US 20140324897A1

(19) United States

(12) Patent Application Publication

(10) Pub. No.: US 2014/0324897 A1

(43) Pub. Date: Oct. 30, 2014

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(54) **DECISION TREE WITH JUST-IN-TIME NODAL COMPUTATIONS**

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(21) Appl. No.: **13/874,281**

(22) Filed: **Apr. 30, 2013**

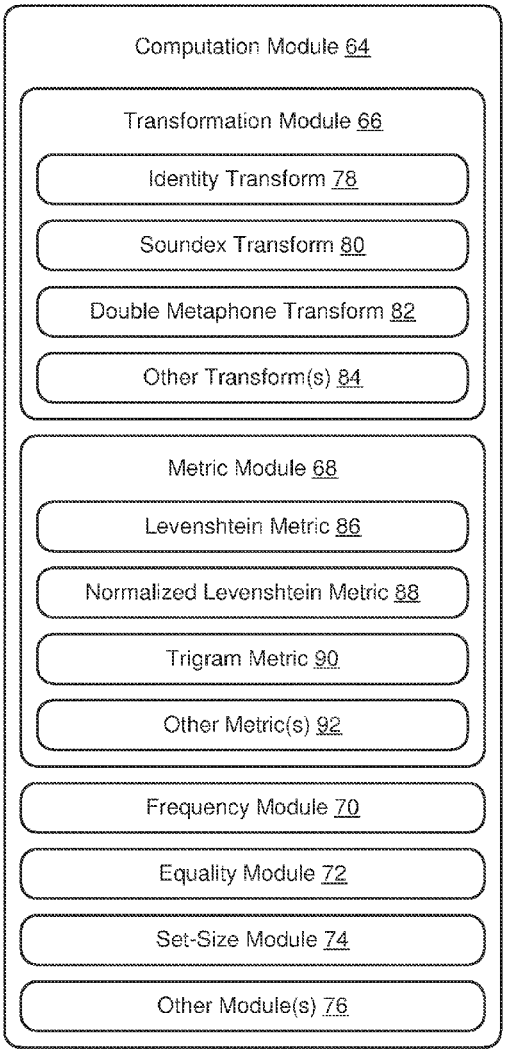
Publication Classification

(51) **Int. Cl.**
G06F 17/30 (2006.01)

(52) **U.S. Cl.**
CPC ***G06F 17/30289*** (2013.01)
USPC **707/758**

(57) **ABSTRACT**

A computer-implemented method is disclosed for efficiently processing a large number of records. In the method, a computer system may obtain a plurality of records and a decision tree. The decision tree may include a distinction node corresponding to a distinction requiring completion of a computation. Due to the fact that the computation may be, in the overall context of the process, computationally expensive, it may initially be left uncomputed. Accordingly, if the distinction node is never reached when records are being processed, no computation time gets wasted. However, if and when the distinction node is reached, the computer system may complete the computation and make the distinction based on results of the computation.



