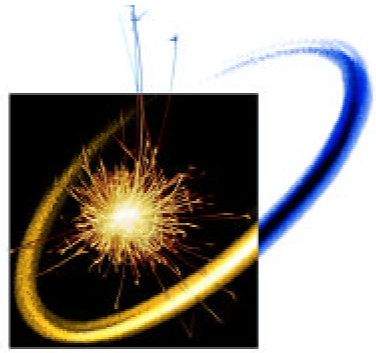
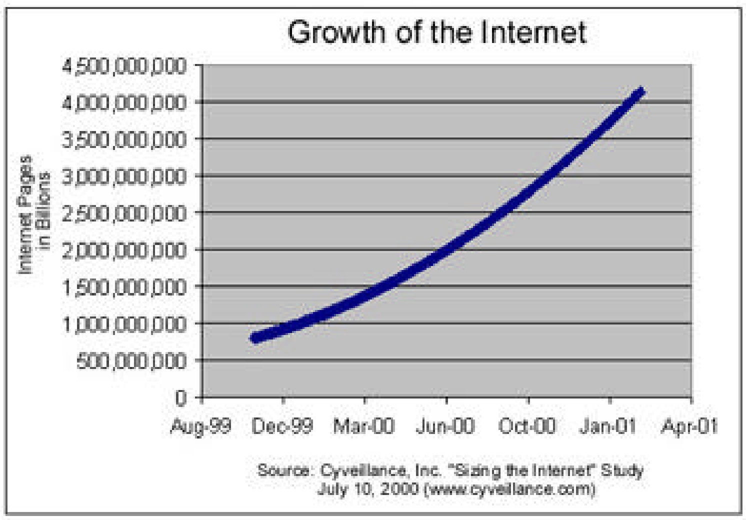


White Paper

Accelerate your speed to Knowledge

Introduction

Today, everyone who works with knowledge is familiar with the information overload problem. The overall market is crowded with over 140 different vendors offering browse and text search tools that claims to do everything from text search to knowledge retrieval. Knowledge retrieval represents a significant advancement over simple search engines and conventional information retrieval. Search engines such as AltaVista, Yahoo and Lycos use Boolean word matching to identify words in target documents that basically match the words contained in a user's query, without regard to the meaning of the words in the query. These engines narrow the amount of information a user can find, on the Internet, for example, but most often add to the problem of information overload by returning thousands of irrelevant query results.



With the current growth rate of the Internet it will reach over 4 billion pages in year 2001. The information overload problem will not likely be solved with currently used search technology. And, even though in a smaller scale, many larger corporations are facing the same problem with their Intranets.

This white paper discusses issues involved in resolving the knowledge retrieval problem using the latest advancements in Natural Language Processing technology by Invention Machine Corp.

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Knowledge Retrieval Methods

Finding relevant knowledge quickly and easily from a large collection of documents, like the Internet or larger companies' Intranet, has rapidly become one of the most important key competitive factors. At the same pace as we can access larger amount of data it has become painfully clear how difficult this task is. Paradoxically, the access of more information has made knowledge research more difficult than ever before.

Keyword search

The most commonly used way to find relevant documents and ultimately useful knowledge has been keyword search using Boolean operations in it simplest form. It has its main advantage in being instantly understood by the user. But with access to increasingly more documents, it has becomes almost hopeless to use this method for any serious research. Either too many documents are returned or a too constrained query will miss relevant documents.

Statistical based search methods

One major approach to resolve this problem and improve document and knowledge retrieval is the use of statistical analysis methods. Traditionally, the statistical approach has been found to be the most practical to implement in order to improve the keyword search method. Bayesian, Probabilistic, Scoring, Pattern recognition, Proximity searching, Word frequency, Claude Shannon's principles, Data Visualization, Data Mining, etc., are popular names used for statistical based methods.

Lately, statistical search also can be found in combination with a Natural Language query[1] interface. Many times this is used in conjunction with a semantic knowledgebase for query expansion (sometimes called Semantic Network or something similar), based on sample representative documents.

Statistic search has a number of built in weaknesses that set a limit to what can be achieved. A statistical method makes a very "mechanical" document analysis using, for example, word-by-word comparison, word distance calculations, or word frequency counting. The document author's attempts to explain facts and cause and effect relationships are totally ignored. That is why statistical methods many times are, or can easily be made, language independent - the language itself is not considered!

From the very nature of statistics, knowledge retrieval does not work well when important information is only mentioned only once or twice in thousands of scanned documents.

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[1] See page 11 for more information on Natural Language query interface

