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Naam et al.

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(54) **MACHINE DIRECTED IMPROVEMENT OF RANKING ALGORITHMS**

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G06F 17/30 (2006.01)
G06F 7/00 (2006.01)

(52) **U.S. Cl.** **707/7**; 707/2; 707/6

(58) **Field of Classification Search** 707/1-7, 707/10, 100, 102, 104.1; 706/13, 19, 21, 706/25; 709/223, 224, 225
See application file for complete search history.

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(57) **ABSTRACT**

Improving ranking algorithms for information retrieval. The ranking algorithms operate on search results obtained from a search engine. Input information including information describing a first ranking algorithm, a first score associated with the first ranking algorithm, a second ranking algorithm, a second score associated with the second ranking algorithm, and causal information relating a difference between the first ranking algorithm and the second ranking algorithm with a difference between the first score and the second score is received. An optimizing algorithm is applied to the received input information to identify an optimal ranking algorithm having an optimal score. The optimal ranking algorithm is defined by a plurality of parameters and a plurality of weights associated with the plurality of parameters.

17 Claims, 6 Drawing Sheets

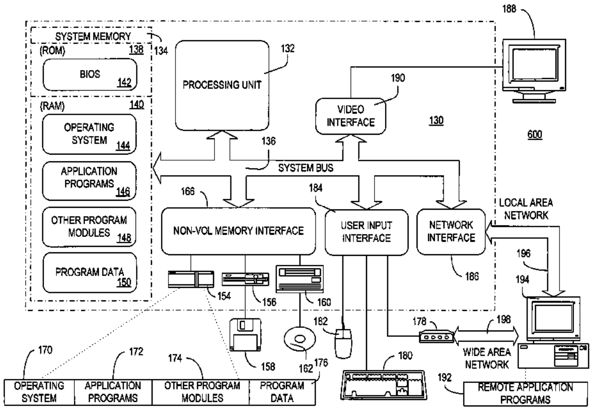

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FIG. 1

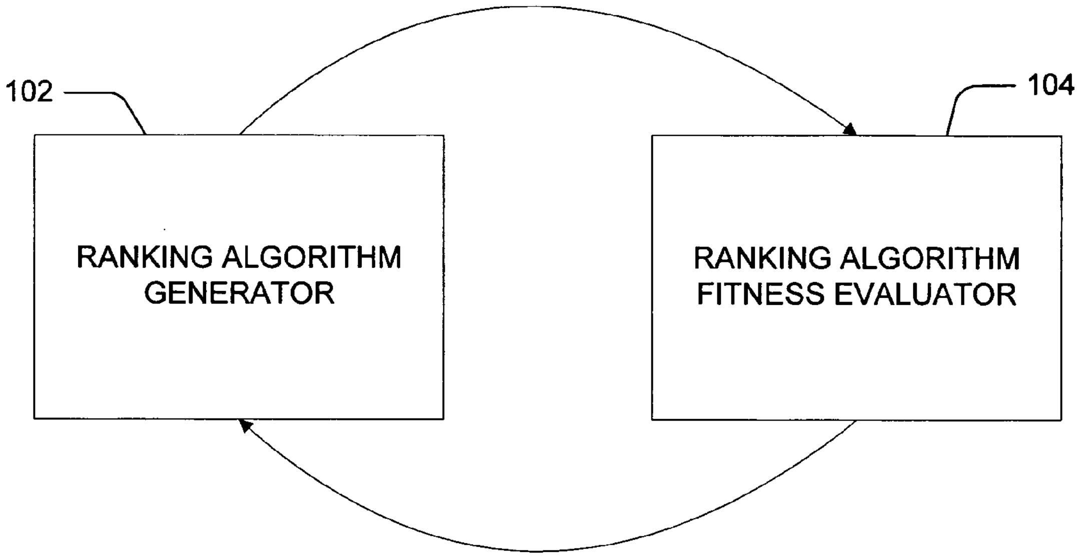

102
RANKING ALGORITHM GENERATOR
104
RANKING ALGORITHM FITNESS EVALUATOR

FIG. 2

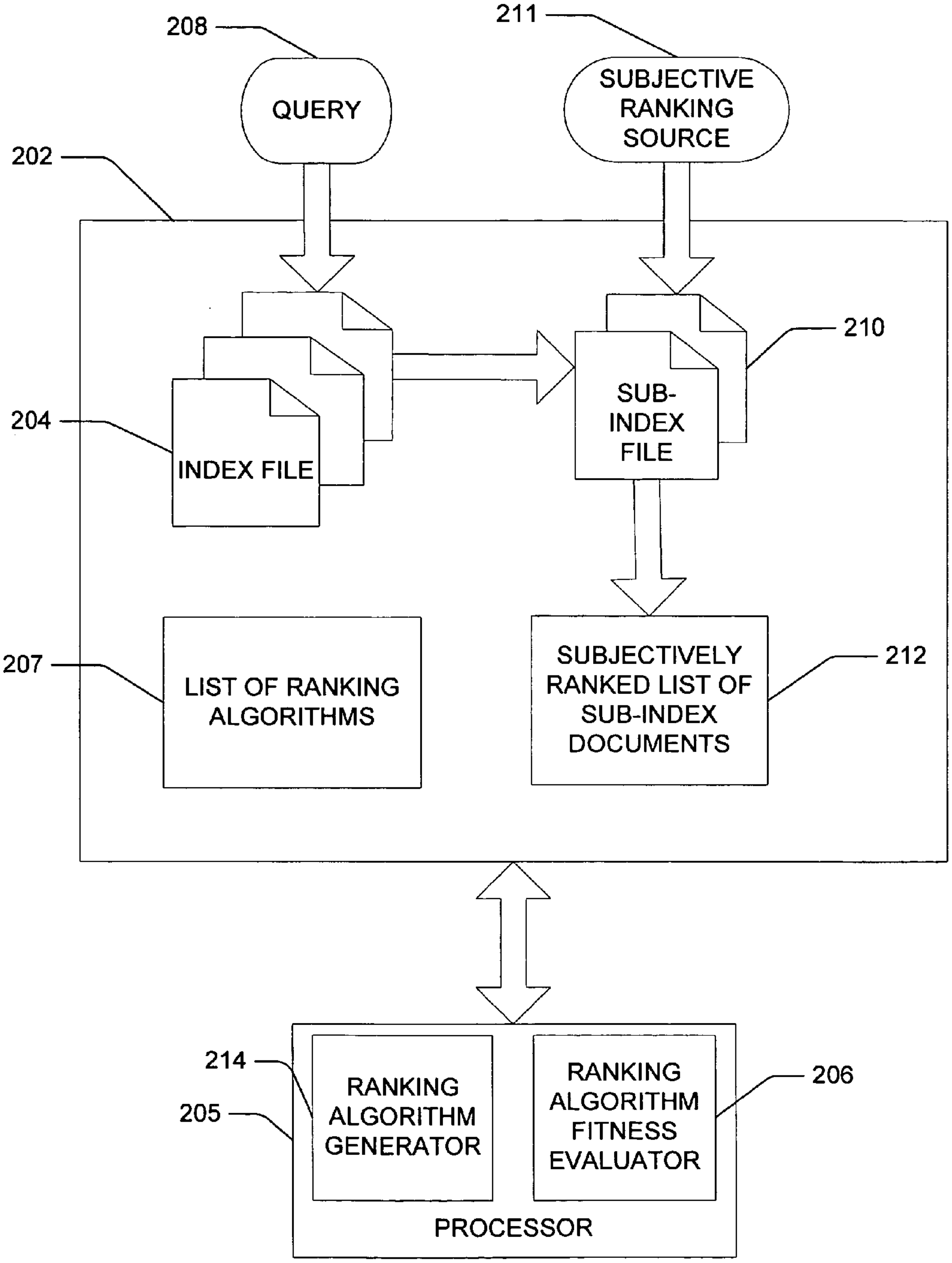

208
QUERY
211
SUBJECTIVE RANKING SOURCE
202
210
204
INDEX FILE
SUB-INDEX FILE
207
LIST OF RANKING ALGORITHMS
SUBJECTIVELY RANKED LIST OF SUB-INDEX DOCUMENTS
212
214
205
RANKING ALGORITHM GENERATOR
RANKING ALGORITHM FITNESS EVALUATOR
206
PROCESSOR