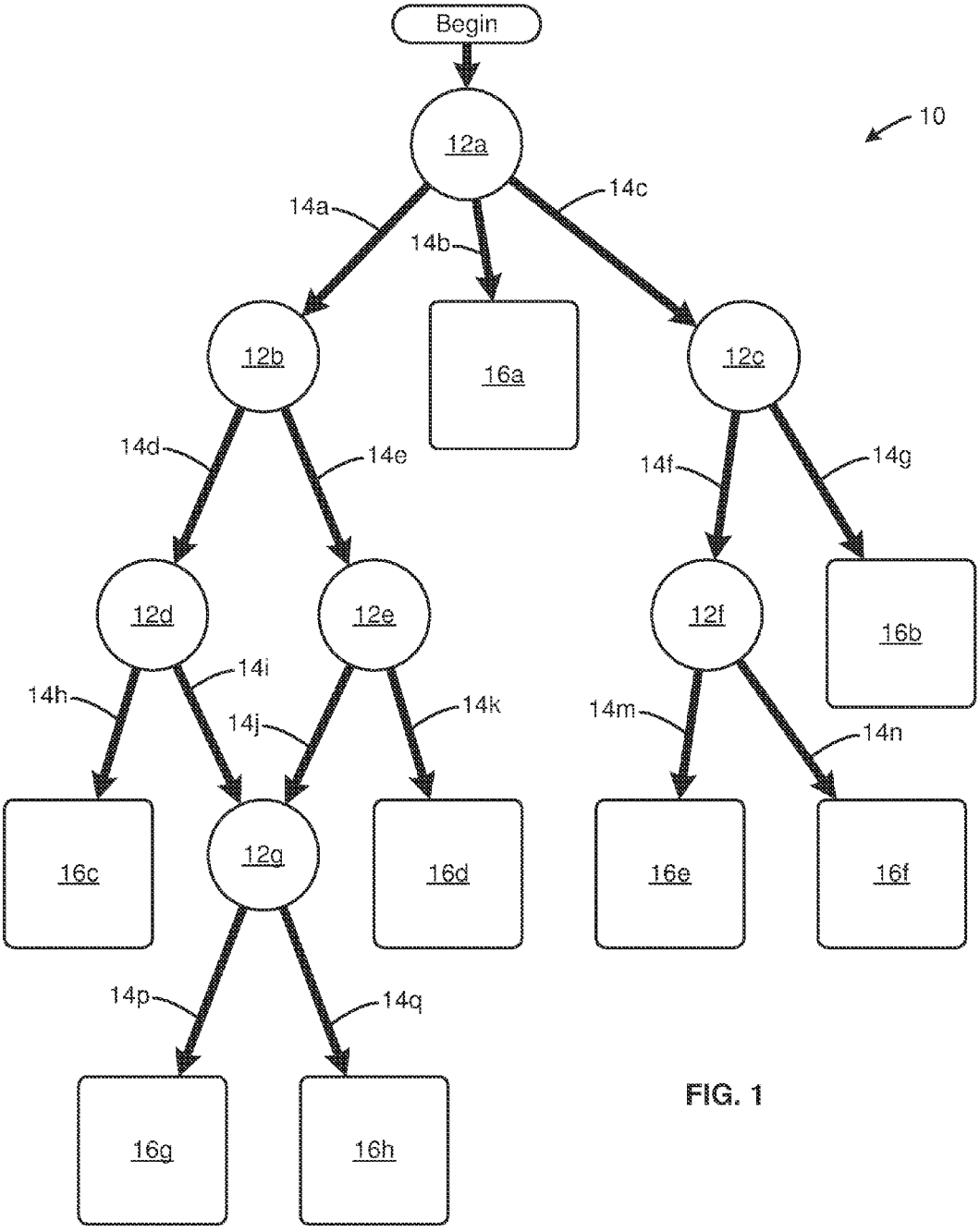

Begin
10
12a
14a
14b
14c
12b
16a
12c
14d
14e
14f
14g
12d
12e
12f
16b
14h
14i
14j
14k
14m
14n
16c
12g
16d
16e
16f
14p
14q
16g
16h