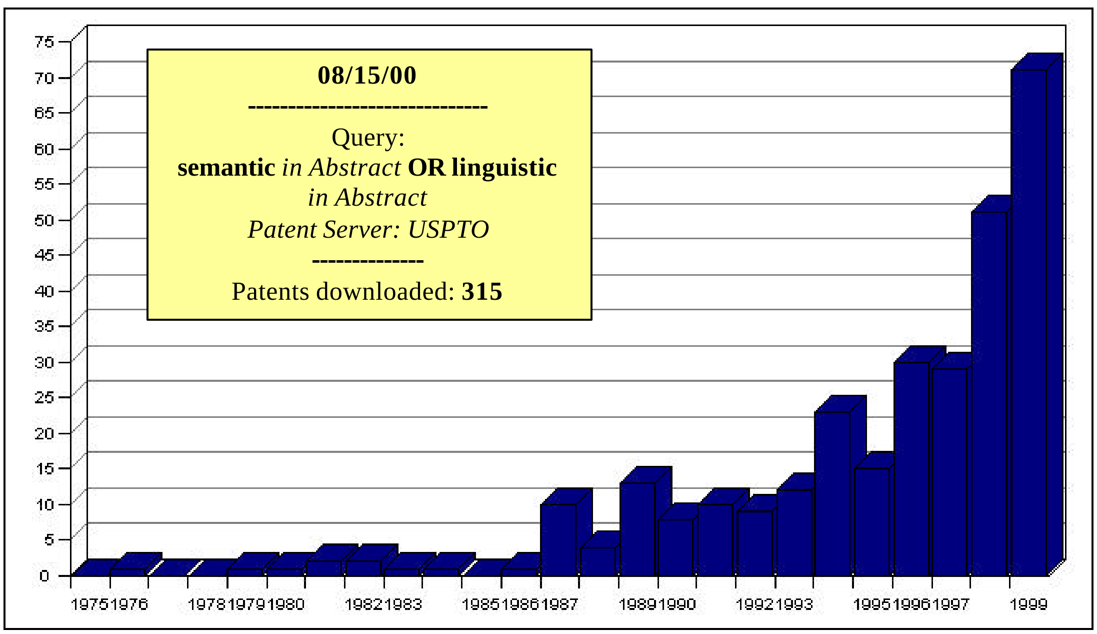
Another limitation is, since the match between a query and a found document is statistically based, it is very difficult to pinpoint the exact place in the document where the interesting information is located. It is the statistical pattern in the document that represents the search match, not what is said in the document. The user has to read the document to find the place where the relevant information is located.

Finally, and perhaps the biggest disadvantage, knowledge retrieval is usually done in order to find new information, not the same old information. A statistical approach will give the highest relevance to bringing back the exact same information as used in the query. In order to bring fresh new information to old questions, it's required that the knowledge retrieval tool perform reasoning or understand cause and effect relationships. To achieve this, you need to look for something beyond a statistical approach.

If the language itself can be understood, as it is by a human reader, improved search results obviously could be achieved. This is the goal of IMC in using Natural Language Processing (NLP). For a long time the use of NLP turned out to be far more complicated than expected. But with the drastic increase of computing power and the creation of comprehensive language dictionaries for NLP, the goal has now become achievable.

Natural Language Processing

Natural Language Processing or Linguistic Analysis has been a science by itself for many years. As can be seen from this trend below, the patent activity in Linguistics and Semantics has dramatically increased in the last 12 years. More and more companies are picking up the opportunity within NLP.

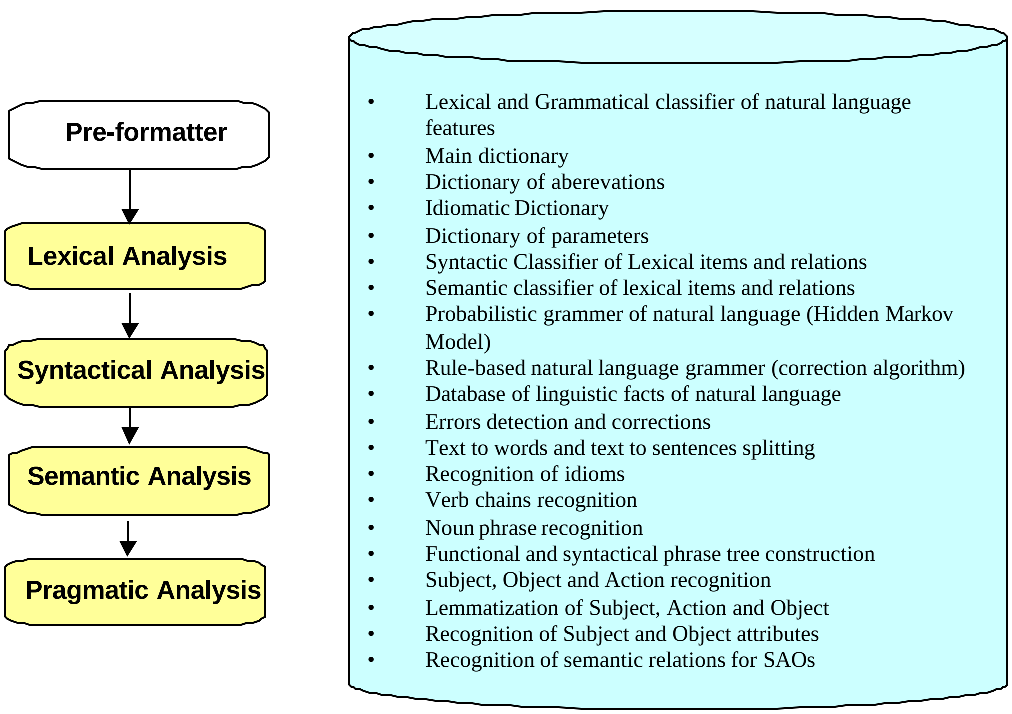


To better understand what Linguistic Analysis is about, consider a person in the process of learning to read the English language. In addition to learning a large number of new words, the person needs to understand grammatical rules, word classes, and sentence construction. To verify that a sentence construction is complete, the student answers these types of questions:

What is going on in the sentence? ⇒ *the action*
Who is performing the action? ⇒ *the subject*
What is changed as a result of *the subject* performing *the action*? ⇒ *the object*

The same questions are later used to read English text. After some time this process is performed quickly and efficiently in the background of the student's brain without actively thinking. The student is reading and understanding the English text material!

The goal of Linguistic Analysis, in the context of knowledge retrieval, is to repeat the same process and analysis a human reader performs when reading a document. With the rapid increase of computer capabilities and processing speed, and the creation of sufficient dictionaries and grammatical rules databases, this is now possible. Linguistic Analysis consists of different levels of analysis each increasing in complexity. Each level can be performed more or less comprehensively. IMC is performing following levels:



IMC Linguistic Database

In order to perform Linguistic Analysis, a linguistic database is required. Everything, from basic dictionaries to sophisticated rules based algorithms, is part of the database. The IMC Linguistic Database consists both of extended public dictionaries and ones they created. The quality or accuracy of Linguistic Analysis is highly dependent on the linguistic database used. (One side effect of creating an efficient Linguistic Analysis tool is that it can be used to improve the Linguistic Database.)