FIG. 3

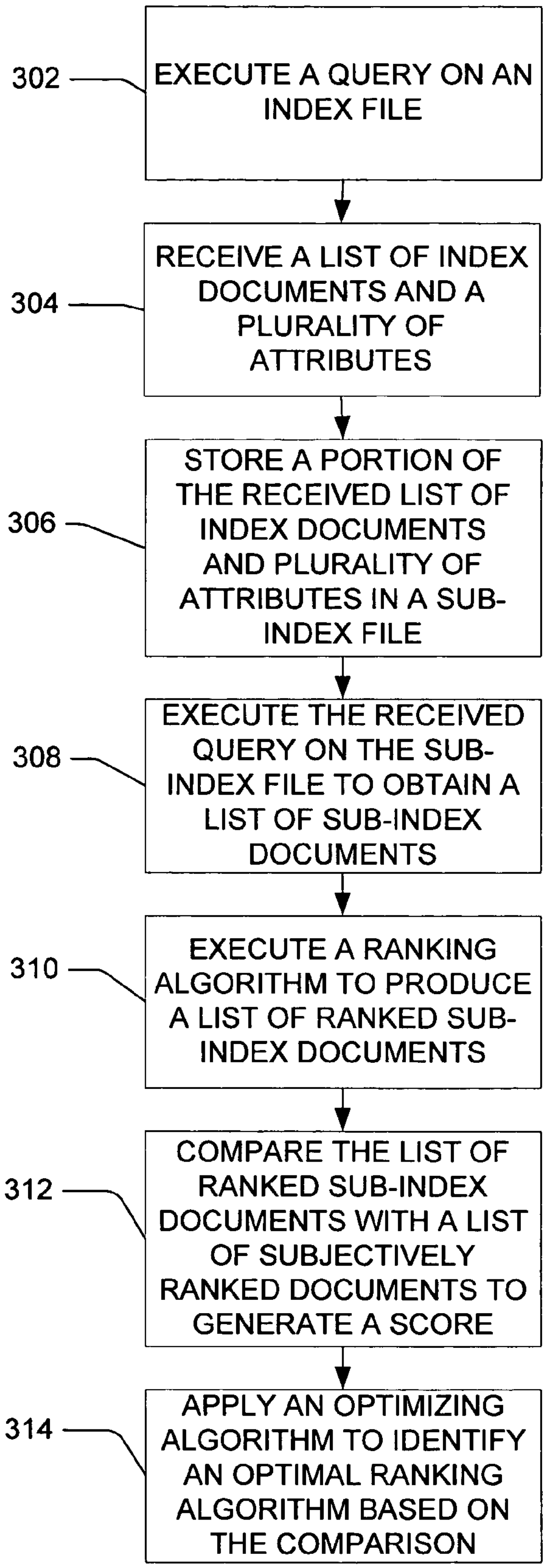

302
EXECUTE A QUERY ON AN INDEX FILE
304
RECEIVE A LIST OF INDEX DOCUMENTS AND A PLURALITY OF ATTRIBUTES
306
STORE A PORTION OF THE RECEIVED LIST OF INDEX DOCUMENTS AND PLURALITY OF ATTRIBUTES IN A SUB-INDEX FILE
308
EXECUTE THE RECEIVED QUERY ON THE SUB-INDEX FILE TO OBTAIN A LIST OF SUB-INDEX DOCUMENTS
310
EXECUTE A RANKING ALGORITHM TO PRODUCE A LIST OF RANKED SUB-INDEX DOCUMENTS
312
COMPARE THE LIST OF RANKED SUB-INDEX DOCUMENTS WITH A LIST OF SUBJECTIVELY RANKED DOCUMENTS TO GENERATE A SCORE
314
APPLY AN OPTIMIZING ALGORITHM TO IDENTIFY AN OPTIMAL RANKING ALGORITHM BASED ON THE COMPARISON

FIG. 4

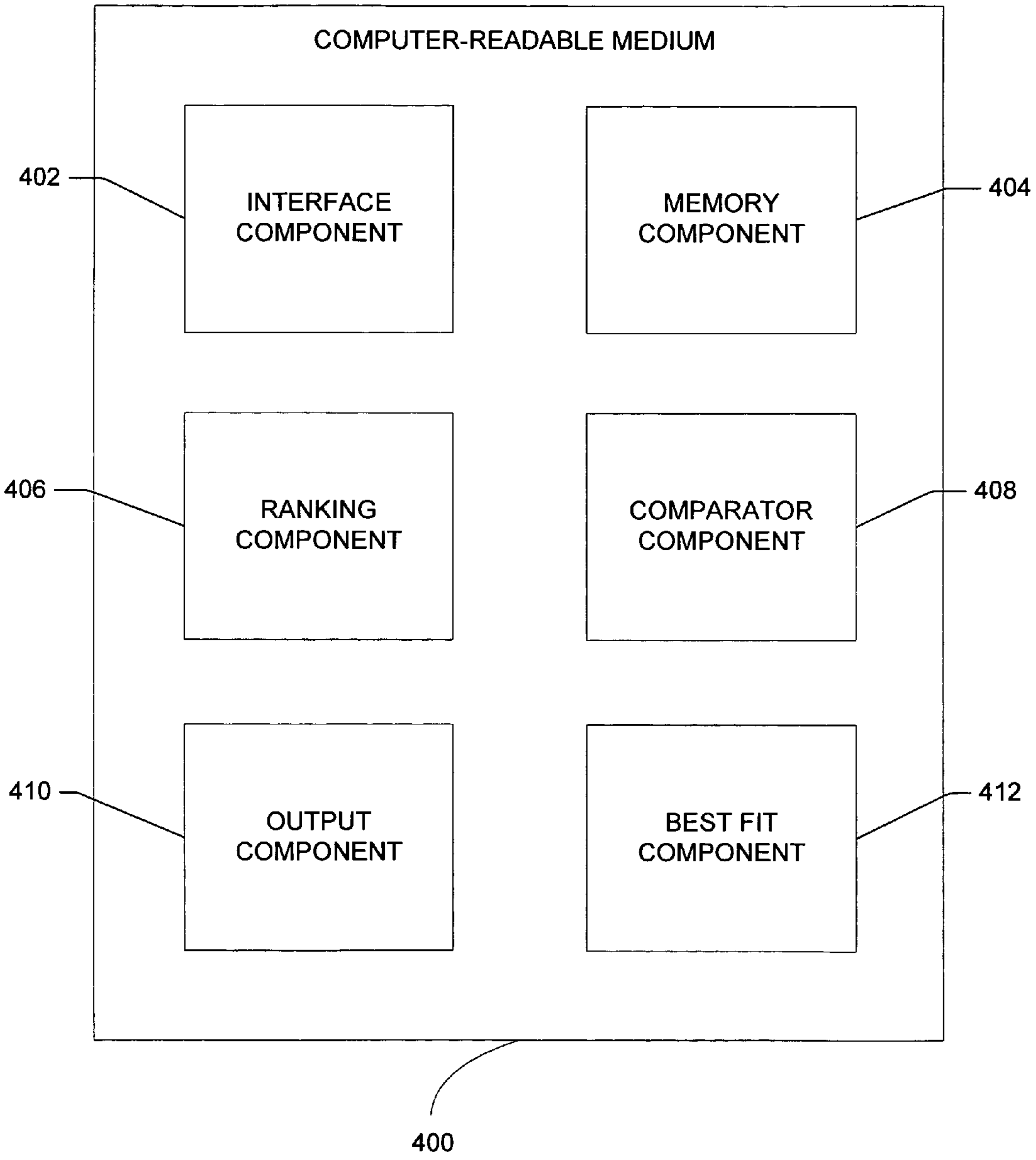

COMPUTER-READABLE MEDIUM
402
INTERFACE COMPONENT
MEMORY COMPONENT
404
406
RANKING COMPONENT
COMPARATOR COMPONENT
408
410
OUTPUT COMPONENT
BEST FIT COMPONENT
412
400