FIG. 1

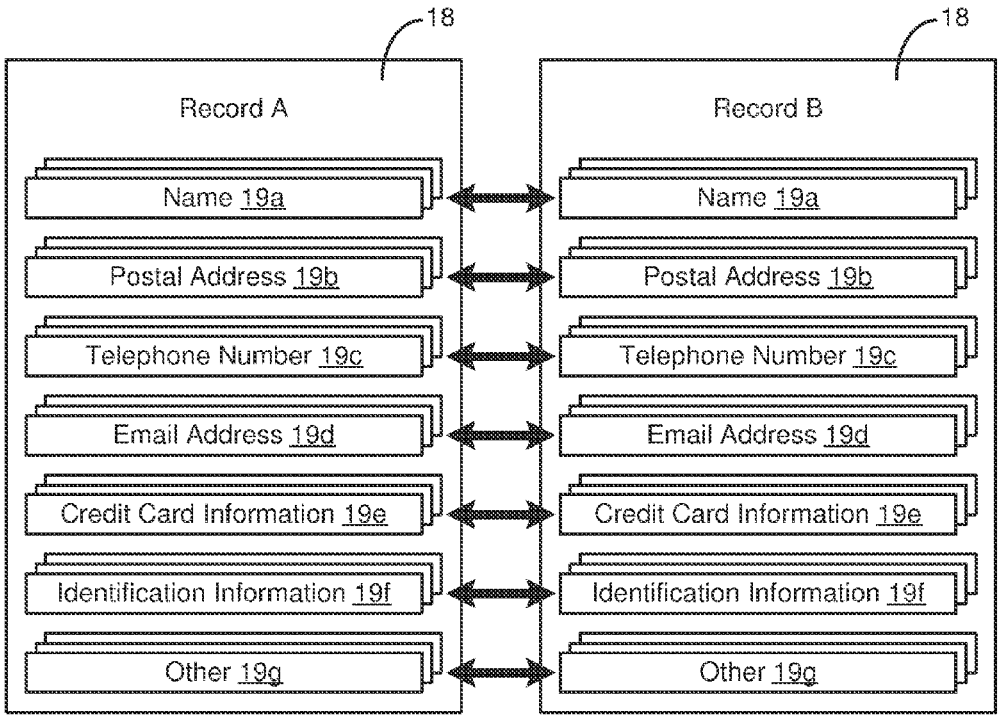

18
18
Record A
Record B
Name 19a
Name 19a
Postal Address 19b
Postal Address 19b
Telephone Number 19c
Telephone Number 19c
Email Address 19d
Email Address 19d
Credit Card Information 19e
Credit Card Information 19e
Identification Information 19f
Identification Information 19f
Other 19g
Other 19g