Pre-formatter

Before the Linguistic Analysis can start the source has to be pre-formatted. This involves converting formats (rtf, doc, pdf, html, etc…) into simple text, ignoring images and other non-text objects, correcting errors and finally splitting the text into sentences.

Lexical Analysis

Lexical Analysis involves reading the input sentences, extracting individual words and retrieving the possible word classes (part of speech) by using dictionary databases. This is a context independent analysis that relies on the fact that each word found in the analyzed sentence can be found in the dictionary used. Each word found in the dictionary is tagged with the corresponding word class. Since many words can be of more than one word class, some words will have more than one tag. For example, consider the word "screen". It can be a noun (door screen) or a verb (screen the candidates).

Syntactic Analysis

The syntactic analysis objective is to complete the tagging of all words from the Lexical Analysis. All words must have exactly one tag, no more or less. This step is performed by taking into account the context of the sentence.

The Syntactic Analysis is done in two steps. The first step is performed using grammatical rules. From all theoretically possible sequences of word classes, only a subset is accepted in accordance with grammatical rules. For example, no sentence contains only verbs. Thereby, a number of incorrect tags can be removed and unknown words can be tagged. See the sample sentence below, before and after word class tagging:

Untagged sentence:
In order to provide consistent water pressure at the fixtures, the pump first moves water to a storage tank.
Tagged sentence:
In_order_to_TO provide_VB consistent_JJ water_NN pressure_NN at_IN the_ATI fixtures_NNS ,_, the_ATI pump_NN first_RB moves_VBZ water_NN to_TO a_AT storage_NN tank_NN ._.

The second step is performed using statistical information. Some sequences of word classes are less often used than others. By studying a gigantic volume of documents a probability distribution for the sequence of word classes can be derived. By using the "Hidden Markov Model" the statistical numbers can be used to determine the most likely sequence of word classes in a sentence.

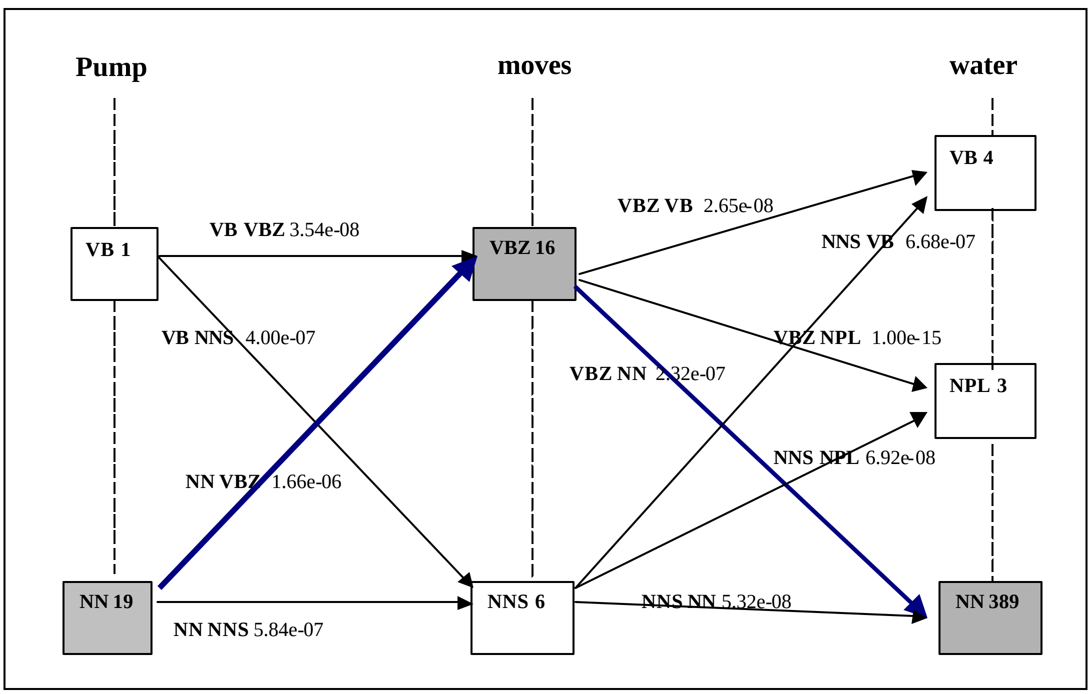
In the IMC implementation of the Hidden Markov Model, a matrix with 104 identified word classes on each side has been created (104x104). See picture below.

	NNS	NPL	IN	JJ	VBZ	NN	PP3A	VB
NNS		6.92E-08				5.32E-08		6.68E-07
NPL								
IN								
JJ								
VBZ		1.00E-15				2.32E-07		2.65E+08
NN	5.84E-07				1.66E-06			
PP3A								
VB	4.00E-07				3.54E-08			

Tag	Word-class	Example
NNS	common noun plural	machines, systems, etc
NPL	capitalized locative noun singular	Abbey, Bridge, etc
IN	preposition	about, above, etc
JJ	adjective	conceptual, sequential, etc
VBZ	verb in its simple present 3d person singular tense form	comprises, etc
NN	common noun singular	computer, network, etc
PP3A	personal pronoun 3d person singular common case	he, she
VB	infinitive or verb in its present simple tense form except 3d person singular	concentrate, compute, etc