FIG. 5

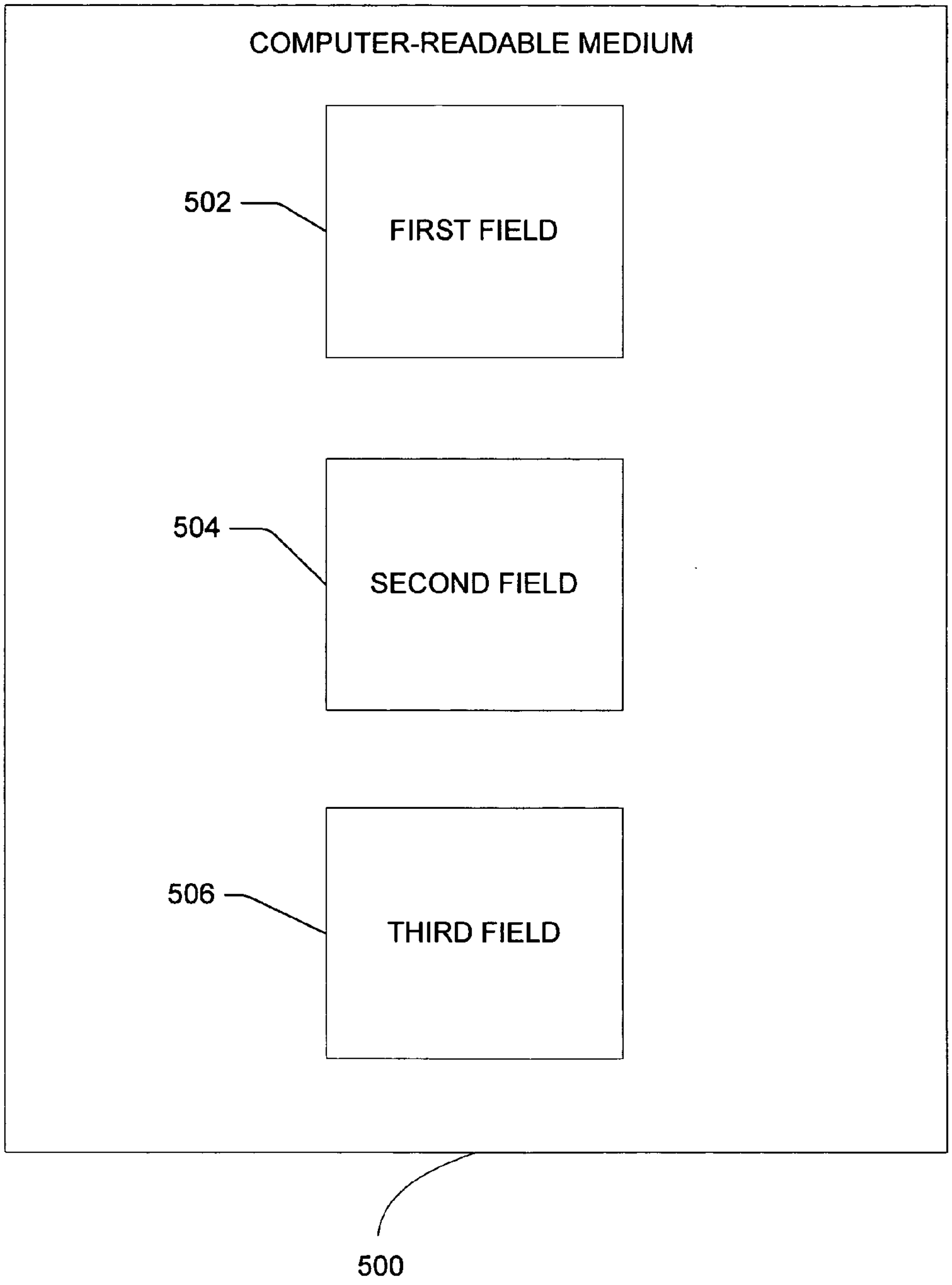
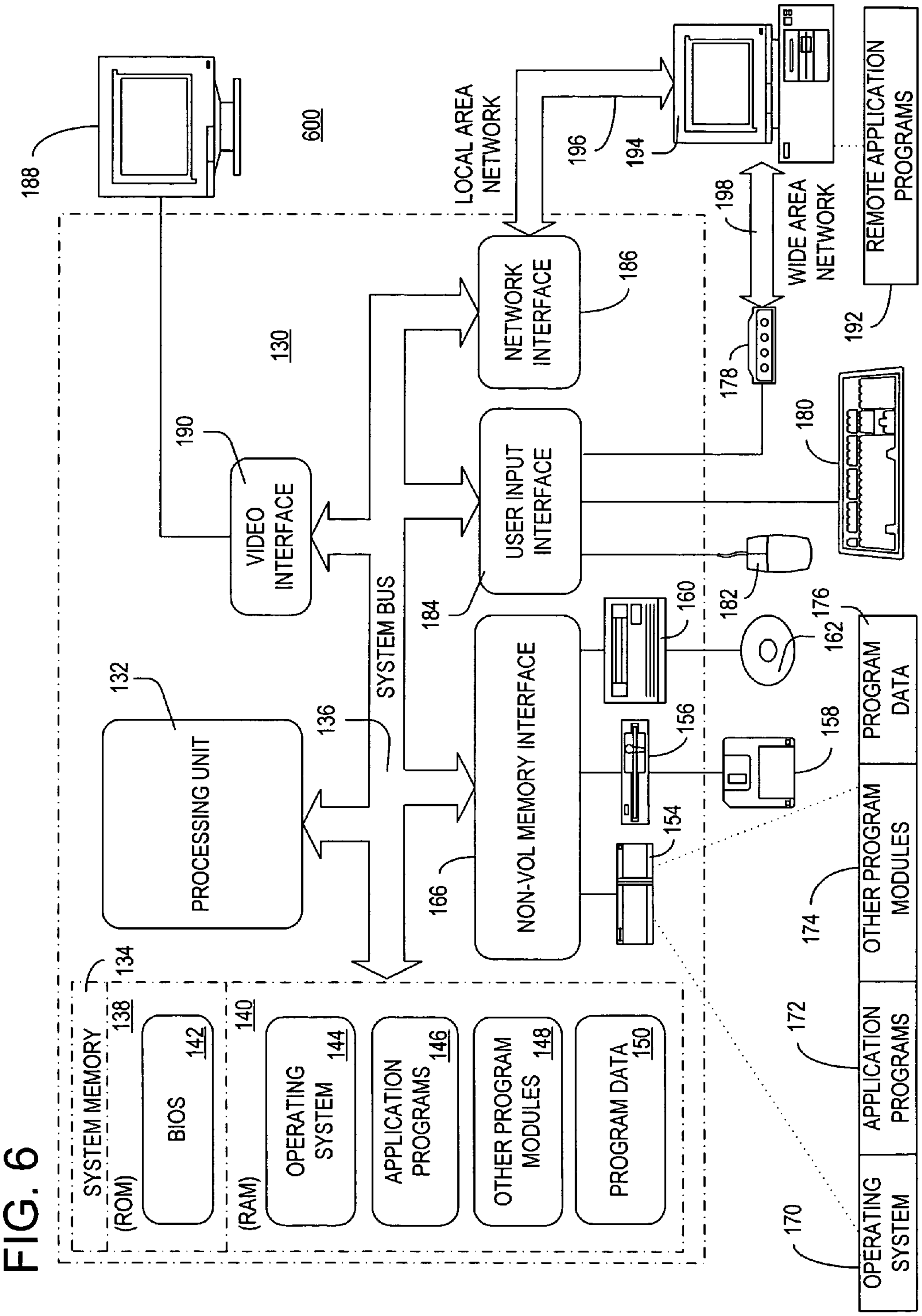

COMPUTER-READABLE MEDIUM
502
FIRST FIELD
504
SECOND FIELD
506
THIRD FIELD
500

FIG. 6


600
130
SYSTEM MEMORY
134
(ROM)
138
BIOS
142
(RAM)
140
OPERATING SYSTEM
144
APPLICATION PROGRAMS
146
OTHER PROGRAM MODULES
148
PROGRAM DATA
150
PROCESSING UNIT
132
136
SYSTEM BUS
NON-VOL MEMORY INTERFACE
166
USER INPUT INTERFACE
184
VIDEO INTERFACE
190
NETWORK INTERFACE
186
188
154
156
158
160
162
182
180
178
OPERATING SYSTEM
170
APPLICATION PROGRAMS
172
OTHER PROGRAM MODULES
174
PROGRAM DATA
176
LOCAL AREA NETWORK
196
194
WIDE AREA NETWORK
198
REMOTE APPLICATION PROGRAMS
192

MACHINE DIRECTED IMPROVEMENT OF RANKING ALGORITHMS

TECHNICAL FIELD

Embodiments of the present invention relate to the field of information retrieval. In particular, embodiments of the invention relate to evaluating information retrieval ranking algorithms and improving ranking algorithms for information retrieval.

BACKGROUND OF THE INVENTION

The Internet has vast amounts of information distributed over a multitude of computers, hence providing users with large amounts of information on various topics. This is also true for a number of other communication networks, such as intranets and extranets. Although large amounts of information may be available on a network, finding the desired information can be difficult.

Search engines have been developed to address the problem of finding desired information on a network. Typically, a user who has an idea of the type of information desired enters one or more search terms to a search engine. The search engine then returns a list of network locations (e.g., uniform resource locators (URLs)) that the search engine has determined to include an electronic document relating to the user-specified search terms. Many search engines also provide a relevance ranking. A typical relevance ranking is a relative estimate of the likelihood that an electronic document at a given network location is related to the user-specified search terms in comparison to other electronic documents. For example, a conventional search engine may provide a relevance ranking based on the number of times a particular search term appears in an electronic document, its placement in the electronic document (e.g., a term appearing in the title is often deemed more important than the term appearing at the end of the electronic document). In addition, link analysis has also become a powerful technique in ranking web pages and other hyperlinked documents. Anchor-text analysis, web page structure analysis, the use of a key term listing, and the URL text are other techniques used to provide a relevance ranking.