FIG. 2

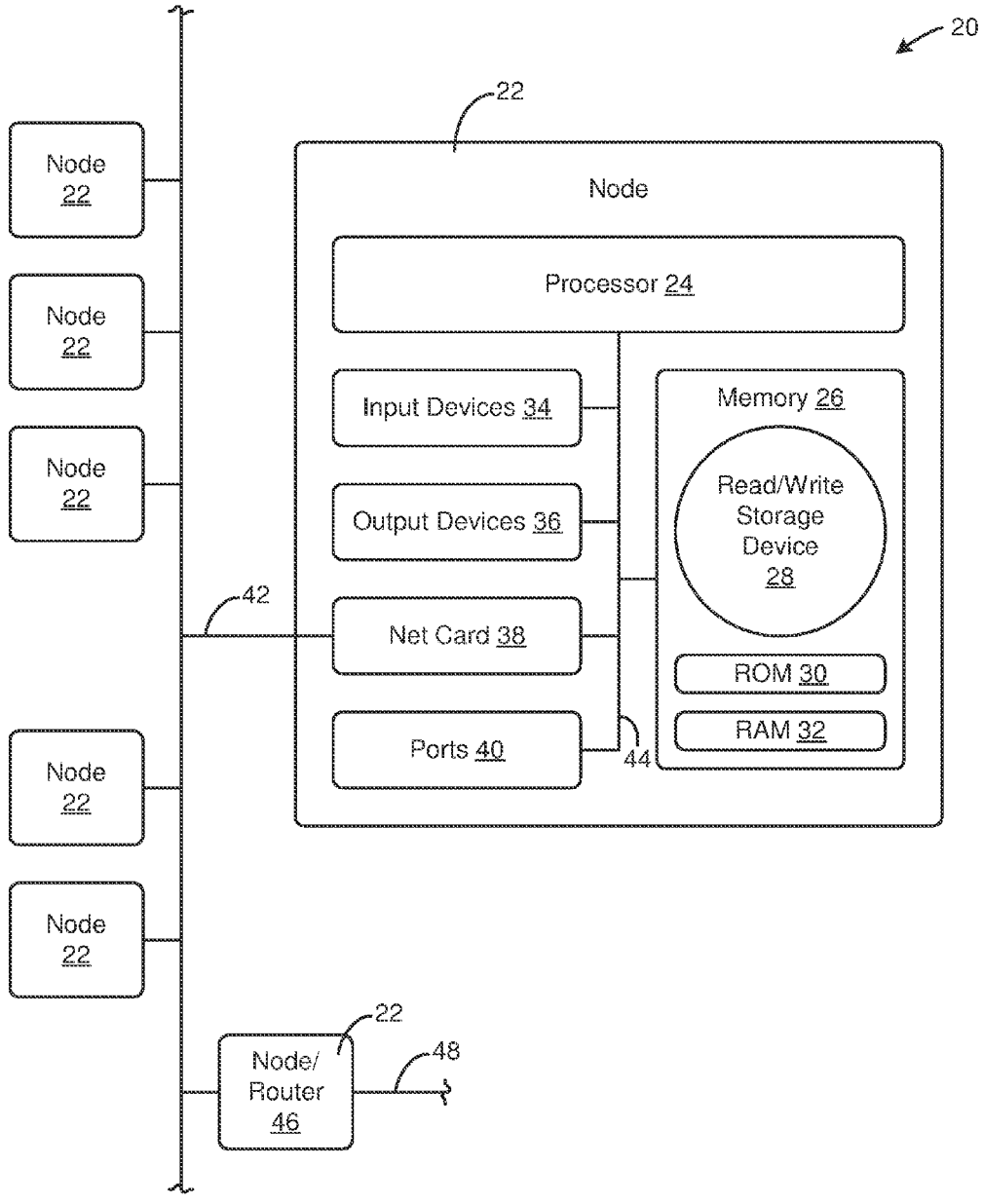

20
22
Node
Processor 24
Input Devices 34
Memory 26
Read/Write Storage Device 28
Output Devices 36
Net Card 38
ROM 30
RAM 32
Ports 40
44
42
Node 22
Node 22
Node 22
Node 22
Node 22
22
Node/ Router 46
48

FIG. 3

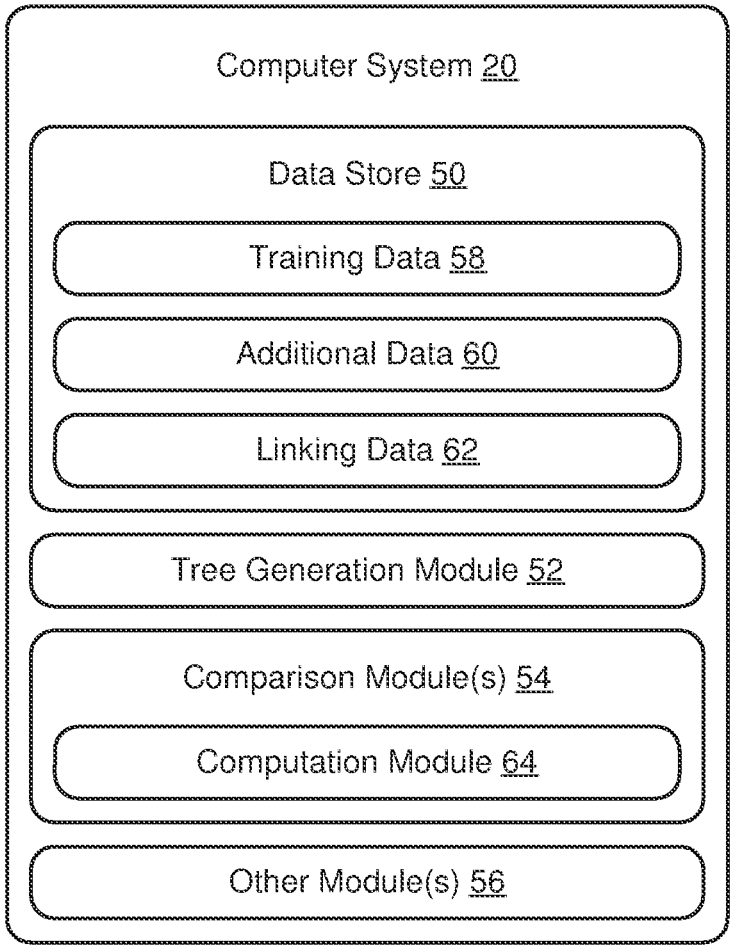

Computer System 20
Data Store 50
Training Data 58
Additional Data 60
Linking Data 62
Tree Generation Module 52
Comparison Module(s) 54
Computation Module 64
Other Module(s) 56