Example of Hidden Markov Model (incomplete), matrix size 8x8

The Hidden Markov Model predicts the probability that two word classes comes after each other. Additionally, a database containing probability values for a word class alone is used. Now, for a sentence consisting of more than two words, the probability can be calculated by using the matrix multiple times. See the example sentence “Pump moves water” below:



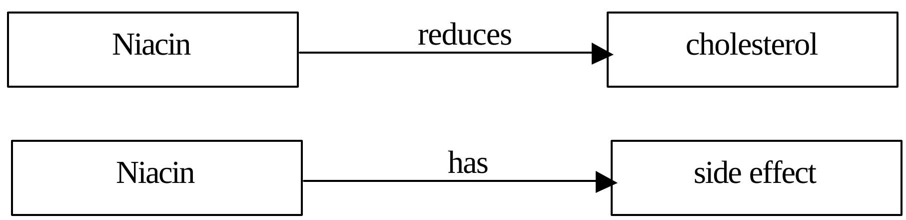
As can be seen in the above diagram, using dictionaries to determine the classes of words is not enough. For example, the word “pump” can both be a verb (VB) or a noun (NN). The numbers in boxes (i.e., VB 1) are probability values for word classes alone. The values along the arrows (i.e., VB VBZ 3.35e-008) are the probability value for this combination of word classes, found in the Hidden Markov matrix. For each possible combination of word classes, (in this example, there are 12 (2x2x3) possible combinations) a probability value is calculated. The combination with the highest probability is selected. In this case: "Pump_NN moves_VB water_NN."

Semantic Analysis:

As a result of the Syntactic Analysis the exact word class for each word in the sentence has now been identified. But you still don't know what the author of the text is trying to express. This is the objective of the Semantic Analysis: trying to determine the meaning of the sentence (if there is any!). To perform this step, the sentence structure is analyzed. The major structural elements of a sentence are the Subject, Action and Object. Consider the following sentence:

"*Niacin also reduces cholesterol in high doses, but also has side effects*."[2]

From the Lexical and the Syntactic Analysis it can be determined that both "Niacin" and "cholesterol" are nouns. But what is the relationship between them in this sentence? The Semantic analysis can identify "*Niacin*" as the Subject, "*cholesterol*" as the Object, and "*reduces*" as the Action connecting them. Indirect Objects or conditions as "in high doses" can be identified. Additionally, the fact that Niacin has side effects can also be extracted.



Pragmatic Analysis:

Pragmatic Analysis involves organizing the extracted semantic information in a way so it becomes useful for a certain purpose. For example, the extracted subject, action and object can be organized in a "Problem-Solution" format where the action-object forms the problem statement and the subject the solution. This format has proved to be very successful for engineering and scientific problems and is expected be useful in other domains as well. See the example below from a patent text:

[2] Sentence from: Mount Desert Island Hospital, Health information "Eating to reduce Cholesterol"

United States Patent 5,969,235 October 19, 1999
System and method for measuring scale deposition including a tuning fork for use in the system and the method
…
DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EMBODIMENTS

The present invention provides a tuning fork capable of use in a system that includes a liquid or other fluid that is often subjected to scale being deposited into the system. The tuning fork has particular applications within a mineral processing system wherein deposits of scale often cause problems with fouling of the system components and/or creating low flow conditions. Of course, the tuning fork may be applied to any system where it is important to measure scale and control the build-up of scale deposits in the system. *The **tuning fork** can also be used to **measure** the **viscosity** of a liquid.* A system and method for measuring scale deposition using the tuning fork of the present invention are also described hereinafter.
…

A text paragraph from patent US5969235

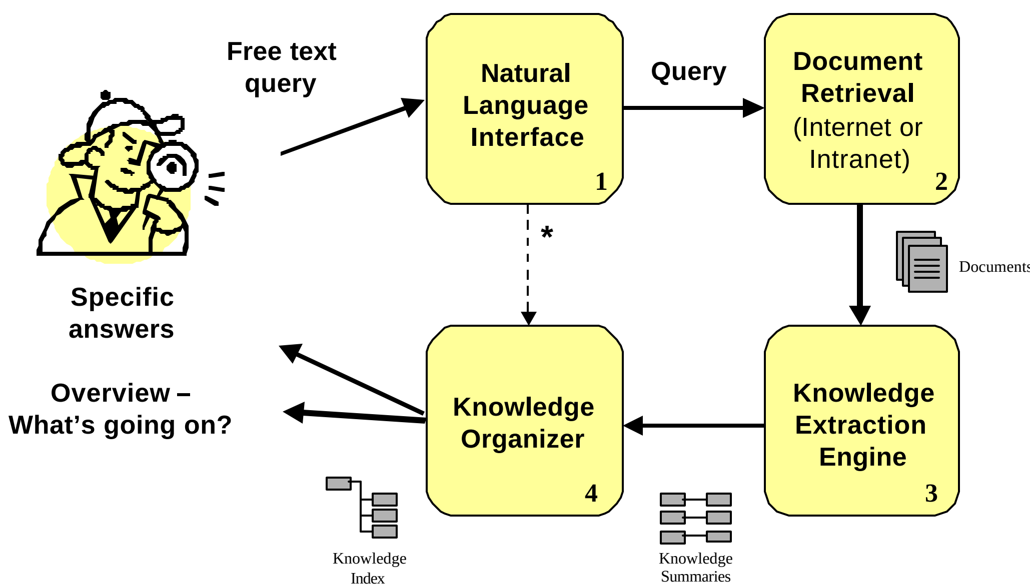
Imagine that an engineer needs to find new ways to measure the viscosity of a liquid. The patent quoted above turns out to have as a side effect, mentioned only once in the text, that the new innovative device "tuning fork" can actually be used for measuring viscosity in liquids. This information would be very difficult to find without using Semantic Analysis and the ability to list all "solutions" to the problem "measure viscosity" neatly in one place.