Many search engines employ various ranking algorithms to produce such a relevance ranking reflecting the relative importance of the different electronic documents resulting from a search query. The ability of current ranking algorithms to produce an accurate relevance ranking depends on numerous, tunable dimensions or other parameters (e.g., 200 or more). Thus, a technique to identify an optimal ranking algorithm that has optimal dimensions or parameters for producing an accurate relevance ranking is desired.

In some existing systems and methods, human intuition is used to tune the parameters of a given ranking algorithm in an attempt to produce a relevance ranking that is correlated to a human-judged ranking of electronic documents. However, human intuition fails to identify an optimal ranking algorithm with optimal parameters efficiently, reliably, and effectively.

In some fields of computer science, "best fit" or "minima/maxima seeking" algorithms are used to solve various problems. A technique that applies these algorithms to explore a multi-dimensional space of parameters associated with a ranking algorithm is generally desired. However, a given ranking algorithm may have an order of 50 to 100 parameters. If each parameter has 10 possible values, there will be 10ˆ50 to 10ˆ100 possible combinations of parameters for the given ranking algorithm. This large space of combinations renders searching of an optimal set of parameters difficult. Moreover, because of the potentially billions of electronic documents located on a network, executing an optimizing algorithm on these billions of electronic documents to identify an optimal ranking algorithm is time consuming. In other words, searching a large index of electronic documents to identify an optimal ranking algorithm having a set of optimal parameters is impractical.

In existing frameworks for identifying an optimal ranking algorithm, the optimizing algorithm utilized to identify the optimal ranking algorithm is usually "hard-coded" in the frameworks. As a result, changes to the optimizing algorithm in such frameworks usually require code-level changes, which are then distributed to other machines if the index of electronic documents is spread across multiple machines. Therefore, a framework that provides interchangeable optimizing algorithms is desired such that an optimizing algorithm may be easily upgraded or substituted.

Accordingly, a solution that effectively evaluates information retrieval ranking algorithms and improves ranking algorithms for information retrieval is desired.

SUMMARY OF THE INVENTION

Embodiments of the invention overcome one or more deficiencies in the prior art by providing, among other things, evaluation and improvement of information retrieval ranking algorithms. In particular, embodiments of the invention provide a framework for identifying an optimal ranking algorithm that accurately ranks tens of billions of electronic documents. According to one or more embodiments of the invention, a subindex storing relevant attributes of electronic documents is generated as a function of a search query to facilitate the process of identifying an optimal ranking algorithm. In particular, an embodiment of the invention rates various ranking algorithms by applying the search query to the subindex to produce search results, iteratively applying the ranking algorithms to the search results to produce ranked query results, and comparing the ranked query results with human judgments to produce the rating.

According to one embodiment, the invention employs an optimizing algorithm to explore a parameter space of a set of predefined ranking algorithms, including the ratings associated with each of the ranking algorithms, to identify an optimal ranking algorithm and a set of optimal parameters associated with the optimal ranking algorithm. In particular, the framework receives a large number of parameter permutations (e.g., tens to hundreds of millions of parameters resulting in trillions of permutations) and determines a set of optimal parameters. Embodiments of the invention also allow interchangeability of the optimizing algorithm such that other optimizing algorithms may be added to the framework with minimal effort.

Thus, embodiments of the invention result in an efficient system and method for identifying an optimal ranking algorithm and the associated optimal parameters.

In accordance with one aspect of the invention, a method improves ranking algorithms for information retrieval. The ranking algorithms operate on query results obtained from a search engine. The method includes receiving input information including information describing a first ranking algorithm for ranking a list of search results, a first score associated with the first ranking algorithm, a second ranking algorithm for ranking the list of search results, a second score associated with the second ranking algorithm, and causal information relating a difference between the first ranking algorithm and the second ranking algorithm with a difference between the first score and the second score. The first score represents a comparison of output of the first ranking algorithm and a subjective ranking of the list of search results. The second score represents a comparison of output of the second ranking algorithm and the subjective ranking of the list of search results. The method also includes applying an optimizing algorithm to the received input information to identify an optimal ranking algorithm having an optimal score. The optimal ranking algorithm is defined by a plurality of parameters and a plurality of weights associated with the plurality of parameters.

In accordance with another aspect of the invention, one or more computer-readable media have computer-executable instructions for improving ranking algorithms for information retrieval. The ranking algorithms operate on query results obtained from a search engine. The components include an interface component for receiving input information including information describing a first ranking algorithm for ranking a list of search results, a first score associated with the first ranking algorithm, a second ranking algorithm for ranking the list of search results, a second score associated with the second ranking algorithm, and causal information relating a difference between the first ranking algorithm and the second ranking algorithm with a difference between the first score and the second score. The first score represents a comparison of output of the first ranking algorithm and a subjective ranking of the list of search results. The second score represents a comparison of output of the second ranking algorithm and the subjective ranking of the list of search results. The components also include a best fit component for applying an optimizing algorithm to the received input information to identify an optimal ranking algorithm having an optimal score. The optimal ranking algorithm is defined by a plurality of parameters and a plurality of weights associated with the plurality of parameters. The optimizing algorithm is interchangeable with another optimizing algorithm without recompilation of the best fit component.

In accordance with still another aspect of the invention, a system improves ranking algorithms for information retrieval. The system includes a memory area for storing input information including information describing a first ranking algorithm for ranking a list of search results, a first score associated with the first ranking algorithm, a second ranking algorithm, a second score associated with the second ranking algorithm for ranking the list of search results, and causal information relating a difference between the first ranking algorithm and the second ranking algorithm with a difference between the first score and the second score. The system also includes a processor configured to execute computer-executable instructions for applying a machine learning algorithm to the input information stored in the memory area to identify an optimal ranking algorithm having an optimal score. The optimal ranking algorithm is defined by a plurality of parameters and a plurality of weights associated with the plurality of parameters.

In accordance with yet another aspect of the invention, a method identifies an improved information retrieval algorithm for ranking query results. The method includes receiving a query and a list of index documents resulting from execution of the query on an index file storing a plurality of documents. The method also includes storing a portion of the received list of index documents in a subindex file. The method also includes executing the received query on the subindex file to obtain a list of subindex documents. The method also includes iteratively executing a plurality of ranking algorithms to produce a plurality of lists of ranked subindex documents associated therewith. The method also includes comparing each of the plurality of lists of ranked subindex documents with a list of subjectively ranked documents associated with the received query to determine a degree of correlation between each of the plurality of lists of ranked subindex documents and the list of subjectively ranked documents. The method also includes applying an optimizing algorithm to identify an optimal ranking algorithm based on the plurality of ranking algorithms and the plurality of lists of ranked subindex documents associated therewith. The optimal ranking algorithm produces a list of ranked subindex documents exhibiting an optimal degree of correlation with the list of subjectively ranked documents.

Computer-readable media having computer-executable instructions for performing methods of rating information retrieval ranking algorithms and improving ranking algorithms for information retrieval embody further aspects of the invention.

Alternatively, embodiments of the invention may comprise various other methods and apparatuses.

Other features will be in part apparent and in part pointed out hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram illustrating an exemplary framework in which embodiments of the present invention may be utilized.

FIG. **2** is a block diagram illustrating an exemplary implementation of a framework to evaluate and improve a ranking algorithm according to one embodiment of the invention.

FIG. **3** is an exemplary flow diagram illustrating process flow according to one embodiment of the invention for evaluating and improving a ranking algorithm.

FIG. **4** is a block diagram illustrating an exemplary computer-readable medium according to one embodiment of the invention.

FIG. **5** is a block diagram illustrating another exemplary computer-readable medium according to one embodiment of the invention.

FIG. **6** is a block diagram illustrating an exemplary embodiment of a suitable computing system environment in which one embodiment of the invention may be implemented.

Corresponding reference characters indicate corresponding parts throughout the drawings.