FIG. 4

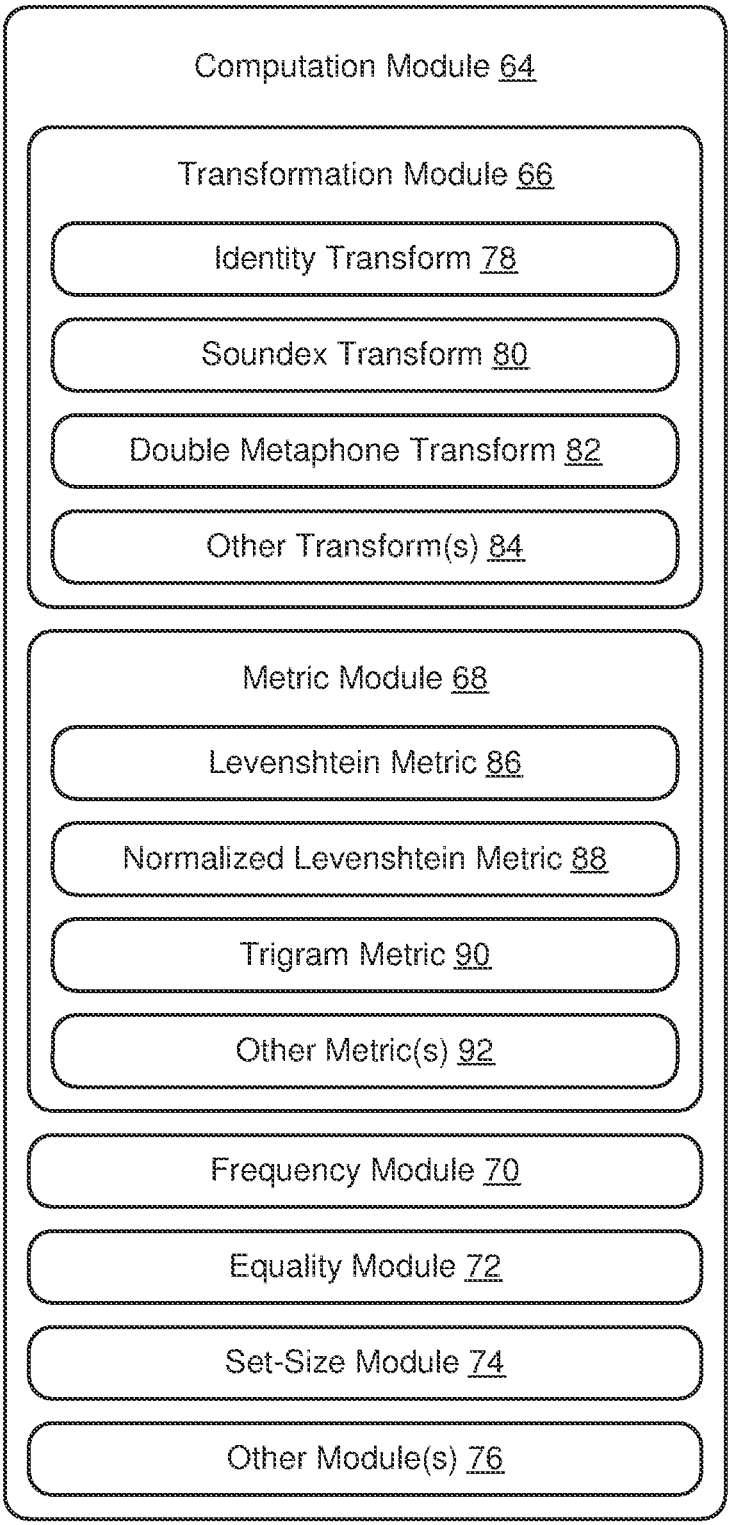

Computation Module 64
Transformation Module 66
Identity Transform 78
Soundex Transform 80
Double Metaphone Transform 82
Other Transform(s) 84
Metric Module 68
Levenshtein Metric 86
Normalized Levenshtein Metric 88
Trigram Metric 90
Other Metric(s) 92
Frequency Module 70
Equality Module 72
Set-Size Module 74
Other Module(s) 76