IMC Achievements:

The above mentioned levels of Linguistic Analysis have been achieved by significantly improving the patented IMC innovations, both by adding a significant amount of dictionary and statistical data to the IMC Linguistic Database and by developing a unique rule base databases to reach a yield level above 2/3 correct extraction. This is also accomplished without compromising the speed of extraction, currently about 1MB text per minute.

Below are 4 important integrated steps of knowledge retrieval showing how IMC technology can be used.

IMC Technology - Power Knowledge Retrieval



* If a knowledge index already exist for a given query, step 2 and 3 can be skipped!

1.Natural Language Interface:

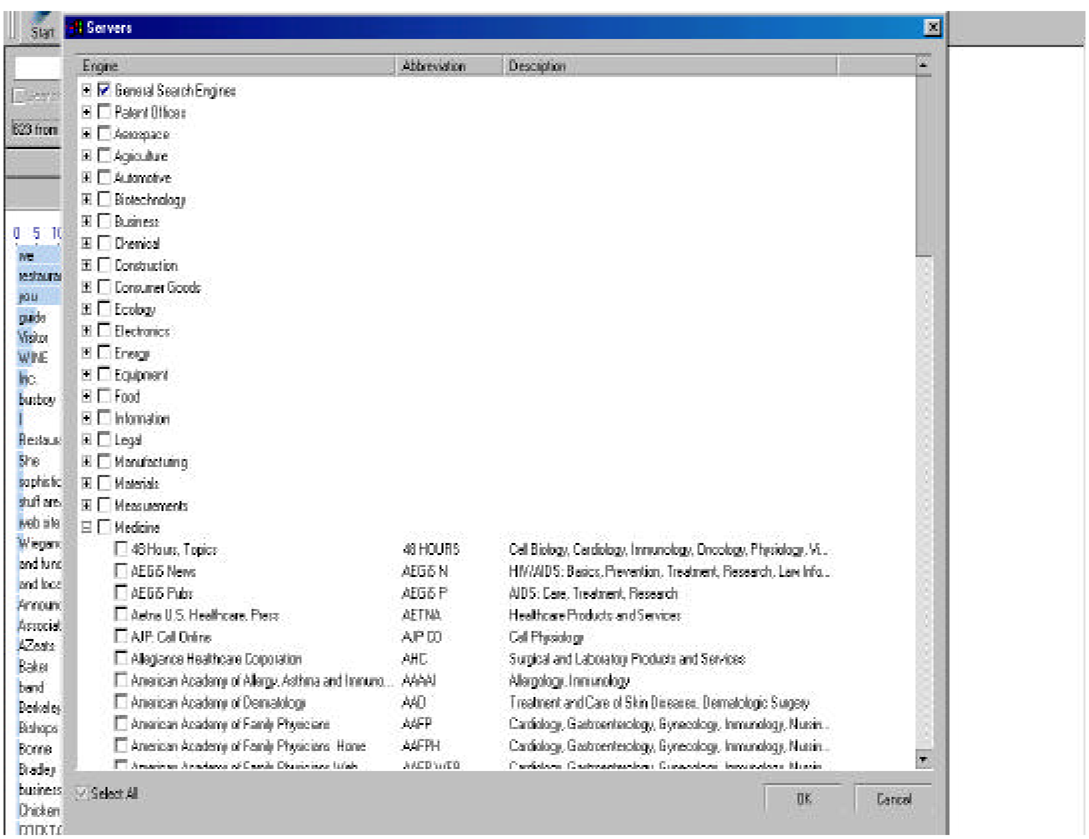
A constant challenge for every knowledge worker is to produce a precise query with syntax accepted by the search tool. One reason for this difficulty is that it is almost impossible to create a "perfect" query for any search without already having read the potential result. Another reason is that, even for a very precise search string tailored by an expert, no one can remember all possible synonyms and variants that the searched documents could contain.

IMC has developed a Natural Language query interface. This enables the user to put a question in a free text format, which would be the same format as if the question were given to another person. IMC is using NLP technology to interpret the user's question, extract and reformulates the main words into a query, and expand the query using synonym dictionaries. IMC has developed its own dictionaries for synonyms that currently contain several hundred thousand words.

2.Document Retrieval:

For knowledge workers doing research outside the company's document repository, the Web is today a natural source. Discussions about how big the Web is, are currently a popular debate. Nevertheless, two things are commonly accepted and recognized. First, the Web contains a gigantic collection of documents that is increasing every month. Second, with currently available public search engines one can only scratch the surface of it, unfortunately. As discussed in detail by other published documents, the "hidden" Web consists of database sites that must be accessed directly, using the sites selected query syntax, in order to return information.

IMC is using automated internal tools to identify, qualify and group Web sites by industry or field. Currently IMC products access over 700 sites to enable users to take advantage of the "hidden" Web. IMC adds more Web sites every month and expects to make available several thousand sites within a 12 months period.



Web server collection.

3.Knowledge Extraction Engine:

The task of bringing relevant knowledge from a large document collection to the user (or finding the needle in the haystack) can be reformulated as the contradiction: how to automatically make a very short summary of a document or sentence without leaving out important information. IMC is pioneering the knowledge retrieval community in recognizing that the *Subject-Action-Object* format is the shortest form for summarizing a sentence without losing its content or meaning.

One critical step in correctly extracting the meaning using the *Subject-Action-Object* format is being able to distinguish between the Subject and the Object. IMC has developed its own technology to achieve this step. Below are two example sentences. For each sentence two summaries have been created, with and without noun attributes enabled.