DETAILED DESCRIPTION OF THE INVENTION

Referring first to FIG. **1**, a block diagram illustrates one example of a suitable framework in which embodiments of the invention may be utilized. A ranking algorithm generator **102** is configured to receive a set of ranking algorithms and to produce a new set of ranking algorithms based on the received set of ranking algorithms. A ranking algorithm fitness evaluator **104** is configured to determine the effectiveness of a given ranking algorithm in producing a relevance ranking that accurately reflects the relative importance of electronic documents with respect to a search query. In one embodiment of the invention, the ranking algorithm generator **102** (or alternatively, a human operator) creates an initial set of ranking algorithms and communicates the created set of ranking algorithms to the ranking algorithm fitness evaluator **104**. Ranking algorithm fitness evaluator

104 then evaluates each of the ranking algorithms and identifies the most effective ranking algorithm in the set. Ranking algorithm fitness evaluator **104** further communicates the most effective ranking algorithm that it identifies in the set to ranking algorithm generator **102**. Based on the most effective ranking algorithm identified by ranking algorithm fitness evaluator **104**, ranking algorithm generator **102** produces a new set of ranking algorithms (e.g., using a genetic algorithm or evolutionary algorithm). Ranking algorithm generator **102** again communicates this new set of ranking algorithms to ranking algorithm fitness evaluator **104**. Ranking algorithm fitness evaluator further identifies the most effective ranking algorithm in the new set. This framework of ranking algorithm generator **102** and ranking algorithm fitness evaluator **104**, which produce a set of ranking algorithms and identify the most effective ranking algorithm in the set, respectively, is iterated to find an optimal ranking algorithm that produces an optimal relevance ranking for a given search query.

Ranking Algorithms

According to an embodiment of the invention, a particular ranking algorithm may perform dynamic ranking. Dynamic ranking is a process that ranks electronic documents determined to match a search query. Searching and dynamic ranking are well known in the art. Generally, the ranking algorithm calculates a single numeric value called the ranking score for each electronic document determined to match the search query. The ranking score represents how well the electronic document matches the search query. A query processor then orders matching electronic documents based on their corresponding ranking scores (e.g., an electronic document with a higher ranking score may be ordered higher in the relevance ranking).

The ranking algorithm that calculates the ranking score is a function that takes several arguments as inputs. One of such arguments is an attribute that represents various information about an electronic document and about how well the electronic document matches a search query. Such an attribute may be document-specific and query-independent. For example, document-specific attributes may include static rank, length of the electronic document, link structure (e.g., how many links point to the electronic document), age of the electronic document, depth of the electronic document within a domain, language of the electronic document, country of the electronic document, etc. The attribute may also be query-specific and independent of the electronic document. Such query-specific attributes may include a frequency of an individual query term across the electronic document in various document locations (e.g., anchor text, title, body, etc.). Certain attributes also describe how well the electronic document matches one or more query terms specified in the search query. Such attributes may include a frequency of each query term, phrase, or span in the title, body, anchor text, URL, etc. of the electronic document. Alternatively, such attributes may assume binary values (e.g., "some query terms appear in the title of the electronic document" or "too many matches").

Another argument representative of an input to the ranking algorithm is a parameter. A parameter is a variable that is used as a weight or constant (e.g., a parameter with zero range) in the ranking algorithm that combines the attributes for a given (document, query) pair. Since a parameter may change constantly, it is not hard-coded in the ranking algorithm but is stored in a configuration file such that changes to the parameter are isolated from code changes. One of the goals of ranking algorithm generator **102** is that for a given set of training search queries and their predetermined ratings, to find a set of optimal parameters for a given ranking algorithm such that the relevance ranking produced by the ranking algorithm will match the predetermined ratings as closely as possible.

For each search result, there may be two different types of attributes and parameters. Static attributes and parameters have one instance per query. Examples of such static attributes and parameters include static ranks and weights to be given to the static ranks. On the other hand, dynamic attributes and parameters may occur in multiple types for a given search result. Examples of dynamic attributes include "frequency in anchor text," "frequency in body," etc., and the corresponding types may be "query term 1," "query term 2," "matched phrase," etc. Dynamic parameters assume different attributes (and have different ranges) depending on what the current type is. Similarly, a ranking algorithm may be either dynamic or static. A dynamic ranking algorithm combines dynamic attributes and parameters for each type instance given for a search result. A static ranking algorithm combines static items (such as attributes, parameters, other results of the ranking algorithm) and optimally dynamic results.

Referring to FIG. **2**, a block diagram illustrates an exemplary implementation of a framework to evaluate and improve a ranking algorithm according to one embodiment of the invention. FIG. **2** shows a memory area **202**. The memory area **202** stores an index file **204**. The index file **204** includes reference information and pointers to a plurality of electronic documents located on a communications network (e.g., an intranet, an extranet, or the Internet) to which the reference information applies. Thus, index file **204** may include one or more index terms identified from electronic documents collected by a crawler and analyzed by an index builder (not shown). Index file **204** further stores a list of network locations (e.g., URLs or internet protocol (IP) addresses) for a stored index term. A network location may be used to locate an electronic document on a communications network that includes data corresponding to the index term.

Rating the Ranking Algorithm

In FIG. **2**, a processor **205** implements a ranking algorithm fitness evaluator **206** to evaluate a list **207** of ranking algorithms stored in memory area **202**. Specifically, the processor **205** receives a query **208** and executes the query **208** on index file **204**. The query **208** may be a web search query for a business listing, residential listing, mail item, news item, media content (e.g., an image, video content, audio content, etc.), product, or service. Based on query **208**, processor **205** parses index file **204** to determine if one or more query terms of query **208** correspond to an index term stored in index file **204**. If one or more query terms of query **208** correspond to a stored index term, processor **205** then generates a subindex file **210** as a function of executing query **208** on index file **204**. In an embodiment of the invention, the subindex file **210** stores information regarding a few hundred electronic documents. In particular, subindex file **210** stores a list of document IDs representative of electronic documents that include one or more index terms determined by processor **205** as corresponding to the query terms specified in query **208**. Accordingly, subindex file **210** represents a portion of index file **204** and is generated based on query **208**. That is, subindex file **210** stores information regarding electronic documents initially included in index file **204** and determined by processor **205** as "hits" of query **208**. Subindex file **210** further stores a list of attributes relevant to the query terms specified in query **208**. For example, if query **208** specifies the term “college” as a query term, then subindex file **210** may store a list of attributes relevant to the term “college” but may not store attributes that are irrelevant to this query term.

After processor **205** generates subindex file **210**, a subjective ranking source **211** analyzes the electronic documents included in subindex file **210** based on query **208** to determine a subjective ranking of the electronic documents. More specifically, the subjective ranking source **211** looks at each of the electronic documents included in subindex file **210** and determines a degree of correlation between each electronic document and the query terms specified in query **208**. Based on this degree of correlation, subjective ranking source **211** determines a subjective score for each electronic document and produces a subjectively ranked list **212** of subindex documents based on the subjective scores of the electronic documents. In an embodiment of the invention, an electronic document with a higher subjective score is ordered higher in the subjectively ranked list **212** than an electronic document with a lower subjective score. Subjectively ranked list **212** of subindex documents is then stored in memory area **202**.

Evaluating the ranking algorithms based on subindex file **210** rather than on the index file **204** provides improved efficiency and practicality. For example, subindex file **210** may be substantially smaller in size than the index file **204**. As such, performing operations on the subindex file **210** involves reduced processing time.

As one particular example, if query **208** specifies the term “college” as a query term, subindex file **210** will include electronic documents having the term “college.” Accordingly, subjective ranking source **211** may look at each of these electronic documents having the term “college” and determine the relevancy of each electronic document with respect to query **208**. Subjective ranking source **211** then generates a subjective score for each electronic document based on the determined relevancy of this particular electronic document to query **208**. Subjective ranking source **211** then orders the electronic documents having the term “college” based on their subjective scores to form subjectively ranked list **212**.

According to one embodiment of the invention, subjective ranking source **211** is a human who analyzes the electronic documents listed in subindex file **210**. Alternatively, subjective ranking source **211** may be a programming instruction or software program configured to analyze these electronic documents automatically. For example, such a programming instruction or software program may be trained by machine learning to generate subjective scores for the electronic documents listed in subindex file **210**. Additionally, subjectively ranked list **212** of subindex documents may be stored in subindex file **210**. However, it is contemplated that subjectively ranked list **212** is accessible to processor **205** but not stored in subindex file **210**.

As discussed, memory area **202** also stores the list **207** of ranking algorithms. The list **207** of ranking algorithms may be selected by a human or by a genetic algorithm. Each of the ranking algorithms in list **207** is configured to rank the electronic documents included in subindex file **210**. In one embodiment of the invention, memory area **202** further stores a configuration file that includes one or more sets of potential parameters for each ranking algorithm and one or more sets of weights for each set of potential parameters. Alternatively, memory area **202** may store a range of weights for each parameter.

Processor **205** implementing the ranking algorithm fitness evaluator **206** is configured to execute query **208** on subindex file **210** to obtain a list of subindex documents. Processor **205** also executes each of the ranking algorithms included in list **207** on the list of subindex documents to obtain a relevance ranking of the subindex documents based on one or more attributes associated with each subindex document. The relevance ranking orders the subindex documents based on a degree of correlation between each subindex document and query **208** as determined by a given ranking algorithm.

