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(54) **STOCHASTIC OPTIMIZATION TECHNIQUES OF EVOLUTIONARY COMPUTATION SEARCH STRATEGIES FOR AN INFORMATION SHARING SYSTEM**

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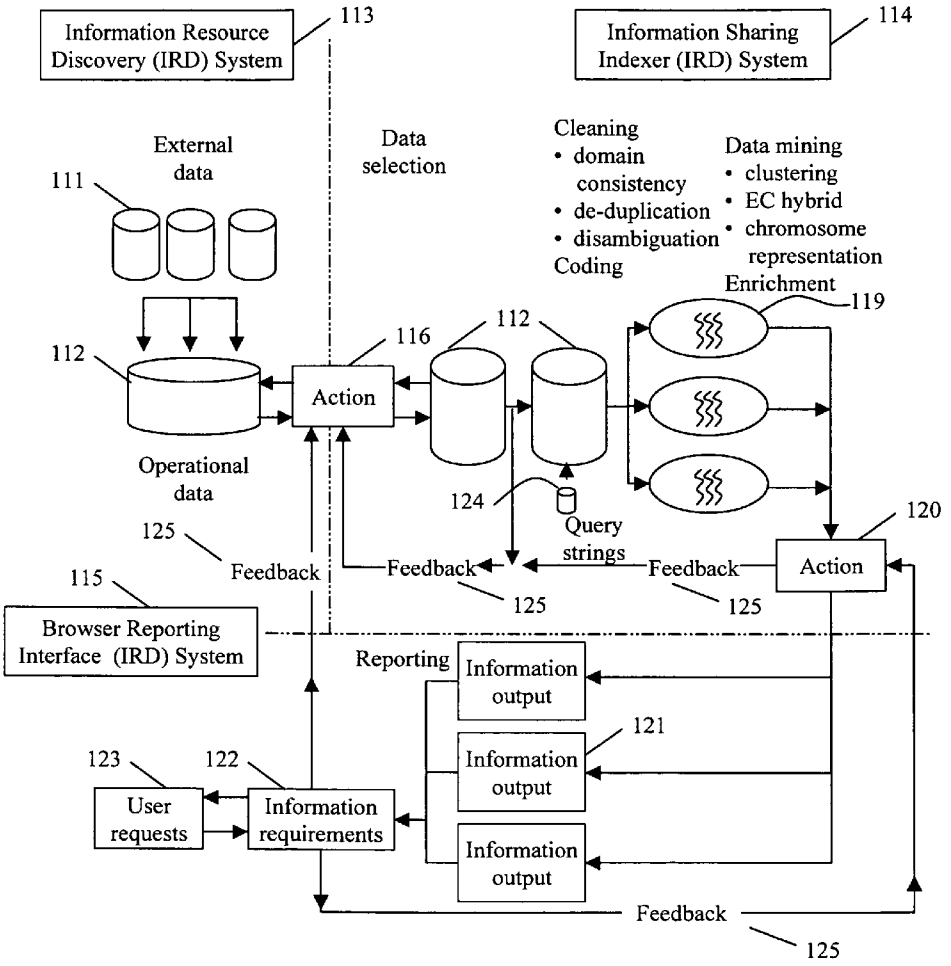
(57) **ABSTRACT**

An information sharing system to solve one or more information retrieval problems is concerned with the novel, hybrid use of the stochastic optimization techniques of evolutionary computation (EC) search strategies for computer information systems such as search engines, or service oriented architectures (SOAs). The information sharing system uses stochastic optimization agents for task distribution and communication when foraging a system of stored documents for information, assessing the computational effort required to retrieve information in the form of stored documents, sharing information among stochastic optimization agent processes and processors, and extracting knowledge from the information. The field of evolutionary computation encompasses stochastic optimization techniques, such as randomized search strategies, in the form of evolutionary strategies (ES), evolutionary programming (EP), genetic algorithms (GA), classifier systems, evolvable hardware (EHW), and genetic programming (GP). The information sharing system is an attempt to harness information processing models by adapting to information system fluctuations that occur within a computer, a local area network, and a wide area network that encompasses the whole Internet.