*"**ASPs** can **cut your technology expenses** because you won't need to upgrade hardware and software, integrate different software applications or worry that the software you purchase may become obsolete"*

- ⇨ Summary #1: ASPs – cut – expenses (subject – action – object)
- ⇨ Summary #2: ASPs – cut – *your technology* expenses

*"Intelligent homebuyers, lenders and real-estate professionals often use home **inspections** to **uncover** hidden **problems and** potential safety **issues** before the purchase in order to avoid unpleasant surprises after the fact."*

- ⇨ Summary #1: inspections – uncover – problems and issues
- ⇨ Summary #2: *home* inspections – uncover – *hidden* problems and *potential safety* issues

Example of summary extraction. Sentences from Wall Street Journal 08/12/00

4.Knowledge Organizer:

Given a large collection of sentence summaries (Subject-Action-Object), IMC has developed a process to create automatically a taxonomy structure or knowledge index to group similar type of knowledge for easy retrieval.

IMC is currently using two different methods in parallel to achieve the Knowledge Organization: main word extraction and synonym databases. Also, a manually created keyword or taxonomy list can be added if similar type of knowledge is repeatedly extracted.

Example of Knowledge Organization

Consider the implementation of Knowledge Organization, exemplified in the following five steps:

1. The **algorithm** is based on a notion of similarity assessment and was developed for **supporting flexible retrieval of relevant information**.
2. **Case-based indexing, matching, adaptation, and retrieval** must be **supported** by **both** the **database mechanisms and knowledge representation scheme**.
3. The **digital library** will **provide information preservation, storage, and retrieval**; information access and delivery via electronic communications; online publishing of the scholarly and scientific knowledge base or knowledge management; ...
4. **Modelling multimedia documents** to **support** an **effective content-based retrieval**.
5. **Retrieval of heterogeneous information** from large multimedia databases can be **supported** by a knowledge based system containing domain model, i.e., **fundamental notions and relations** between them.
6. Likewise, **fuzzy relational databases** generalize their classical and imprecise counterparts by **supporting fuzzy information storage and retrieval**.
7. **Retrieval of heterogeneous information** from large multimedia databases can be **supported** by a **knowledge based system containing domain** model, i.e., fundamental notions and relations between them.
8. The **Knowledge Management Process** has been designed to **provide fast information search and retrieval** to a large audience over a narrow bandwidth.
9. **Knowledge Navigators provides customized information search and retrieval** using advanced electronic databases and traditional library-based information sources.
10. **LaSSIE** helps programmers in searching useful information about a large software system and also **supports** the **retrieval of components** for reuse.
11. These tools depend on a **streamlined index of specified information stores** that **provide fast search and retrieval** speeds for one or more users across large volumes of data.
12. Amount and **type of knowledge** needed to **support navigation and retrieval**, .

Step 1: The source sentences found on the Web searching for "knowledge retrieval".

Above are 12 sample sentences randomly chosen from the WWW regarding knowledge retrieval. From these sentences the Knowledge Extraction engine has produced the summaries shown below.

1. algorithm - support - flexible retrieval of relevant information
2. both database mechanisms and knowledge representation scheme - support - Case-based indexing , matching , adaptation and retrieval
3. digital library - provide - information preservation , storage and retrieval
4. documenting Modelling multimedia - support - effective content-based retrieval
5. fundamental notions and relation - support - Retrieval of heterogeneous information
6. fuzzy relational database - support - fuzzy information storage and retrieval
7. knowledge based system containing domain - support - Retrieval of heterogeneous information
8. Knowledge Management Process - provide - fast information search and retrieval
9. Knowledge Navigator - provide - customized information search and retrieval
10. LaSSIE - support - retrieval of components
11. streamlined index of specified information stores - provide - fast search and retrieval
12. type of knowledge - support - navigation and retrieval

Step 2: Knowledge extraction from source sentences in Subject-Action-Object format.

The next step is to introduce knowledge organization. This can be done in several ways. In step 3, the "action-object" or "how to" is selected as the first level and the solution extracted from the text as the second level.

1	**provide**	**customized information search and retrieval**	
			Knowledge Navigator
2	**provide**	**fast information search and retrieval**	
			Knowledge Management Process
3	**provide**	**fast search and retrieval**	
			streamlined index of specified information stores
4	**provide**	**"information preservation , storage and retrieval"**	
			digital library
5	**support**	**"Case-based indexing , matching , adaptation and retrieval"**	
			both database mechanisms and knowledge representation scheme
6	**support**	**effective content-based retrieval**	
			documenting Modelling multimedia
7	**support**	**flexible retrieval of relevant information**	
			algorithm
8	**support**	**fuzzy information storage and retrieval**	
			fuzzy relational database
9	**support**	**navigation and retrieval**	
			type of knowledge
10	**support**	**retrieval of components**	
			LaSSIE
11	**support**	**Retrieval of heterogeneous information**	
			fundamental notions and relation
12	**support**	**Retrieval of heterogeneous information**	
			knowledge based system containing domain

Step 3: Extracted knowledge organized into two levels, “how to” and its solution.