In an embodiment of the invention, processor **205** implementing ranking algorithm fitness evaluator **206** further executes computer-executable instructions to compare the relevance ranking produced by each ranking algorithm with subjectively ranked list **212** to calculate a comparison score for each ranking algorithm included in list **207**. The comparison score indicates a degree of correlation or similarity between the relevance ranking produced by a particular ranking algorithm and subjectively ranked list **212**. Based on the comparison score calculated for each ranking algorithm, processor **205** may determine which of the ranking algorithms produces a relevance ranking that most resembles subjectively ranked list **212** and thus most accurately ranks the electronic documents included in subindex file **210**.

After processor **205** generates the comparison score for each ranking algorithm, it produces an output file that stores each of the comparison scores and information describing each of the ranking algorithms. The output file also stores causal information relating a difference between a particular ranking algorithm and another ranking algorithm with a difference between the comparison scores of these ranking algorithms. Therefore, an operator may receive the output file and examine the information included in the output file to analyze the reason behind the relative comparison scores of the ranking algorithms and to determine a technique to improve a ranking algorithm for producing an accurate relevance ranking.

According to an embodiment of the invention, processor **205** or another processor implements a ranking algorithm generator **214** to improve a given ranking algorithm included in list **207**. As discussed, memory area **202** stores one or more sets of potential parameters for a given ranking algorithm and one or more sets of weights associated with these parameters. Thus, processor **205** is configured to iteratively vary at least one of the parameters (and the associated weight) of a given ranking algorithm to generate a different ranking algorithm. More specifically, a particular ranking algorithm may have a plurality of parameters and weights associated therewith, and processor **205** implementing the ranking algorithm generator **214** may generate a different ranking algorithm by varying one or more of the parameters and weights of the particular ranking algorithm using the sets of parameters and weights stored in memory area **202** as inputs. Therefore, processor **205** may iteratively vary one or more parameters of a ranking algorithm and execute the ranking algorithm with varied parameters (and weights) on subindex documents to produce various comparison scores. As one an example, a particular ranking algorithm may include the function X^2+X^3, where X and Y represent two different parameters of the ranking algorithm. Accordingly, processor **205** implementing ranking algorithm generator **214** may vary the values of X and Y to produce different functions and thus different ranking algorithms. Applying the different ranking algorithms to the subindex documents and comparing the ranked results to the subjectively ranked list **212** produces various comparison scores.

The ranking algorithms (including various sets of parameters and weights), the comparison scores, and other output data (e.g., a set of scoring components for each search result to explain how the parameters are derived) may be used to determine an optimal ranking algorithm, as discussed next.

Determining an Optimal Ranking Algorithm

Processor **205** repeatedly varies the parameters and weights to identify an optimal ranking algorithm with an optimal set of parameters and weights such that the comparison score of the optimal ranking algorithm indicates that a relevance ranking produced by the optimal ranking algorithm highly resembles subjectively ranked list **212**. In particular, processor **205** is configured to apply an optimizing algorithm to search a multi-dimensional space of parameters and weights to identify an optimal ranking algorithm having an optimal comparison score. The optimal ranking algorithm identified by the optimizing algorithm is defined by a plurality of optimal parameters and a plurality of optimal weights associated with the optimal parameters.

It is noted that an operator or a genetic algorithm may select the list **207** of ranking algorithms by choosing a set of mathematical functions and specifying what arguments they take. Arguments include, for example, attributes, parameters, constants, or results of previously defined functions. In a recursive approach, the operator or genetic algorithm models a ranking algorithm by combining basic functions. Processor **205** implementing ranking algorithm generator **214** takes as an input a training set of queries (e.g., query **208**) and search results to find an optimal ranking algorithm. Essentially, each search result includes a number of attributes that are used in a ranking algorithm along with a rating that describes the quality of the search result with respect to its corresponding query. Two types of ratings may be used as inputs to rating algorithm generator **214**: definitive rating (0-not definitive, 1-definitive) and scale rating (e.g., 5-point scale).

Processor **205** implementing ranking algorithm generator **214** searches the space of possible values for each parameter to identify a combination of parameters that result in a "good" ranking of query **208**. In general, for a good ranking, electronic documents with higher ratings occur before electronic documents with lower ratings in a search result. This is generally referred to as the "quality of ranking." For a definitive rating, for each ranking, the quality is 1/(position of definitive). The output of ranking algorithm generator **214** of processor **205** includes a set of optimal parameters and a set of optimal weights associated with the optimal parameters.

However, for a typical ranking algorithm, there may be an order of 50-100 parameters. Even if ranking algorithm generator **214** considers **10** values for each parameter, there may be 10ˆ50 to 10ˆ100 possible combinations of parameters. Thus, in one embodiment of the invention, the optimizing algorithm executed by ranking algorithm generator **214** of processor **205** may be a binary search algorithm. For instance, the binary search algorithm may initially consider two values (e.g., 25th and 75th percentiles) for each parameter. For 30 parameters, this results in 2̂30 possible combinations of parameters. The binary search algorithm then keeps the better combination of these two values for each parameter and determines if each parameter is set to the 25th or 75th percentile. The binary search algorithm then reduces the range for each parameter to half of the original range. This technique is repeated a number of times to gradually refine the parameter.

Embodiments of the invention thus provide a framework for ranking algorithm optimization. It is noted that a wide range of optimizing algorithms or heuristics may be used to identify an optimal ranking algorithm. For example, the binary search algorithm may be substituted in the framework with other optimizing algorithms such as non-linear optimization techniques, machine learning, neural networks, and regression models to tune the parameter space.

In an embodiment of the invention, input information is received and stored in memory area **202**. The input information describes a first ranking algorithm, a first score associated with the first ranking algorithm, a second ranking algorithm, a second score associated with the second ranking algorithm, and causal information relating a difference between the first ranking algorithm and the second ranking algorithm with a difference between the first score and the second score. Processor **205** then executes an optimizing algorithm such as a binary search algorithm or machine learning to the input information stored in memory area **202** to identify an optimal ranking algorithm having an optimal comparison score. The optimizing algorithm is interchangeable with another optimizing algorithm without re-compilation of software of the invention.

Exemplary Operation

FIG. **3** illustrates an exemplary method for evaluating and improving a ranking algorithm according to one embodiment of the invention. At **302**, a query is received, and the received query is submitted to a search engine for execution on an index file. At **304**, a list of index documents and a plurality of attributes are received from the search engine in response to the submitted query. At **306**, a portion of the received list of index documents and the received plurality of attributes are stored in a subindex file. At **308**, the received query is executed on the subindex file to obtain a list of subindex documents. At **310**, one or more ranking algorithms are iteratively executed on the obtained list of subindex documents to rank the obtained list of subindex documents using the associated attributes. Thus, the one or more ranking algorithms produce one or more lists of ranked subindex documents. Moreover, each ranking algorithm includes a particular set of parameters, which may include the received query. A set or range of weights is also associated with a particular parameter.

At **312**, each of the lists of ranked subindex documents is compared with a list of subjectively ranked documents associated with the received query to generate a score for each ranking algorithm. The list of subjectively ranked documents is generated by submitting the received list of index documents to a subjective ranking source and receiving the list of subjectively ranked documents from the subjective ranking source, which may be a human or a software program. Moreover, the received list of subjectively ranked documents may be stored in the subindex file. The score indicates a degree of correlation or similarity between a particular list of ranked subindex documents and the list of subjectively ranked documents. Additionally, information regarding a particular ranking algorithm and its score, information regarding another ranking algorithm and a score of the other ranking algorithm, and causal information relating a difference between the particular ranking algorithm and the other ranking algorithm with a difference between the scores of these ranking algorithms may be stored in an output file for analysis by an operator. In an embodiment of the invention, the ranking algorithms may be selected by a human or by a genetic algorithm. Alternatively, the ranking algorithms may be created by iteratively varying at least one of the parameters of a particular ranking algorithm.

At **314**, an optimizing algorithm is applied to identify an optimal ranking algorithm as a function of the received query, the ranking algorithms, the lists of ranked subindex documents, and/or the list of subjectively ranked documents. In one embodiment of the invention, the optimizing algorithm may be a binary search algorithm, non-linear optimization technique, machine learning, neural network, regression model, etc. The optimal ranking algorithm produces a list of ranked subindex documents exhibiting an optimal degree of correlation with the list of subjectively ranked documents.

Exemplary Computer-Executable Components

FIG. **4** is a block diagram illustrating an exemplary computer-readable medium **400** according to one embodiment of the invention. As shown, the computer-readable medium **400** includes an interface component **402**, a memory component **404**, a ranking component **406**, a comparator component **408**, an output component **410**, and a best-fit component **412**. However, it is contemplated that computer-readable medium **400** may be any quantity of computer readable media and may comprise various combinations of components and functionalities associated with each component.

