

Toward a better Web Information Retrieval System

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Goal: With the fast growth of the Internet, more and more information is available on the Web and as a result, Web Information Retrieval (IR) has become a fact of life for most Internet users. However, compared with classic information retrieval, web information retrieval systems are faced with totally different datasets (bulk documents, dynamism of the Internet, duplication, heterogeneity, high linkage, ill-formed queries, etc...). It is estimated that nearly 85% users only look at the first screen of the returned results from search engines. 78% users never modify their very first query. So the big challenge to the Web information retrieval is to meet the users information needs given the uniqueness of Web. The performance of an IR system is evaluated along three lines: recall (the percentage of relevant pages that are returned), precision (the percentage of pages retrieved that are relevant) and precision at top 10 result pages. In Web IR, the quality of pages varies widely and thus just being relevant is not enough.

The goal of an efficient Web Information Retrieval system is to return both high-relevance and high-quality (valuable) pages.

There are a few studies in IR literature that use Genetic Algorithms (GAs). The main idea of the proposed research is to exploit the power and speed of GAs to try to solve one or more of the problems and challenges of a Web IR system, such as: ontology document mapping, query representation, matching user requirements (queries) with document representations, and the synthesis of user's profile. A parallel direction of research to be investigated is the possibility to exploit the newly developed concepts of Interactive GAs and KeyGraphs in text document retrieval and Chance Discovery.

1. Basic Information Retrieval System

A document based IR system typically consists of three main subsystems:

- **document retrieval and representation**
- **representation of users' requirements (queries)**
- **the algorithms used to match user requirements (queries) with document representations**

A document retrieval engine (also called crawler, spider or robot) collects documents by recursively fetching links from a set of starting pages. Each crawler has different policies with respect to which links are followed, how deeply sites are explored, etc.

A document collection consists of many documents containing information about various subjects or topics of interests. Document contents are transformed into a document representation (either manually or automatically). Document representations are done in a way such that matching these with queries is easy.

Another consideration in document representation is that such a representation should correctly reflect the author's intention. The primary concern in representation is how to select proper index terms. Typically representation proceeds by extracting keywords that are considered as content identifiers and organizing them into a given format.

Domain specific text characteristics:

- Vocabulary set is limited
- Word usage has patterns
- Semantic ambiguities are rare
- Terms and jargon of the domain appear frequently

These characteristics allow us to build ontologies and use machine learning algorithms to extract knowledge.

There are some basic **IR Paradigms**.

- **Probabilistic IR:** Probabilistic retrieval is based on estimating a probability of relevance of a document to the user for the given user query. Typically relevance feedback from a few documents is used to establish the probability of relevance for other documents in the collection. There are three different learning strategies used in probabilistic retrieval. Estimation of probabilities of relevance is done for a set of sample documents, or a set of sample queries and extended to all the documents or queries. Inference networks use a document and query network that capture probabilistic dependencies among the nodes in the network.

- ***Knowledge based IR***: This approach focuses on modeling two areas. First, it tries to model the knowledge of an expert retriever in terms of the expert's domain knowledge, that is, his or her search strategies and feedback heuristics. An example of such an approach is the Unified Medical Language System. Another area that has been modeled is the user of the system. This typically follows the way the librarian develops a client profile. Although knowledge based approaches might be effective in certain domains, it may not be applicable in all domains.
- ***Learning systems based IR***: This approach is based on algorithmic extraction of knowledge or identifying patterns in the data. There are three broad areas within this approach: Symbolic learning, Neural networks and Evolution based algorithms.

Knowledge extraction is a form of text processing that locates a set of relevant items in a natural-language document. Evolutionary algorithms are based on the Darwinian principles of natural selection. These algorithms can be further divided into: GA's, evolutionary strategies, and evolutionary programming. While evolutionary programming utilizes changes at the level of species, the evolutionary strategies exploit changes at individual behavioral level. GAs are based on genetic operators of selection, crossover, and mutation. There are a few studies in IR literature that use GAs. Also, parallel GAs tend to be widely used.

2. Functionalities lacking in traditional engines

- ***filtering***: A user looking for some topic on Internet retrieves too much information.
- ***ranking of retrieved documents***: The system provides no qualitative distinction among the documents.
- ***support of relevance feedback***: The user cannot tell his subjective evaluation of the relevance of the document.
- ***personalization***: There is a need of personal systems that serve the specific interest of the users and build users' profiles.
- ***adaptation***: The system should notice when the user changes his/her interests.

3. Research directions

3.1. Ontology document mapping

The ontological approach used in the treatment of rough information enables a knowledge detection machine to generate domain relevant knowledge organized in XML format. Machine learning algorithms were applied for this purpose by systems like RAPIER, WHISK and HMM, complemented with text processing techniques (like part of speech tagging, text segmentation, noun phrase identification, etc...).