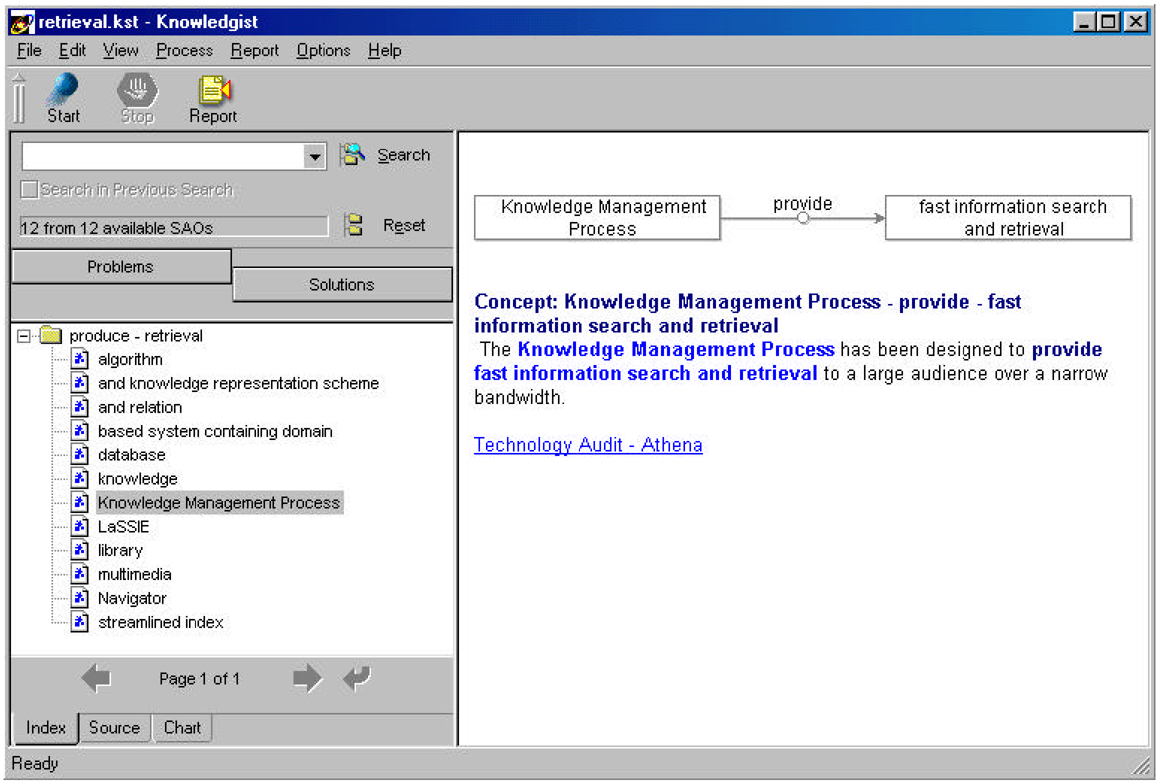
The 12 summary sentences shown above are now organized into two levels, the “how to” on the first level and corresponding solution on the second level.

The next step is to remove all attributes from the noun-phrases and re-sort. For example, the text string “*provide customized information search and retrieval*” is shortened to “*provide retrieval*”. See the result below, step 4.

1	**provide**	**retrieval**	
			Knowledge Navigator
			Knowledge Management Process
			streamlined index of specified information stores
			digital library
2	**support**	**retrieval**	
			both database mechanisms and knowledge representation scheme
			documenting Modelling multimedia
			algorithm
			fuzzy relational database
			type of knowledge
			LaSSIE
			fundamental notions and relation
			knowledge based system containing domain

Step 4: Noun phrase with attributes removed.

The last step in Knowledge Organization is the use of synonyms. If “provide” and “support” are accepted as synonyms, then all knowledge about “provide retrieval” can be neatly put into one place, automatically by the software.



Step 5: The result of example with Knowledge Organization.

Knowledge Index types:

The IMC technology enables production of a various number of knowledge indexes. It should be recognized that a knowledge index never can be better than the underlying documents from which it was created. Therefore, different types of indexes might be useful depending on the document source and type of knowledge. Two types of indexes will be discussed here:

1. Noun-Phrase Index
2. Subject-Action-Object Index

Noun-Phrase Index:

A noun-phrase is a noun together with all its attributes or descriptive words. Consider the noun-phrase *“a very attractive and affordable house*”. The noun “*house*” is the main word and “*a very attractive and affordable*” are the attributes. A Noun-Phrase Index organizes all noun-phrases based on the noun. Once the user has found an interesting noun, its attributes can be viewed to pinpoint interesting documents. For less structured documents or text, this index type has been found useful. Documents that contain incomplete sentences (picture text, tables, lists, indirect statements, text fragments, etc.) are here considered as less structured. A noun phrase index is object oriented and takes into account all descriptive words surrounding the object or main word. The Noun-Phrase Index does not capture the "cause and effect" relationship from the source sentence and thus is less informative than the Subject-Action-Object Index. But it has its main advantage in finding documents containing the key noun-phrase where the related information is hidden in the document, i.e., in a picture. Below is an example of a noun phrase index for the noun group "*foam*".

```
Foam NPs (15569)
    Foam (3265)
    Material (571)
        foam material (372)
            foam material (96)
            cell foam material (23)
                closed cell foam material (15)
                open cell foam material (8)
                    open cell foam material
                    open cell foam material
                    open cell foam material
                    open cell foam material
                    open cell foam material
                    open cell foam material
                    open cell foam material
                    open cell foam material
            polymeric foam material (23)
            absorbent foam material (15)
            plastic foam material (14)
            polyurethane foam material (10)
            ceramic foam material (7)
            polymer foam material (6)
            polyisocyanurate foam material (5)
            resilient foam material (5)
            …
        foamed material (23)
        plastic material (22)
        foaming material (10)
        …
    layer (554)
    …
```