The interface component **402** receives a query, a list of index documents resulting from execution of the query on an index file that stores a plurality of documents, and a plurality of attributes including data describing the list of index documents. The memory component **404** stores in a subindex file a portion of the list of index documents and the plurality of associated attributes received by interface component **402**. Memory component **404** further stores the plurality of attributes including the query received by interface component **402**. The ranking component **406** executes the received query on the subindex file to obtain a list of subindex documents and ranks, by a particular ranking algorithm, the obtained list of subindex documents using the associated attributes. The comparator component **408** compares the list of subindex documents ranked by ranking component **406** with a list of subjectively ranked documents to generate a score for the particular ranking algorithm. The generated score represents a degree of correlation or similarity between the list of subindex documents ranked by ranking component **406** and the list of subjectively ranked documents.

Ranking component **406** further ranks the obtained list of subindex documents using another ranking algorithm to obtain another list of ranked subindex documents and compares the other list of ranked subindex documents with the list of subjectively ranked documents to generate another score for the other ranking algorithm. The output component **410** stores in an output file information describing the particular ranking algorithm and its score, information describing the other ranking algorithm and the score of the other ranking algorithm, and causal information relating a difference between the particular ranking algorithm and the other ranking algorithm with a difference between the scores of these ranking algorithms.

In an embodiment of the invention, interface component **402** further receives input information including information describing a first ranking algorithm, a first score associated with the first ranking algorithm, a second ranking algorithm, a second score associated with the second ranking algorithm, and causal information relating a difference between the first ranking algorithm and the second ranking algorithm with a difference between the first score and the second score. The best-fit component **412** then applies an optimizing algorithm to the received input information to identify an optimal ranking algorithm having an optimal score. The optimal ranking algorithm is defined by a plurality of parameters and a plurality of weights associated with the plurality of parameters. The optimizing algorithm is interchangeable with another optimizing algorithm without recompilation of best-fit component **412**.

In FIG. **5**, an exemplary computer-readable medium **500** according to one embodiment of the invention stores thereon a data structure representing a subindex file created from an index file as a function of a particular query executed on the index file. The execution of the particular query on the index file results in a list of documents. It is contemplated that computer-readable medium **500** may be any quantity of computer-readable media and may comprise various combinations of data structures and functionalities associated with each structure. As shown in FIG. **5**, the data structure includes a first field **502**, a second field **504**, and a third field **506**. The first field **502** stores a portion of the list of documents. The second field **504** stores a plurality of attributes related to the portion of the list of documents stored in first field **502**. The third field **506** stores a list of subjectively ranked documents. The list of subjectively ranked documents is for use to identify an optimal ranking algorithm from a plurality of ranking algorithms by comparing rankings by the plurality of ranking algorithms of the portion of the list of documents stored in first field **502** with the list of subjectively ranked documents stored in third field **506**.

Second field **504** also stores query dependent information such as one or more of the following: a query term, a frequency of the query term in a URL of an electronic document, a frequency of the query term in a title of the electronic document, a frequency of the query term in a body of the electronic document, and a frequency of the query term in an anchor text of the electronic document. Second field **504** further stores query independent information such as one or more of the following: link structure, age of an electronic document, depth of the electronic document within a domain, language of the electronic document, country of the electronic document, and a size of the electronic document.

Exemplary Operating Environment

FIG. **6** shows one example of a general purpose computing device in the form of a computer **130**. In one embodiment of the invention, a computer such as the computer **130** is suitable for use in the other figures illustrated and described herein. Computer **130** has one or more processors or processing units **132** and a system memory **134**. In the illustrated embodiment, a system bus **136** couples various system components including the system memory **134** to the processors **132**. The bus **136** represents one or more of any of several types of bus structures, including a memory bus or memory controller, a peripheral bus, an accelerated graphics port, and a processor or local bus using any of a variety of bus architectures. By way of example, and not limitation, such architectures include Industry Standard Architecture (ISA) bus, Micro Channel Architecture (MCA) bus, Enhanced ISA (EISA) bus, Video Electronics Standards Association (VESA) local bus, and Peripheral Component Interconnect (PCI) bus also known as Mezzanine bus.

The computer **130** typically has at least some form of computer readable media. Computer readable media, which include both volatile and nonvolatile media, removable and non-removable media, may be any available medium that may be accessed by computer **130**. By way of example and not limitation, computer readable media comprise computer storage media and communication media. Computer storage media include volatile and nonvolatile, removable and non-removable media implemented in any method or technology for storage of information such as computer readable instructions, data structures, program modules or other data. For example, computer storage media include RAM, ROM, EEPROM, flash memory or other memory technology, CD-ROM, digital versatile disks (DVD) or other optical disk storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium that may be used to store the desired information and that may be accessed by computer **130**. Communication media typically embody computer readable instructions, data structures, program modules, or other data in a modulated data signal such as a carrier wave or other transport mechanism and include any information delivery media. Those skilled in the art are familiar with the modulated data signal, which has one or more of its characteristics set or changed in such a manner as to encode information in the signal. Wired media, such as a wired network or direct-wired connection, and wireless media, such as acoustic, RF, infrared, and other wireless media, are examples of communication media. Combinations of the any of the above are also included within the scope of computer readable media.

The system memory **134** includes computer storage media in the form of removable and/or non-removable, volatile and/or nonvolatile memory. In the illustrated embodiment, system memory **134** includes read only memory (ROM) **138** and random access memory (RAM) **140**. A basic input/output system **142** (BIOS), including the basic routines that help to transfer information between elements within computer **130**, such as during start-up, is typically stored in ROM **138**. RAM **140** typically includes data and/or program modules that are immediately accessible to and/or presently being operated on by processing unit **132**. By way of example, and not limitation, FIG. **6** illustrates operating system **144**, application programs **146**, other program modules **148**, and program data **150**.

The computer **130** may also include other removable/non-removable, volatile/nonvolatile computer storage media. For example, FIG. **6** illustrates a hard disk drive **154** that reads from or writes to non-removable, nonvolatile magnetic media. FIG. **6** also shows a magnetic disk drive **156** that reads from or writes to a removable, nonvolatile magnetic disk **158**, and an optical disk drive **160** that reads from or writes to a removable, nonvolatile optical disk **162** such as a CD-ROM or other optical media. Other removable/non-removable, volatile/nonvolatile computer storage media that may be used in the exemplary operating environment include, but are not limited to, magnetic tape cassettes, flash memory cards, digital versatile disks, digital video tape, solid state RAM, solid state ROM, and the like. The hard disk drive **154**, and magnetic disk drive **156** and optical disk drive **160** are typically connected to the system bus **136** by a non-volatile memory interface, such as interface **166**.

The drives or other mass storage devices and their associated computer storage media discussed above and illustrated in FIG. **6**, provide storage of computer readable instructions, data structures, program modules and other data for the computer **130**. In FIG. **6**, for example, hard disk drive **154** is illustrated as storing operating system **170**, application programs **172**, other program modules **174**, and program data **176**. Note that these components may either be the same as or different from operating system **144**, application programs **146**, other program modules **148**, and program data **150**. Operating system **170**, application programs **172**, other program modules **174**, and program data **176** are given different numbers here to illustrate that, at a minimum, they are different copies.

A user may enter commands and information into computer **130** through input devices or user interface selection devices such as a keyboard **180** and a pointing device **182** (e.g., a mouse, trackball, pen, or touch pad). Other input devices (not shown) may include a microphone, joystick, game pad, satellite dish, scanner, or the like. These and other input devices are connected to processing unit **132** through a user input interface **184** that is coupled to system bus **136**, but may be connected by other interface and bus structures, such as a parallel port, game port, or a Universal Serial Bus (USB). A monitor **188** or other type of display device is also connected to system bus **136** via an interface, such as a video interface **190**. In addition to the monitor **188**, computers often include other peripheral output devices (not shown) such as a printer and speakers, which may be connected through an output peripheral interface (not shown).

The computer **130** may operate in a networked environment using logical connections to one or more remote computers, such as a remote computer **194**. The remote computer **194** may be a personal computer, a server, a router, a network PC, a peer device or other common network node, and typically includes many or all of the elements described above relative to computer **130**. The logical connections depicted in FIG. **6** include a local area network (LAN) **196** and a wide area network (WAN) **198**, but may also include other networks. LAN **136** and/or WAN **138** may be a wired network, a wireless network, a combination thereof, and so on. Such networking environments are commonplace in offices, enterprise-wide computer networks, intranets, and global computer networks (e.g., the Internet).

When used in a local area networking environment, computer **130** is connected to the LAN **196** through a network interface or adapter **186**. When used in a wide area networking environment, computer **130** typically includes a modem **178** or other means for establishing communications over the WAN **198**, such as the Internet. The modem **178**, which may be internal or external, is connected to system bus **136** via the user input interface **184**, or other appropriate mechanism. In a networked environment, program modules depicted relative to computer **130**, or portions thereof, may be stored in a remote memory storage device (not shown). By way of example, and not limitation, FIG. **6** illustrates remote application programs **192** as residing on the memory device. The network connections shown are exemplary and other means of establishing a communications link between the computers may be used.