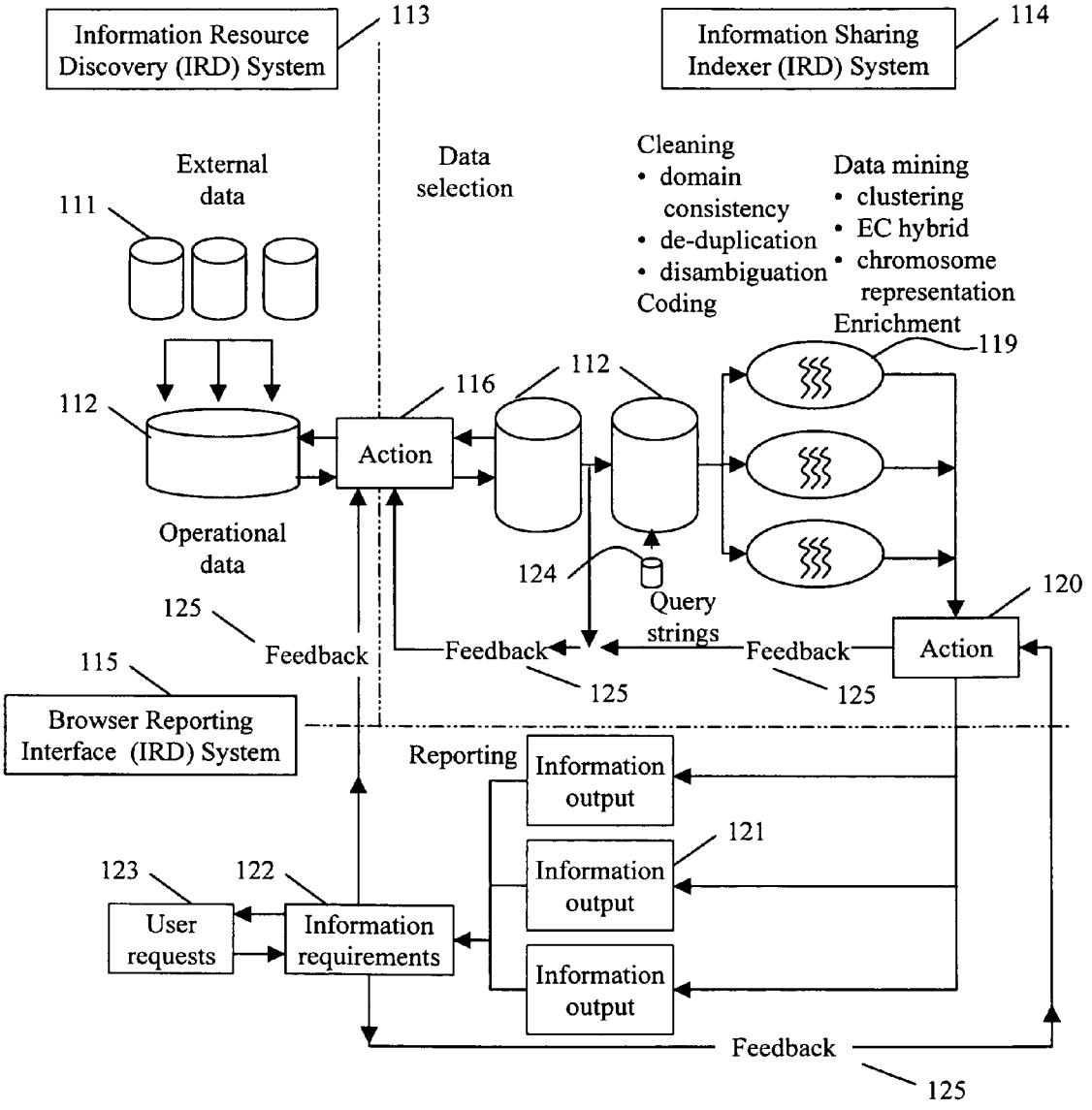

Information Resource Discovery (IRD) System
113
Information Sharing Indexer (IRD) System
114
External data
111
Data selection
Cleaning
• domain consistency
• de-duplication
• disambiguation
Coding
Data mining
• clustering
• EC hybrid
• chromosome representation
Enrichment
119
112
116
112
Action
Operational data
124
Query strings
120
125
Feedback
Feedback
Feedback
Action
125
125
115
Browser Reporting Interface (IRD) System
Reporting
Information output
121
Information output
123
122
User requests
Information requirements
Information output
Feedback
125