FIG. 5

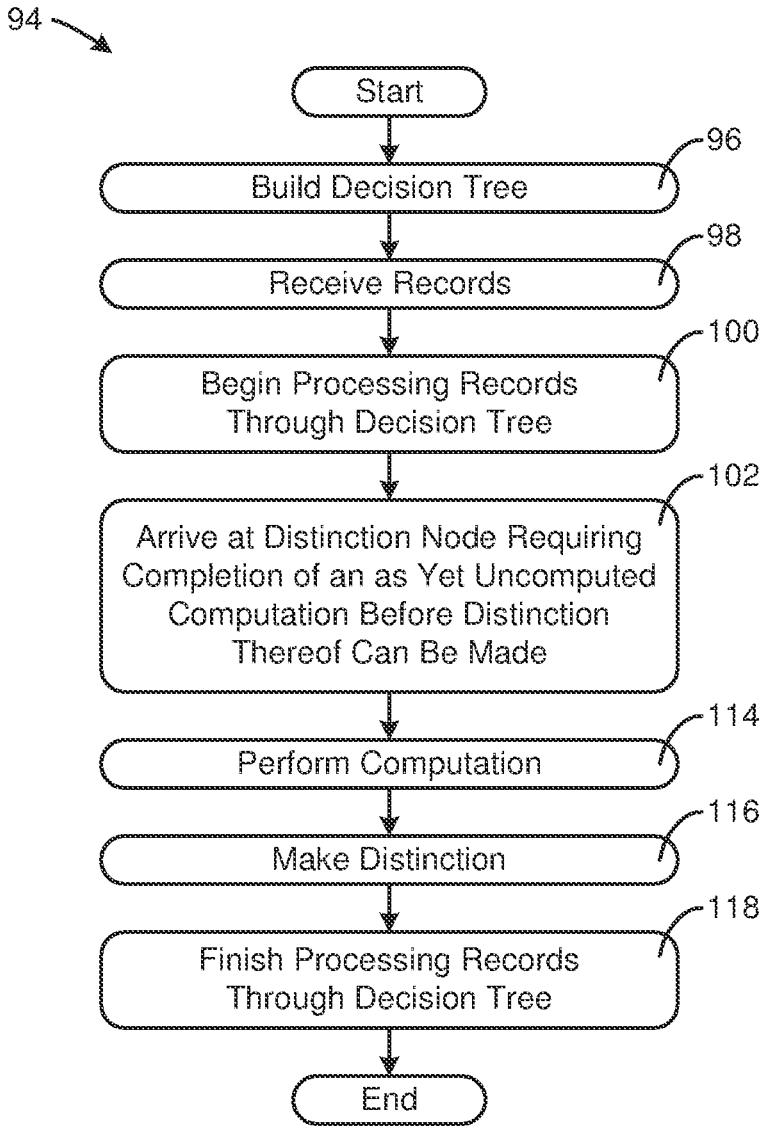

94
Start
96
Build Decision Tree
98
Receive Records
100
Begin Processing Records Through Decision Tree
102
Arrive at Distinction Node Requiring Completion of an as Yet Uncomputed Computation Before Distinction Thereof Can Be Made
114
Perform Computation
116
Make Distinction
118
Finish Processing Records Through Decision Tree
End

FIG. 6

DECISION TREE WITH JUST-IN-TIME NODAL COMPUTATIONS

BACKGROUND

[0001] 1. Field of the Invention

[0002] This invention relates to computerized record processing systems and more particularly to systems and methods for efficiently processing a collection of records through one or more decision trees.

[0003] 2. Background of the Invention

[0004] The computation time required for certain types of record processing increases rapidly as the number of records increases. For example, record linkage requires comparing pairs of records. Each such comparison is computationally expensive. Additionally, as the number records increases, the number of comparisons that need to be conducted grows exponentially. Accordingly, what is needed is a computer system configured to efficiently process large numbers of records.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] In order that the advantages of the invention will be readily understood, a more particular description of the invention briefly described above will be rendered by reference to specific embodiments illustrated in the appended drawings. Understanding that these drawings depict only typical embodiments of the invention and are not therefore to be considered limiting of its scope, the invention will be described and explained with additional specificity and detail through use of the accompanying drawings, in which:

[0006] FIG. **1** is a schematic block diagram of one embodiment of a decision tree in accordance with the present invention;

[0007] FIG. **2** is a schematic block diagram showing a comparison of two computerized records in accordance with the present invention;

[0008] FIG. **3** is a schematic block diagram of one embodiment of a computer system in accordance with the present invention;

[0009] FIG. **4** is a schematic block diagram of various functional modules that may be included within a computer system in accordance with the present invention;

[0010] FIG. **5** is a schematic block diagram of one embodiment of a computation module in accordance with the present invention; and

[0011] FIG. **6** is a schematic block diagram of one embodiment of a method for just-in-time nodal computation in accordance with the present invention.

DETAILED DESCRIPTION

[0012] It will be readily understood that the components of the present invention, as generally described and illustrated in the Figures herein, could be arranged and designed in a wide variety of different configurations. Thus, the following more detailed description of the embodiments of the invention, as represented in the Figures, is not intended to limit the scope of the invention, as claimed, but is merely representative of certain examples of presently contemplated embodiments in accordance with the invention. The presently described embodiments will be best understood by reference to the drawings, wherein like parts are designated by like numerals throughout.