Generally, the data processors of computer **130** are programmed by means of instructions stored at different times in the various computer-readable storage media of the computer. Programs and operating systems are typically distributed, for example, on floppy disks or CD-ROMs. From there, they are installed or loaded into the secondary memory of a computer. At execution, they are loaded at least partially into the computer's primary electronic memory. Embodiments of the invention described herein include these and other various types of computer-readable storage media when such media include instructions or programs for implementing the steps described below in conjunction with a microprocessor or other data processor. One embodiment of the invention also includes the computer itself when programmed according to the methods and techniques described herein.

For purposes of illustration, programs and other executable program components, such as the operating system, are illustrated herein as discrete blocks. It is recognized, however, that such programs and components reside at various times in different storage components of the computer, and are executed by the data processor(s) of the computer.

Although described in connection with an exemplary computing system environment, including computer **130**, one embodiment of the invention is operational with numerous other general purpose or special purpose computing system environments or configurations. The computing system environment is not intended to suggest any limitation as to the scope of use or functionality of embodiments of the invention. Moreover, the computing system environment should not be interpreted as having any dependency or requirement relating to any one or combination of components illustrated in the exemplary operating environment. Examples of well known computing systems, environments, and/or configurations that may be suitable for use with the embodiments of the invention include, but are not limited to, personal computers, server computers, hand-held or laptop devices, multiprocessor systems, microprocessor-based systems, set top boxes, programmable consumer electronics, mobile telephones, network PCs, minicomputers, mainframe computers, distributed computing environments that include any of the above systems or devices, and the like.

Embodiments of the invention may be described in the general context of computer-executable instructions, such as program modules, executed by one or more computers or other devices. Generally, program modules include, but are not limited to, routines, programs, objects, components, and data structures that perform particular tasks or implement particular abstract data types. Embodiments of the invention may also be practiced in distributed computing environments where tasks are performed by remote processing devices that are linked through a communications network. In a distributed computing environment, program modules may be located on both local and remote computer storage media including memory storage devices.

In operation, computer **130** executes computer-executable instructions such as those described herein to rate information retrieval ranking algorithms.

The order of execution or performance of the methods illustrated and described herein is not essential, unless otherwise specified. That is, it is contemplated by the inventors that elements of the methods may be performed in any order, unless otherwise specified, and that the methods may include more or less elements than those disclosed herein.

When introducing elements of the present invention or the embodiments thereof, the articles “a,” “an,” “the,” and “said” are intended to mean that there are one or more of the elements. The terms “comprising,” “including,” and “having” are intended to be inclusive and mean that there may be additional elements other than the listed elements.

In view of the above, it will be seen that the several objects of the invention are achieved and other advantageous results attained.

As various changes could be made in the above constructions and methods without departing from the scope of embodiments of the invention, it is intended that all matter contained in the above description and shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A method for improving ranking algorithms for information retrieval, said ranking algorithms operating on query results obtained from a search engine, said method comprising:

receiving input information including information describing a first ranking algorithm for ranking a list of search results, a first score associated with the first ranking algorithm, a second ranking algorithm for ranking the list of search results, a second score associated with the second ranking algorithm, and causal information relating a difference between the first ranking algorithm and the second ranking algorithm with a difference between the first score and the second score, said first score representing a comparison of output of the first ranking algorithm and a subjective ranking of the list of search results, said second score representing a comparison of output of the second ranking algorithm and the subjective ranking of the list of search results; and

applying an optimizing algorithm to the received input information to identify an optimal ranking algorithm having an optimal score, said optimal ranking algorithm being defined by a plurality of parameters and a plurality of weights associated with the plurality of parameters.

2. The method of claim **1**, wherein applying the optimizing algorithm to the received input information comprises applying a machine learning algorithm to the received input information to identify the optimal ranking algorithm.

3. The method of claim **1**, wherein applying the optimizing algorithm to the received input information comprises applying a binary search algorithm to the received input information to identify the optimal ranking algorithm.

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

receiving a query;

submitting the received query to a search engine for execution on an index file, wherein the index file stores a plurality of documents;

receiving a list of index documents and a plurality of attributes from the search engine in response to the submitted query, said received plurality of attributes including data describing the received list of index documents, said received list of index documents representing the list of search results;

storing a portion of the received list of index documents and the received plurality of attributes associated therewith in a subindex file;

executing the received query on the subindex file to obtain a list of subindex documents;

ranking, by the first ranking algorithm, the obtained list of subindex documents using the attributes associated therewith; and

comparing the list of ranked subindex documents with the subjective ranking of the list of search results to generate the first score associated with the first ranking algorithm, said generated first score representing a degree of correlation between the list of ranked subindex documents and the subjective ranking of the list of search results.

5. The method of claim **4**, further comprising:

ranking the obtained list of subindex documents using the second ranking algorithm to obtain a second list of ranked subindex document; and comparing the second list of ranked subindex documents with the subjective ranking of the list of search results to generate the second score associated with the second ranking algorithm.

6. The method of claim **1**, wherein one or more computer-readable media have computer-executable instructions for performing the method recited in claim **1**.

7. One or more computer storage media having computer-executable instructions for improving ranking algorithms for information retrieval, said ranking algorithms operating on query results obtained from a search engine, said components comprising:

a first component for receiving input information including information describing a first ranking algorithm for ranking a list of search results, a first score associated with the first ranking algorithm, a second ranking algorithm for ranking the list of search results, a second score associated with the second ranking algorithm, and causal information relating a difference between the first ranking algorithm and the second ranking algorithm with a difference between the first score and the second score, said first score representing a comparison of output of the first ranking algorithm and a subjective ranking of the list of search results, said second score representing a comparison of output of the second ranking algorithm and the subjective ranking of the list of search results; and

a second component for applying an optimizing algorithm to the received input information to identify an optimal ranking algorithm having an optimal score, said optimal ranking algorithm being defined by a plurality of parameters and a plurality of weights associated with the plurality of parameters, said optimizing algorithm being interchangeable with another optimizing algorithm without re-compilation of the second component.

8. The computer storage media of claim **7**, further comprising an interface component for receiving a query, a list of index documents resulting from execution of the query on an index file storing a plurality of documents, and a plurality of attributes including data describing the list of index documents.

9. The computer storage media of claim **8**, further comprising a memory component for storing, in a subindex file, a portion of the list of index documents and the plurality of attributes associated therewith received by the interface component.

10. The computer storage media of claim **9**, further comprising a ranking component for executing the received query on the subindex file to obtain a list of subindex documents and for ranking, by the first ranking algorithm, the obtained list of subindex documents using the attributes associated therewith.

11. The computer storage media of claim **10**, further comprising a comparator component for comparing the list of subindex documents ranked by the ranking component with the subjective ranking of the list of search results to generate a score for the first ranking algorithm, said generated score representing a degree of correlation between the list of subindex documents ranked by the ranking component and the subjective ranking of the list of search results.

12. The method of claim **1**, further comprising storing the optimal ranking algorithm, the plurality of parameters for the optimal ranking algorithm, and the plurality of weights for the plurality of parameters.

13. A method for identifying an improved information retrieval algorithm for ranking query results, said method comprising:

receiving a query and a list of index documents resulting from execution of the query on an index file storing a plurality of documents;

storing a portion of the received list of index documents in a subindex file;

executing the received query on the subindex file to obtain a list of subindex documents;

executing each of a plurality of ranking algorithms to produce a plurality of lists of ranked subindex documents associated therewith;

comparing each of the plurality of lists of ranked subindex documents with a list of subjectively ranked documents associated with the received query to determine a degree of correlation between each of the plurality of lists of ranked subindex documents and the list of subjectively ranked documents; and

applying an optimizing algorithm to identify an optimal ranking algorithm based on the plurality of ranking algorithms and the plurality of lists of ranked subindex documents associated therewith, said optimal ranking algorithm producing a list of ranked subindex documents exhibiting an optimal degree of correlation with the list of subjectively ranked documents.

14. The method of claim **13**, wherein each of the plurality of ranking algorithms has a plurality of parameters associated therewith.

15. The method of claim **13**, wherein receiving the query comprises receiving one or more of the following: a query for a business listing, a query for a residential listing, a query for a mail item, a query for a news item, a query for media content, and a product query.

16. The method of claim **13**, wherein receiving the query further comprises receiving a plurality of attributes associated with the received list of subindex documents, said received plurality of attributes being used as input for the plurality of ranking algorithms.

17. The method of claim **13**, wherein one or more computer storage media have computer-executable instructions for performing the method recited in claim **13**.

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