FIG. 1

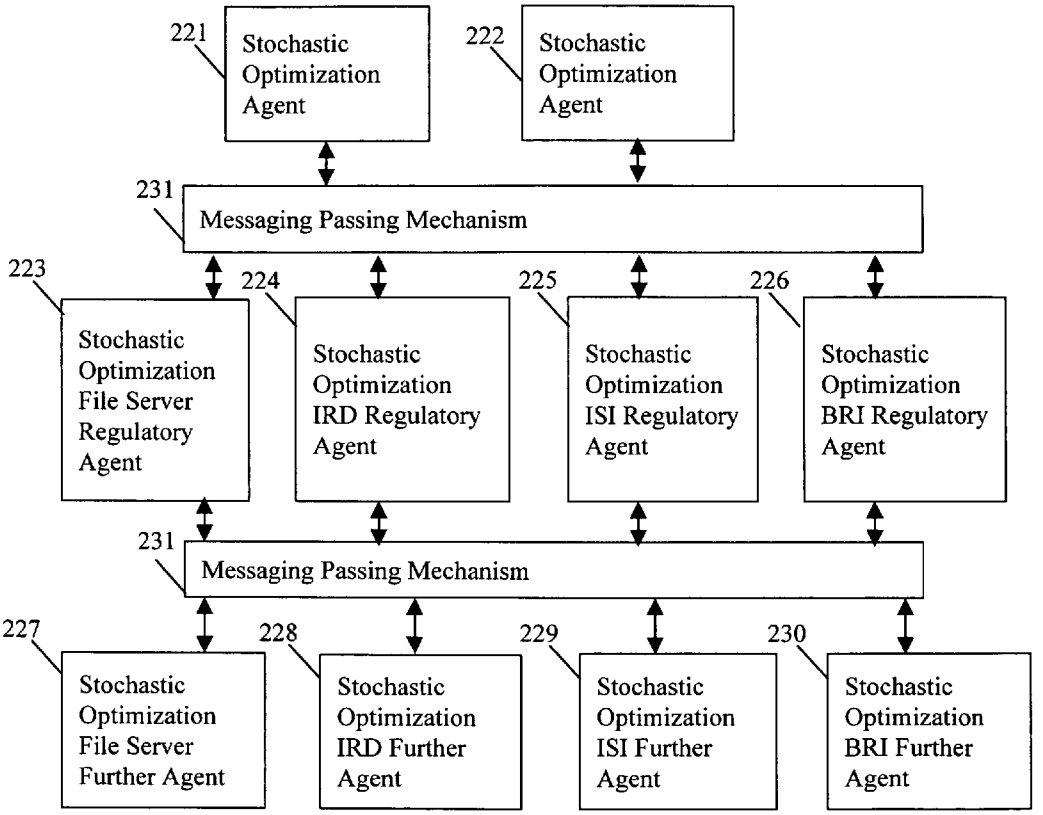

221
Stochastic Optimization Agent
222
Stochastic Optimization Agent
231
Messaging Passing Mechanism
223
Stochastic Optimization File Server Regulatory Agent
224
Stochastic Optimization IRD Regulatory Agent
225
Stochastic Optimization ISI Regulatory Agent
226
Stochastic Optimization BRI Regulatory Agent
231
Messaging Passing Mechanism
227
Stochastic Optimization File Server Further Agent
228
Stochastic Optimization IRD Further Agent
229
Stochastic Optimization ISI Further Agent
230
Stochastic Optimization BRI Further Agent