Knowledge extraction module:

- rule based machine learning algorithm
 - RAPIER(Mary Elaine Califf 1997)
 - WHISK(Stephen Soderland 1999)
- Statistical
 - HMM(Hidden Markov Model)

One possible direction of research is to use knowledge extraction based on genetic algorithm to develop ontology based XML knowledge management system that will exploit advanced knowledge discovery techniques and will process text documents residing on Internet, databases, or private document repositories. One possible ontology representation to meet this goal may be RDFS (Resource Description Framework Schema).

3.2. Query representation

Queries transform the user's information need into a form that correctly represents the user's underlying information requirement and is suitable for the matching process. Query formatting depends on the underlying model of retrieval used: Boolean models, vector space models, probabilistic models, fuzzy retrieval models, models based on artificial intelligence techniques and models including GAs [P. Pathak, M. D. Gordon and W. Fan, 2000].

Previous attempts at using GAs have concentrated on modifying document representations or modifying query representations. One possible direction of research is of applying GAs to adapt various matching functions. Such an adaptation of the matching functions may lead to a better retrieval performance than that obtained by using a single matching function. An overall matching function may be treated as a weighted combination of scores produced by individual matching functions. This overall score may be used to rank and retrieve documents. Weights associated with individual functions may be searched using Genetic Algorithm.

3.3. Matching user requirements with document representations

A matching algorithm matches a user's requests (in terms of queries) with the document representations and retrieves documents that are most likely to be relevant to the user.

A matching algorithm addresses two issues:

- How to decide how well documents match a user's information request. Blair & Maron [1985] showed that it is very difficult for users to predict the exact words or phrases used by authors in desired documents. Hence if a document term does not match search terms then a relevant document may not be retrieved.
- Another issue involved in matching is how to decide the order in which the documents are to be shown to the user. Typically the matching algorithms calculate a matching number for each document and retrieve the documents in the decreasing order of this number.

Both problems may be attacked, presumably, by using genetic algorithms, namely to synthesize new words and/or phrases to perform the search and to select the right order of presenting retrieved documents to the user.

3.4. User's profile

Each web user varies widely in their needs, expectations and knowledge. For best results in web information retrieval, we have to focus on a system with the ability to dynamically adapt to its users. In particular, one possible direction of research is to consider methods for automatically improving the systems recommendation policy on the basis of feedback from the users.

Genetic Algorithms seem to be a good candidate for developing such a method. Interactive Genetic Algorithms (IGA), as the ones presented in [F. C. Hsu, J. S. Chen and P. Chen, 2000] are particularly well suited for such an approach. An IGA is a GA except that fitness function is replaced by human evaluation. A specific feature of the IGA is intended to combine the global search ability of GAs and the evaluation capabilities of humans. Interactive GAs have been used to solve problems that cannot be easily solved by GAs, such as design or art.

3.5. Miscellaneous features

Some other challenges in information retrieval that may be investigated during the research are:

3.5.1. Locating the information

- *conceptual search* feature, a revolutionary way of identifying documents by the meaning of the words they contain (ex. search for “ships” and find a document which contains “Titanic”)
- *query disambiguation* feature allows the user to chose an unequivocal meaning for the words in his query (ex. search for “windows” the system will ask to chose between:
 - windows as: open spaces in the wall of a building
 - windows as: an operating system)
- *query increased generality* feature offers the possibility of increasing the power of the conceptual search by finding concepts that are “kind of” the searched concept (ex. search for “pets” and find a document which contains “Tom” which is a “cat” - a kind of “pet”)

3.5.2. Efficient reporting

- **organize the hit list** feature can be used for structuring the hit list in order to speed up the access to the most interesting documents. The result is a tree of documents (a topic map) instead of the simple list.
- **highlighting** feature is used for marking found instances and most relevant paragraphs (with respect to the query).
- **results presentation**
 - simple ranked list
 - tree
 - grouped by domains
 - grouped by derived concepts (in case of ontological subtree search)

3.5.3. Other features

- **document filtering**
- **document categorization**
- **document and knowledge statistics**
- **knowledge processing**

4. KeyGraphs and Chance Discovery

Chance Discovery - *discovering chances*

Chance Discovery (CD) means discovering chances - the breaking points in systems, the marketing windows in business, etc. Despite its infancy as a research field, chance discovery has already attracted considerable interest from researchers of various disciplines, including web-related research, finance, and simulation of natural disasters. It involves determining the significance of some piece of information about an event and then using this new knowledge in decision making. The techniques already developed combine data mining methods for finding rare but important events with knowledge management, group-ware and social psychology. May be used for finding information on the Internet, recognizing changes in customer behavior, detecting the first signs of an imminent earthquake, etc.

