final count.

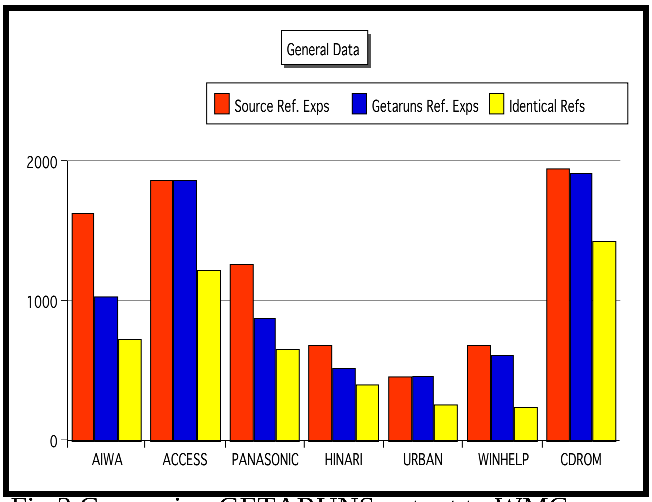


Fig.2 Comparing GETARUNS output to WMC

The final results are reported in the following figure where we plot Precision and Recall for each text and then the comprehensive values. The F measure is computed according to the following formula

$$F = \frac{(W + 1)RP}{(WR) + P}$$

where W represents the relative weight of recall to precision and typically has the value of 1.

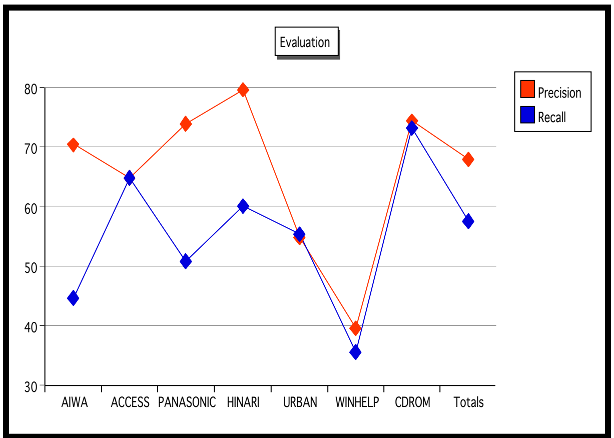


Fig.3 Precision and Recall for the WMC

7. Conclusions

Results reported in the experiment above have been limited to the ability of the system to cope with what has always been regarded as the toughest task for an NLP system to cope with. We have not addressed the problem of question answering for lack of space.
Would it be possible for computers the recognize the layout of a Web page, much in the same manner as a human? Much like the development of the Semantic Web itself, early efforts to integrate natural language technology with the Semantic Web will no doubt be

slow and incremental. By weaving natural language into the basic fabric of the Semantic Web, we can begin to create an enormous network of knowledge easily accessible by both machines and humans alike. Furthermore, we believe that natural language querying capabilities will be a key component of any future Semantic Web system. By providing "natural" means for creating and accessing information on the Semantic Web, we can dramatically lower the barrier of entry to the Semantic Web. Natural language support gives users a whole new way of interacting with any information system, and from a knowledge engineering point of view, natural language technology divorces the majority of users from the need to understand formal ontologies. As we have tried to show in the paper, this calls for better NLP tools where a lot of effort has to be put in order to allow for complete and shallow techniques to coalesce smoothly into one single system. GETARUNS represents such a hybrid system and its performance is steadily improving.

In the future we intend to address the problem of using the database of TEs created by our system in asnswering a more extended set of natural language queries than what has been tried sofar [8].

8. References

[1] Berners-Lee, T., Hendler, J., and Lassila, O. The Semantic Web. Scientific American (May 2001).

[2] Lassila, O. and Swick, R. (eds.). Resource Description Framework (RDF) model and syntax specification. Available at http://www.w3.org/TR/1999/REC-rdf-syntax-19990222.

[3] Bray, T., Hollander, D., and Layman, A. (eds.) Namespaces in XML. Available at http://www.w3.org/TR/REC-xmlnames/.

[4] Kahan, J. and Koivunen, M. Annotea: an open RDF infrastructure for shared web annotations, in Proceedings of WWW10 (May 2001).

[5] Handschuh, S., Staab, S., and Maedche, A. CREAM—creating relational metadata with a component-based ontology-driven annotation framework, in Proceedings of K-CAP 2001 (October 2001).

[6] David R. Karger, Boris Katz, Jimmy Lin, Dennis Quan, Sticky Notes for the Semantic Web, IUI'03, January 12–15, 2003, Miami, Florida, USA, ACM 1-58113-586-6/03/0001.

[7] Boris Katz Jimmy J. Lin Sue Felshin, The START Multimedia Information System: Current Technology and Future Directions, In Proceedings of the International Workshop on Multimedia Information Systems (MIS 2002).

[8] R.Delmonte, 2003. Getaruns: a Hybrid System for Summarization and Question Answering. In Proc. Natural Language Processing (NLP) for Question-Answering, EACL, Budapest.

[9] J. Lin. 2001. Indexing and retrieving natural language using ternary expressions. Master's thesis, Massachusetts Institute of Technology.

[10] B. Katz. 1997. Annotating the World Wide Web using natural language. In RIAO '97.

[11] Delmonte R. 2000d. Generating from a Discourse Model, *Proc. MT-2000*, BCS, Exeter, pp.25-1/10.

[12] Delmonte R., D. Bianchi. 2002. From Deep to Partial Understanding with GETARUNS, *Proc. ROMAND 2002*, Università Roma2, Roma, pp.57-71.

[13] Litkowski, K. C. (2001). Syntactic Clues and Lexical Resources in Question-Answering. In E. M. Voorhees & D. K. Harman (eds.), The Ninth Text Retrieval Conference (TREC-9). NIST Special Publication 500-249. Gaithersburg, MD., 157-166.

[14] Litkowski, K. C. (2002a). CL Research Experiments in TREC-10 Question-Answering. In E. M. Voorhees & D. K. Harman (eds.), The Tenth Text Retrieval Conference (TREC 2001). NIST Special Publication 500-250. Gaithersburg, MD., 122-131.

[15] Litkowski, K. C. (2002b). Digraph Analysis of Dictionary Preposition Definitions. Proceedings of the ACL SIGLEX Workshop: Word Sense Disambiguation. Philadelphia, PA., 9-16.

[16] Ravichandran, D. & E. Hovy. (2002). Learning Surface Text Patterns for a Question Answering System. Proceedings of the 40th Annual Meeting of the Association for Computational Linguistics. Philadelphia, PA., 41-7.

[17] Harabagiu, S., Moldovan, D., Pasca, M., Surdeanu, M., Mihalcea, R., Girju, R., Rus, V., Lacatusu, F., Morarescu, P., & Bunescu, R. (2002). Answering complex, list, and context questions with LCCs Question-Answering Server. In TREC-10 Question-Answering. In E. M. Voorhees & D. K. Harman (eds.), The Tenth Text Retrieval Conference (TREC 2001). NIST Special Publication 500-250. Gaithersburg, MD., 355-361.

[18] Hovy, E., U. Hermjakob, & C. Lin. (2002a). The Use of External Knowledge in Factoid QA. In E. M. Voorhees & D. K. Harman (eds.), The Tenth Text Retrieval Conference (TREC 2001). NIST Special Publication 500-250. Gaithersburg, MD., 644-652.