FIG. 2

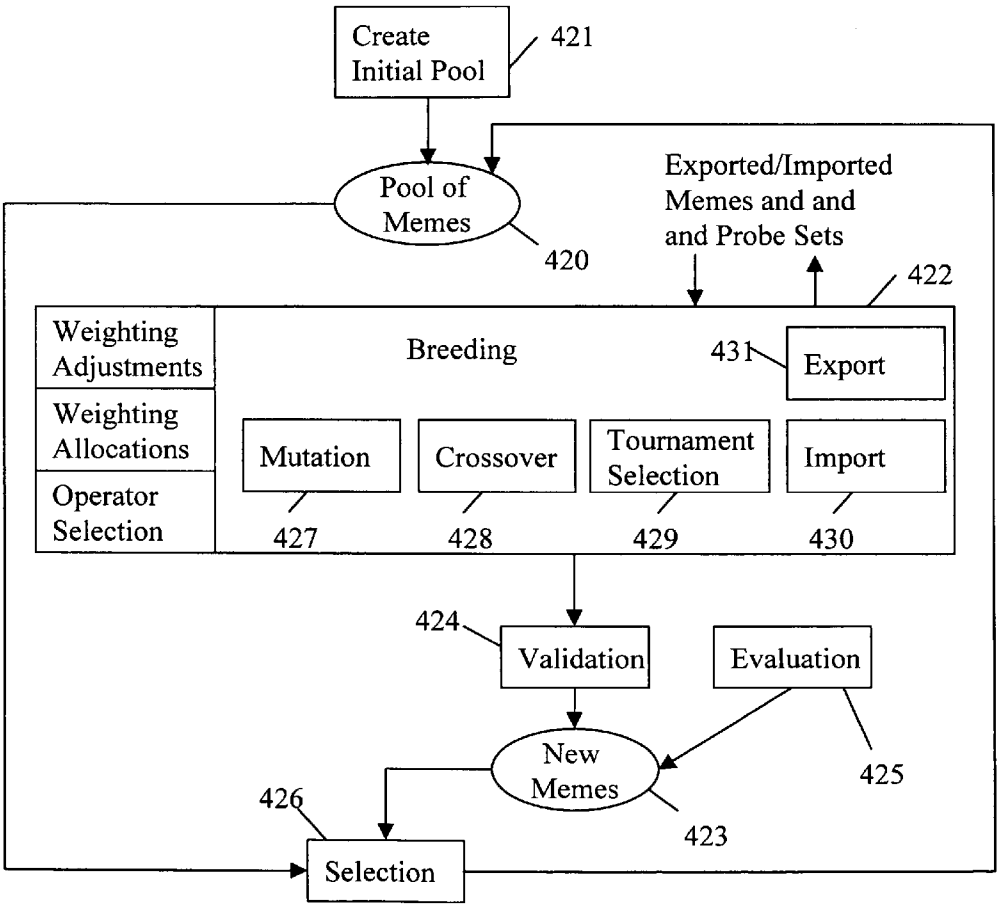

Create Initial Pool
421
Pool of Memes
420
Exported/Imported Memes and and and Probe Sets
422
Weighting Adjustments
Weighting Allocations
Operator Selection
Breeding
431
Export
Mutation
Crossover
Tournament Selection
Import
427
428
429
430
424
Validation
Evaluation
New Memes
425
423
426
Selection

FIG. 3

STOCHASTIC OPTIMIZATION TECHNIQUES OF EVOLUTIONARY COMPUTATION SEARCH STRATEGIES FOR AN INFORMATION SHARING SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims benefit of provisional application Ser. No. 61/276,180, filed on Sep. 9, 2009 by the present inventor.

FEDERALLY SPONSORED RESEARCH

[0002] Not Applicable

SEQUENCE LISTING OR PROGRAM

[0003] Not Applicable

BACKGROUND OF THE INVENTION

Field of Invention

[0004] The invention relates generally to information sharing systems to solve one or more information retrieval problems. More specifically, the invention is concerned with the novel use of the stochastic optimization techniques of evolutionary computation (EC) search strategies in such an information sharing system such as for search engines, or service oriented architectures (SOAs). The information sharing system uses stochastic optimization agents for task distribution and communication when foraging a system of stored documents for information, assessing the computational effort required to retrieve information in the form of stored documents, sharing information among stochastic optimization agent processes and processors, and extracting knowledge from the information.

[0005] The field of evolutionary computation encompasses stochastic optimization techniques, such as randomized search strategies, in the form of evolutionary strategies (ES), evolutionary programming (EP), genetic algorithms (GA), classifier systems, evolvable hardware (EHW), and genetic programming (GP). A common strength of these optimization approaches lies in the use of hybrid algorithms derived by combining one or more of the evolutionary search methodologies.

[0006] The stochastic optimization techniques of evolutionary computation (EC) contain mechanisms which enable the representation of certain unique aspects of individual behavior to improve document discovery and clustering. Principles of the stochastic optimization techniques of EC can be found for example in Reginald Louis Walker (2003) "*Tocorime Apicu: Design of an Experimental Search Engine Using an Information Sharing Model*", University of California Dissertation, UMI Dissertation Publishing, Ann Arbor, Mich. 48106-1346 (www.proquest.com) or rwalker@cs.ucla.edu, which is incorporated by reference herein in its entirety.

[0007] The advent of search engines and service-oriented architectures (SOAs) addressed the shortcomings of early information retrieval (IR) systems. However, current computer information systems are hampered by their reliance on outdated information, the result of an Internet retrieval approach for gathering new and updated documents as opposed to a resource discovery system based on an information sharing model.

[0008] The goal of stochastic optimization agents in IR systems is to discover commonalities among distinct subsets of documents by coupling the methodologies of their IR systems with knowledge discovery in databases (KDD). Improved relevance feedback mechanisms determine the quality (fitness) of the requester's database query by computing the degree of fitness between the precision and recall of relevant documents. This terminology stems from two early performance measures used to judge an IR system—how well it captures relevant documents, and how well it rejects the irrelevant.

[0009] The methodology for the KDD architecture outlines possible approaches taken by computer information systems to improve their IR systems. The conventional approach provided the requester with query results based on the user's knowledge of respective IR systems. Since a typical user often has a limited knowledge of the structural and search methodologies that pertain to individual computer information systems, the user represents a significant limitation to the current computer information systems. The components comprising the KDD model are: 1) data selection, 2) cleaning—reducing the file complexity, 3) enrichment, 4) coding, 5) data mining—the discovery phase, and 6) reporting.