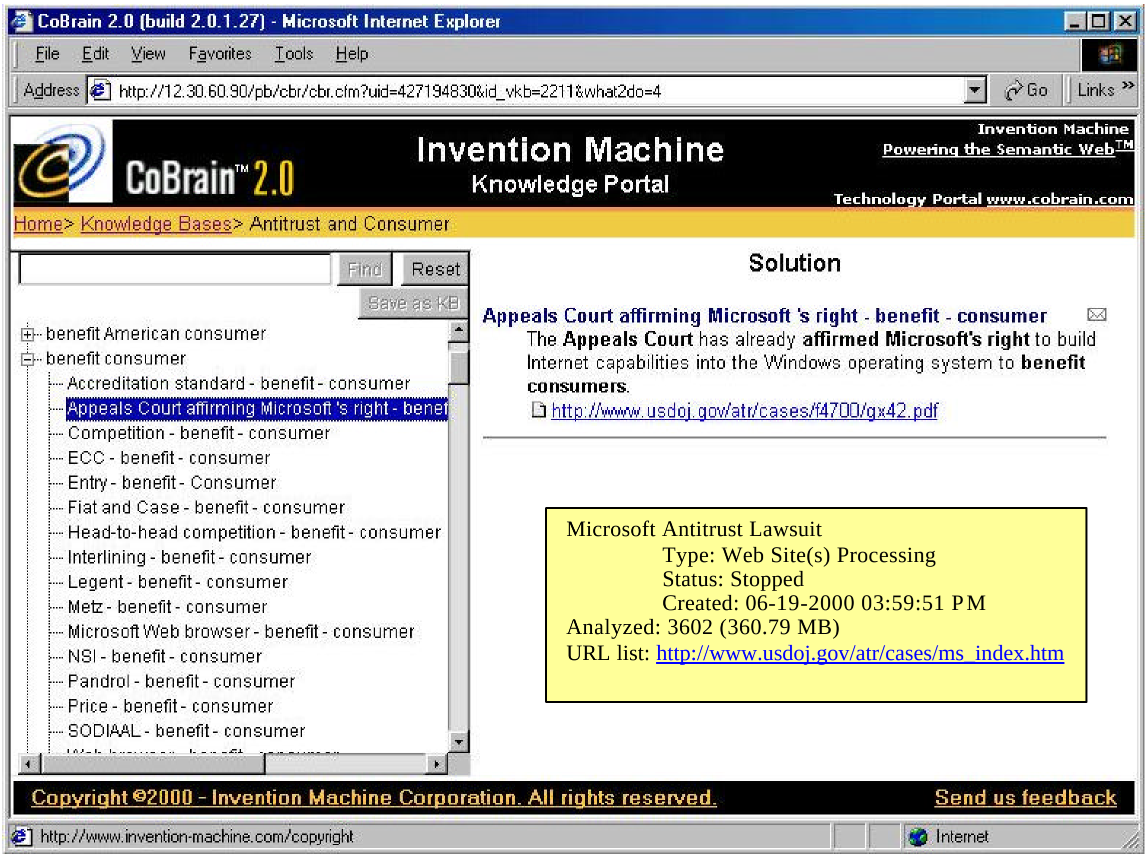
Example of a Noun Phrase Index

This index above consists of 15,569 *foam* references categorized by type. The index was 100% automatically generated. Each branch can be expanded or collapsed with a mouse-click. All *foam* references have a hyperlink to its source document.

Subject-Object-Action Index

For more structured document sources, an index that includes the cause and effect relationship can be used. As described earlier, the **Subject-Action-Object** format captures the cause and effect relationship and is the base for this index.

As an example, all documents describing the Microsoft lawsuit can be processed (about 400 MB of documents!) and the result organized in a Subject-Action-Object index. Thereafter effects of this lawsuit can be studied, for example: how it benefits or hurts consumers. See picture below.



Example of Subject-Action-Object Index.

Processing all documents regarding the Microsoft Antitrust lawsuit created the above index. The folder "benefit consumer" is selected above.

Conclusions

- IMC is proposing the use of Natural Language Processing (NLP) in order to improve the relevance and speed of knowledge retrieval. User-friendly queries can be effectively interpreted and processed. Relevant knowledge can be extracted from selected documents by virtually reading and understanding the contents automatically.

- IMC has advanced the NLP technology significantly by using innovative improvements, thus making it practical in extraction quality and speed.

- IMC is introducing a highly compact format for summarization of text without losing the intrinsic meaning. This paradigm shift enables Knowledge Retrieval on a completely new level.

- IMC is introducing a new concept for Knowledge Organization, which makes it possible to store and organize all similar and relevant knowledge into one place for fast and easy retrieval.

- IMC's Knowledge Retrieval technology is 100% automated. Implementation is simple and requires no manual tuning before use.

- IMC is constantly maintaining and adding new document sites from the WWW to its server list thereby enabling knowledge retrieval research to fully take advantage of the "hidden" Web.

About IMC

Invention Machine Corporation: Powering the Semantic Web™

We have started the semantic revolution - the next wave of advanced processing technology to conquer information overload. Our semantic technology offers a new paradigm for finding relevant information from any source. Whether you are searching your corporate repositories or the World Wide Web, our software understands the meanings of words and the relationships between concepts. Because we extract the content relevant to your work, we will change the way you use the Internet.

Founded in 1992, Invention Machine is a global company. Its headquarters are in Boston, Mass. with offices throughout the USA, and internationally in France, Germany, Italy, Japan, Sweden, and the United Kingdom.

Invention Machine empowers the world to innovate faster. We are the world's leading provider of knowledge-enabling software for the Internet that fundamentally accelerates technical innovation and propels company growth. Global corporations use Invention Machine's technology to automatically build knowledge bases and populate Internet portals and Web sites.

Product Lines

Natural Language Tools

CoBrain

Enterprise Knowledge Portal Builder

Knowledgist

Comprehensive Knowledge Mining Tool

Knowledge-Based Innovation

TechOptimizer

Innovation Acceleration Suite

Knowledge Portals

CoBrain.com

Technical Solutions Knowledge Portal

Wireless Access

WAP and Palm Interfaces

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