Chance discovery is mainly motivated from the practical, application-oriented side. However, this field also gives rise to a series of more foundational questions, which seem highly interesting from a methodological view of science.

KeyGraph - *a keyword extraction method*

KeyGraph, originally an algorithm for extracting terms (words or phrases), expresses assertions based on the co-occurrence graph of terms from textual data. The strategy of KeyGraph comes from considering that a document is constructed like a building for expressing new ideas based on traditional concepts.

KeyGraph is a fast method for extracting keywords representing the asserted core idea in a document. KeyGraph composes clusters of terms, based on co-occurrences between terms in a document. Each cluster represents a concept on which the document is based and terms connecting clusters tightly are obtained as author's assertion.

The KeyGraph procedure is a graphical method for data mining originally developed for indexing a document [Y. Ohsawa, N. E. Benson and M. Yachida, 1998] and recently utilized for chance discovery [Y. Ohsawa, 2001, 2002] including discovery of risky active faults of earthquakes [Y. Ohsawa and M. Yachida, 1999]. Like other text and data mining algorithms, KeyGraph identifies relationships between terms and term clusters in a document. In particular, KeyGraph focuses on co-occurrence relationships, but one thing that sets KeyGraph apart is its emphasis on both high and low probability events.

Glossary

1. **Categorization:** attributing a domain/sub domain to a document
2. **Concept:** an abstract or general idea inferred or derived from specific instances; a class or a category
3. **Conceptual Marked Text:** usually an XML document containing text in which words are identified as concepts or instances; storing links to a specific ontology does this
4. **Conceptual Search:** a method of finding documents containing specific concepts rather than key words
5. **Dictionary:** a list of words stored in machine-readable form, with information given for each word, usually including meaning and POS
6. **Document:** any kind of machine-readable data having a structural or semantic coherence; a source of information
7. **Domain:** a sphere of activity or interest; a field
8. **Free Text:** a piece a text with no topological structure
9. **Genetic Algorithms (GAs):** adaptive methods for solving different problems of searching and optimization. They are based on natural, genetic rules and the process of evolution
10. **Information:** a collection of facts from which conclusions may be drawn; the content of a document
11. **Information Extraction:** a process that takes texts and produces fixed-format, unambiguous data as output
12. **Information Repository:** a collection of documents organized in a manner that facilitates information retrieval
13. **Information Retrieval (IR):** a process that recovers from a collection a subset of documents which are relevant to a query
14. **Instance:** a concrete representation of a concept; an individual object of a certain class
15. **Interactive Genetic Algorithm (IGA):** a GA except that fitness function is replaced by human evaluation
16. **KeyGraph:** a fast method for extracting keywords representing the asserted core idea in a document
17. **Knowledge:** Information represented in machine-understandable format (frames, rules, etc.)
18. **Knowledge Base (KB):** A collection of knowledge, represented using some knowledge representation language
19. **Knowledge Discovery (KD):** nontrivial extraction of implicit, previously unknown, and potentially useful information from data (Frawley 1992); the process of identifying valid, novel, potentially useful, and ultimately understandable patterns/models in data
20. **Knowledge Management:** the collection of processes that govern the creation, dissemination, and utilization of knowledge; newly emerging, interdisciplinary business model dealing with all aspects of knowledge within the context of the firm, including knowledge creation, codification, sharing, and how these activities promote learning and innovation
21. **Knowledge Engineering:** the process of building an expert system, usually consists of three phases: Knowledge Acquisition, Knowledge Elicitation, Knowledge Representation
22. **Machine learning algorithm:** an algorithm that automatically improve its performance with past experiences
23. **Natural Language Processing:** is the engineering of systems that process or analyze written or spoken natural language
24. **Natural Language:** language used in a natural way (the way humans use it when they interact between them)
25. **Ontology:** a description (a formal specification) of the concepts and relationships that exist in specific domain
26. **POS (Part of Speech) tagging:** the process of marking the words in a text specifying the part of speech they represent (nouns, verbs etc.)
27. **RDF/RDFS:** Resource Description Framework / Resource Description Framework Schema; an XML based language here used for describing ontologies
28. **Recommender Systems:** systems developed to adapt web sites gradually to their users. The task of a recommender is to make it easier for the users of a web site to obtain information.
29. **Semantic:** meaning; the sense we give to a word
30. **Structured Document:** a document having a well defined internal structure (ex: a XML document, the result of a database query)
31. **Structured Text:** a piece of text having a rigid topological structure (ex. a table)
32. **Text:** words treated as data by a computer
33. **Unstructured Document:** a document with no relevant internal structure

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