[0010] The benefits of incorporating the KDD model's methodologies include provisions for: 1) long-term vision, 2) mechanisms for updating documents on distributive computers, 3) mechanisms for connecting documents, and 4) mechanisms for interpreting the relations between a diverse collection of files, also known as the formulation of hypertext. The KDD approach, however, derives queries from the resulting databases built by the computer information systems; the IR system, in turn, organizes the database and presents the user with useful information. Thus, the incorporated structure and search methodologies of KDD systems do not require in-depth knowledge by end-users. The KDD IR system does, however, require an intelligent tool coupled with a methodology that eliminates repeated queries and provides useful data back to the end-user for an automated IR system. The intelligent tool in the form of the stochastic optimization agents results from the methodologies of KDD, EC, and distributive computing being coupled, resulting in an information sharing system that encompasses stochastic search strategies

[0011] The object of the present invention is to overcome these problems in a novel manner using an intelligent tool such as an information sharing system based on fitness-enhancing mechanisms which provide feedback—between the stochastic optimization agents, stochastic optimization regulatory agents, and stochastic optimization further agents—that is a result of previous stochastic measurements and adjustments to workload assignments associated with previous iterations. The resulting system is a methodology that employs the stochastic optimization techniques of EC to implement unique aspects of the information sharing model and apply search strategies to explore the disparate regions of the search space of documents by partitioning the search space among the nodes of the information sharing system. The fitness of a population of solutions can be improved by the non-genetic transmission of cultural information that uses a meme as the transmission mechanism rather than the genetically based genotype.

SUMMARY OF THE INVENTION

[0012] According to the invention, there is provided an information sharing system comprising:

[0013] a. at least one stochastic optimization agent comprising means for storing a pool of memes, representing a plurity of possible solutions to one or more of the information retrieval problems encoded in a predetermined manner, breeding means for generating new memes from said pool of memes, evaluation means for evaluating said new memes according to predetermined fitness criteria, and selection means for selecting the fittest of the memes to form the solution meme in said pool;

[0014] b. at least one stochastic optimization regulatory agent comprising means for storing a pool of memes, representing a plurity of possible solutions to one or more of the information retrieval problems encoded in a predetermined manner, breeding means for generating new memes from said pool of memes, evaluation means for evaluating said memes according to predetermined fitness criteria, and selection means for selecting memes to form the solution meme in said pool;

[0015] c. at least two stochastic optimization further agent comprising means for storing a pool of memes, representing a plurity of possible solutions to one or more of the information retrieval problems encoded in a predetermined manner, breeding means for generating new memes from said pool of memes, evaluation means for evaluating said memes according to predetermined fitness criteria, and selection means for selecting memes to form the solution meme in said pool;

[0016] d. wherein said stochastic optimization agent includes means for importing/exporting said further memes from/to said other stochastic optimization agents and adding them to said pool for breeding and selection;

[0017] e. wherein said stochastic optimization agent includes means for importing/exporting said further memes from/to said stochastic optimization regulatory agents and adding them to said pool for breeding and selection;

[0018] f. wherein said stochastic optimization agent includes means for importing/exporting said further memes from/to said stochastic optimization further agents and adding them to said pool for breeding and selection;

[0019] g. wherein said stochastic optimization regulatory agents includes means for importing/exporting said further memes from/to said stochastic optimization regulatory agents and adding them to said pool for breeding and selection;

[0020] h. wherein said stochastic optimization regulatory agents includes means for importing/exporting said further memes from/to said stochastic optimization further agents and adding them to said pool for breeding and selection;

[0021] i. wherein said stochastic optimization further agents includes means for importing/exporting said further memes from/to said stochastic optimization further agents and adding them to said pool for breeding and selection; and

[0022] j. wherein each said stochastic optimization agent, stochastic optimization regulatory agent, and stochastic optimization further agent includes means to facilitate and optimize a plurity of possible solutions to one or more of the information retrieval problems for an information sharing system—i) a model of stored information, ii) a model for transferring stored information, iii) a model for mutating stored information, and iv) a model for translating stored information into a form against which value judgments can be made.

[0023] As will be shown, in such an information sharing system, the stochastic optimization agents, the stochastic optimization regulatory agents, and the stochastic optimization further agents provide a framework within which a number of different problem solving techniques can be integrated, in such way as to achieve synergy between the different techniques. Each stochastic optimization agent coupled with a stochastic optimization regulatory agent and its stochastic optimization further agent(s) is developed as a stand-alone system that can be applied to solve specific problems that fit its application domain.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] FIG. **1** is the architecture of the present invention.

[0025] FIG. **2** is a block diagram of an information sharing system embodying the invention.

[0026] FIG. **3** is a schematic diagram illustrating a stochastic optimization agent, stochastic optimization regulatory agent, and stochastic optimization further agent forming the information sharing system.

DETAILED DESCRIPTION

Preferred Embodiments

[0027] A preferred embodiment of the present invention is now described with reference to the figures where like reference numbers indicate identical or functionally similar elements and reference to the accompanying drawings.

[0028] FIG. **1** shows the information sharing system **10** architecture. The information sharing system is partitioned into four distinct components that use an hierarchical communication topology to access a system of stored information **111**,**112**. The information system components are distributed file system **112**, information resource discovery (IRD) system **113**, an information sharing indexing (ISI) system **114**, and 4) a browser reporting interface (BRI) system **115**. The information sharing system encompasses policies and processes that require mechanisms capable of adaptively adjusting operational parameters **116**,**120**,**122**, and the removal of stop words **124**. These parameters are required to filter, organize, and index any large-scale data set **111**, information stored within a computer, a local area network, and a wide area network that encompasses the whole Internet, that may consists of constantly fluctuating information content over relatively short periods of time. Additionally, the information sharing system (or its individual components) can be applied to hosts of existing computer information systems that require mechanisms to locate new and updated information in a timely manner, mechanisms to integrate new information into existing knowledge bases, and mechanisms to extract, analyze, and disseminate information from large-scale data sets **111**. The pool of query memes **119** is maintained by the distributed file system **112**.

[0029] The fitness-enhancing mechanisms **116**,**120**,**122** provide feedback **125**, between the stochastic optimization agents, stochastic optimization regulatory agents, and stochastic optimization further agents, that is a result of previous stochastic measurements and adjustments to workload assignments associated with previous iterations.

[0030] FIG. **2** shows the information sharing system **10** comprising of a plurity of agents **221**-**230**. These agents may

be processes running on separate processors. Alternatively one or more of the agents may run as time-sharing processes on the same processor. The fitness-enhancing mechanisms **116**,**120**,**122** provide feedback—between the stochastic optimization agents **221**,**222**, stochastic optimization regulatory agents **223-226**, and stochastic optimization further agents **227-230**—that is a result of previous stochastic measurements and adjustments to workload assignments associated with previous iterations. The agents can communicate with each other by a message passing mechanism **231**, which allows any one of the agents to send a message to any other agents.

[0031] The information sharing system design—a result of the integration of various components which include the stochastic optimization agents **221**,**222**, stochastic optimization regulatory agents **223-226**, and stochastic optimization further agents **227-230**. The distinct stochastic optimization regulatory agent hierarchy will be:

[0032] 1. stochastic file server optimization regulatory agent **223** (File Server System **112** for Event E_0), M_0

[0033] 2. stochastic optimization IRD regulatory agent **224** (Information Resource Discovery System **113** for Event E_1), M_1

[0034] 3. stochastic optimization ISI regulatory agent **225** (Information Sharing Indexing System **114** for Event E_2), M_2

[0035] 4. stochastic optimization BRI regulatory agent **226** (Browser Reporting Interface System **115** for Event E_3), M_3.

A single node, a computer processor in the distributed information sharing system, represents the stochastic optimization regulatory agents **223-226**, M_i, for each event set, E_i. Each stochastic optimization regulatory agent **223-226** may time share its processor with at least one corresponding stochastic optimization further agents **228-230** and one stochastic file server optimization further agent **227**.

[0036] The load-balancing model for all M_i **224**,**225** has the responsibility for ensuring that no document duplication occurs among the stochastic optimization further agents **228**, **229** executing the instructions that comprise its event set, E_i. M_1 **224** has to ensure that the network path order used by the stochastic optimization further agents **228** remains distinct. The load-balancing model for M_2 **225** has the responsibility of ensuring that no document duplication occurs within the ISI system **114** among the stochastic optimization further agents **229** executing the instructions that comprise its event set, E_2. Also, coupled with the fact that each meme can not be discarded after the application of the evolutionary computation (EC) operators—the traditional view of the effects of the EC optimization techniques are modified. The difference between the two includes the fact that genetic transmissions (stochastic selection process) evolve over a period of generations, whereas cultural transmissions result from an educational process. The transmission of cultural information can be facilitated by preserving in memory the fitness evaluations associated with a previous generation using an indexed memory scheme. The load-balancing model for M_3 **226** has the responsibility of ensuring that no document duplication occurs in the stochastic optimization further agents **230** results when presenting relevant documents **121** to a user's query **123** for event set E_3. The responsibilities associated with M_3 can be expanded to encompass the clustering of external data sources **111**. Dynamic load-balancing schemes associated with EC can be used to dynamically regulate the irregularity in workload assignments that results from the processor's retrieving and parsing of variable-sized documents which follow the theories associated with the implementation of event managers (EM) **221**,**222**,**223-226**.

[0037] The system includes at least one stochastic optimization agent **221**, capable of solving one or more information retrieval problems by stochastic optimization techniques of evolutionary computations. The other stochastic optimization agent **222**, when present, functions as a monitor for the stochastic optimization regulatory agents **223-226**. In this example, there are two stochastic optimization agents **221**, **222** but in other examples there may be only one or more stochastic optimization agents. The stochastic optimization agent will be described in more detail below.

[0038] The system includes at least one stochastic optimization regulatory agents **223-226**, which are capable of solving one or more information retrieval problems by stochastic optimization techniques of evolutionary computations. In this example, there are at least four stochastic optimization regulatory agents which comprise a stochastic optimization file server regulatory agent **223**, a stochastic optimization IRD regulatory agent **224**, a stochastic optimization ISI regulatory agent **225**, and a stochastic optimization BRI regulatory agent **226**. The stochastic optimization regulatory agent will be described in more detail below.

[0039] The system includes at least two stochastic optimization further agents **227-230**, which are capable of solving one or more information retrieval problems by stochastic optimization techniques of evolutionary computations. In this example, there are four stochastic optimization further agents which comprise of a stochastic optimization file server further agent **227**, a stochastic optimization IRD further agent **228**, a stochastic optimization ISI further agent **229**, and a stochastic optimization BRI further agent **230**.

[0040] The stochastic optimization agent **221** maintains a central pool of memes that have been offered for export by the stochastic optimization BRI regulatory agent **230** for user requests **123**. In this case, whenever stochastic optimization agent **221** requires to import a new meme, it would obtain it from this central pool maintained by the stochastic optimization file system regulatory agent **223** and stochastic optimization BRI regulatory agent **230**.

[0041] In operation, each of the agents **221-230** attempts to create possible solutions to a given problem set, using its own particular hybrid of the stochastic optimization techniques of evolutionary computation. Each of these possible solutions is encoded in some predetermined manner, for example a chromosome of documents. The encoded solution is referred to as a "meme". Each group of stochastic optimization agents uses unique predetermined meme coding scheme using the transmission of cultural information by preserving in memory the fitness evaluations associated with a previous generation using an indexed memory scheme.

[0042] FIG. **3** shows the breeding, validation, evaluation, and selection processes which are executed cyclically, to produce successive generations of memes. This loop continues forever with the goal of always attempting to generate a better meme. The goal of continuously applying the stochastic optimization regulatory mechanisms is to improve the subclustering of documents. The agents **221-230** maintain a pool of query memes **420**, representing a current generation of solutions to the problem in question. When the agents **221-230** are

started up, a process **421** creates an initial generation of memes, for example by randomization, or by using memes stored from a previous run.

[0043] The agents **221-230** includes a breeding process **422** (comprised of weighting adjustments, weighting allocations, and operator selection), which processes the memes in the pool **420**, to produce a set of new memes **423**. Each new meme passes through a validation process **424** which checks whether the meme fitness satisfies any problem-specific information retrieval constraints. The validation process performs a "meme-repair" operation, by searching for values which satisfy the constraints.

[0044] The agents **221-230** also includes an evaluation process **425**, which evaluates new memes, to produce a fitness value for each one, indicating how good a solution the meme represents. The agent further includes a selection process **426** which selects the best of the memes (both from the meme pool **420** and the new meme set **423**, and places the selected memes in the meme pool.

[0045] The breeding process **422** comprises a number of operators, including a mutation operator **427**, a crossover operator **428**, tournament selection operator **429**, an import operator **430**, and an export operator **431**. Each of these operators has a weighting value associated with it, which determines the probability of using the operator. These weighting values are adjusted for successive generations, so as to increase the probability of use of those operators that produce fitter memes.

[0046] The mutation operator **427** takes one of the memes from the pool **420**, and mutates it in some manner. The crossover operator **428** selects from the pool **420** as "parents", and updates the two "parent" memes, by swapping part of their genetic information. The memes are chosen randomly. A crosspoint is randomly selected. The first updated "parent" meme is created by replacing the genetic content of the first meme following the crosspoint with the genetic content of the second meme following the crosspoint. Similarly, The second updated "parent" meme is created by replacing the genetic content of the second meme following the crosspoint with the genetic content of the first meme following the crosspoint. It will be appreciated that in practice other forms of crossover operator may be used, depending on the way the memes are encoded.

[0047] The tournament selection operator **429** selects from the pool **420** two or more memes as "parents", and updates two or more "parent" memes from these, by swapping part of their genetic information (multiple applications of the crossover operator **428**) that stems from overlapping nearest neighbor clusters (NNCs) and is equivalent to sharing information between species of individuals.

[0048] The import operator **430** sends an import message to one or more of the other agents **221**,**222** in the system, one or more of the stochastic optimization regulatory agents **223-226** in the system, and one or more of the stochastic optimization further agents **227-230** in the system, requesting that it send the memes so far created by the other agents. When the requested memes are received, they are validated and added to the set of new memes **423** in exactly the same way as the locally generated memes, produced by the mutation, crossover, and tournament selection operators. The imported meme will then be available for use by the requesting agents **221-230**.

[0049] The export operator **431** sends an export message to one or more of the stochastic optimization agents **221**, in the system, one or more of the stochastic optimization regulatory agents **223-226** in the system, and one or more of the stochastic optimization further agents **227-230** in the system, indicating that it has updated memes ready to send to the other agents. When the requested memes are received, they are validated and added to the set of new memes **423** in exactly the same way as the locally generated memes, produced by the mutation and crossover, and tournament selection operators. The exported meme will then be available for use by other agents **221-230**.

[0050] These optimization techniques form the basis of the agents **221-230** for the information sharing system **10**—migration of documents between processes/processors/computers within the local area network (LAN). The stochastic optimization regulatory agents **223-226** permits the information sharing system to escape from local optima in its attempts to gather related documents by analyzing content and creating information fluctuations among the stochastic optimization ISI regulatory agent **225** and stochastic optimization ISI further agent **229**.

[0051] In summary, it can be seen that the stochastic optimization agents, the stochastic optimization regulatory agents, and stochastic optimization further agents will constantly import and export fit-looking memes and try to evolve them into even fitter individuals.

[0052] In terms of solving commercial problems this has a particularly important advantage. As more problem-tailored approaches are developed, new agents can then be simply added into the architecture without changing the existing agents. This effectively de-risks developments in one of the most high-risk areas of current computer application development.

[0053] It will be appreciated that many modifications may be made to the system described above without departing from the scope of the present invention. For example, some possible modifications are as follows.

[0054] A mechanism may be provided to keep track of the sources of memes, so as to keep a history of which techniques worked best at what stage of optimization.

[0055] While particular embodiments and applications of the present invention have been illustrated and described herein, it is understood that the invention is not limited to the precise construction and components disclosed herein and that various modifications, changes, and variations may be made in the arrangement, operation, and details of the methods and apparatuses of the present invention without departing from the spirit and scope of the invention as it is defined in the appended claims.

I claim:

1. A information sharing system for solving one or more information retrieval problems, the information sharing system consist of at least ten agents, and a message passing mechanism, connected to said agents, for passing messages between said agents wherein said first, second, third, fourth, fifth, sixth, seventh, eighth, ninth, and tenth agents comprises:

a. means for storing a pool of memes, representing solutions to said problems;

b. breeding means, coupled to said pool of memes, for generating new memes from said pool of memes;

c. means, coupled to said breeding means, for evaluating said new memes according to predetermined fitness criteria, and for selecting fittest of said new memes, to form new generation of memes in said pool; and

d. importing/exporting means, coupled to said breeding means,

i. for importing/exporting memes said first from/to said second agent, by way of said message passing mechanisms and adding them to said pool of memes;

ii. for importing/exporting memes said first from/to said third, fourth, fifth, sixth, and seventh agents, by way of said message passing mechanisms and adding them to said pool of memes;

iii. for importing/exporting memes said third from/to said fourth, fifth, sixth, seventh, eighth, ninth, and tenth agent, by way of said message passing mechanisms and adding them to said pool of memes;

iv. for importing/exporting memes said fourth from/to said third, fifth, seventh, and eighth agent, by way of said message passing mechanisms and adding them to said pool of memes;

v. for importing/exporting memes said fifth from/to said third, fourth, sixth, seventh, and ninth agent, by way of said message passing mechanisms and adding them to said pool of memes; and

vi. for importing/exporting memes said sixth from/to said third, fifth, seventh, and tenth agent, by way of said message passing mechanisms and adding them to said pool of memes.

2. An information sharing system according to claim **1** wherein said first and second agent comprises one of the following:

a. stochastic optimization agent, or

b. stochastic optimization monitor agent.

3. An information sharing system according to claim **1** wherein said third, fourth, fifth, and sixth agent comprises one of the following:

a. stochastic optimization file system regulatory agent,

b. stochastic optimization IRD regulatory agent,

c. stochastic optimization ISI regulatory agent, or

d. stochastic optimization BRI regulatory agent.

4. An information sharing system according to claim **1** wherein said seventh, eighth, ninth, and tenth agent comprises one of the following:

a. stochastic optimization file system further agent,

b. stochastic optimization IRD further agent,

c. stochastic optimization ISI further agent, or

d. stochastic optimization BRI further agent.

5. An information sharing system according to claim **1** wherein said breeding means comprises:

a. a plurity of operators for operating meme existing in said pool to produce new memes;

b. means for allocating a weighting value to each of said operators;

c. means for selecting said operators for use, with probabilities determined by weighting values of said operators; and

d. means for adjusting said weighing values by increasing the weighing values for operators that have produced fitter memes and decreasing the weighting values of operators.

* * * * *