[0013] Referring to FIG. **1**, record linkage may include determining if two or more records are the same, correspond or refer to the same entity, or the like. When such records are identified, record linkage may further include linking those records together in some manner.

[0014] For example, in selected embodiments, a collection of computer records may correspond to a plurality of customers (e.g., each record may comprise a customer profile). Accordingly, a computer system in accordance with the present invention may seek to link together all records within the collection that correspond to the same customer or household. In certain embodiments, a system may accomplish this by comparing various attributes of the records (e.g., customer names, addresses, telephone numbers, email addresses, or the like) using one or more decision trees **10** (e.g., a random forest of probability estimation trees **10**).

[0015] A decision tree **10** in accordance with the present invention may have any suitable form, composition, or output. In selected embodiments, a decision tree **10** may comprise a probability estimation tree. Rather than generating a simple class membership, a probability estimation tree may yield an estimate of the probability that subject data (e.g., the data being processed through a decision tree **10**) is in one or more classes. A random forest may comprise a combination of probability estimation trees, where each tree is grown on a subset of the distinctions and then all the estimates of the trees are combined to return a single class membership Probability Distribution Function (PDF) for the forest. In selected embodiments in accordance with the present invention, the subject data may comprise pairs of records that are being compared for the purpose of record linkage.

[0016] A decision tree **10** in accordance with the present invention may comprise multiple distinction or decision nodes **12**. Each distinction node **12** may correspond to a distinction that may be applied by a computer system to all subject data passing therethrough. Although only seven distinction nodes **12***a*-**12***g* are illustrated, a decision tree **10** may include any number of distinction nodes **12**.

[0017] In operation, a computer system may commence analysis of subject data at a first distinction node **12***a*. Paths **14** or branches **14** may extend from the first distinction node **12***a* to other nodes **12***b*, **12***c*. Additional paths **14** may in turn extend to yet more distinction nodes **12**. It should be noted that, although distinction nodes **12** with two and three paths **14** extending therefrom are illustrated, a distinction node **12** in accordance with the present invention may include any suitable number of paths **14** extending therefrom.

[0018] Typically, a distinction node **12** may have only one path **14** extending thereto. For example, only one path **14***a*, **14***c* leads to each of the distinction nodes **12***b*, **12***c* that immediately follow the first distinction node **12***a*. However, in selected embodiments, a decision tree **10** may include multiple paths **14** that converge on a particular distinction node **12** (e.g., paths **14***i* and **14***j* converge on distinction node **12***g*). Such a node **12** may be referred to as a "sink node."

[0019] Based on the subject data as applied to a distinction (or based on the distinction as applied to the subject data), a computer system may select a particular path **14** from among the multiple paths **14** extending from a corresponding distinction node **12**. The subject data may then be directed to (e.g., "arrive" at, "reach") another distinction node **14**. In this manner, the subject data may proceed through a decision tree **10**. At each distinction node **12**, a computer system may learn something new about the subject data.

[0020] Eventually, subject data proceeding through a decision tree **10** may be directed to a terminal point. Such terminal points may be referred to as leaf nodes **16**. A leaf node **16** may provide or correspond to information that may be used by a computer system to characterize the subject data. For example, based on the particular leaf node **16** reached and/or the particular distinction nodes **12** and paths **14** used to get there, a computer system may be able to generate a PDF for the subject data.

[0021] In selected embodiments, a PDF may identify the probabilities corresponding to various characterizations of the subject data. For example, in a record linkage embodiment, the subject data may comprise two records that are being compared to determine whether they correspond to the same person, household, or the like. Accordingly, a PDF may identify (e.g., expressly or inherently) two probabilities. One such probability may characterize the likelihood that the records correspond to the same person, household, or the like. The other such probability may characterize the likelihood that the records do not correspond to the same person, household, or the like.

[0022] Referring to FIG. **2**, computerized records **18** processed in accordance with the present invention may have any suitable form or content. In selected embodiments, records **18** may correspond to the activities of a business, information related to a business, activities of customers of one or more businesses, information related to customers of one or more businesses, or the like or a combination or sub-combination thereof. For example, as noted hereinabove, records **18** may correspond to or comprise customer profiles.

[0023] A computerized record **18** may include or contain one or more fields **19**, members **19**, attributes **19**, or the like. The nature of the attributes **19** may correspond to the nature or purpose of a record **18**. For example, a record **18** that is embodied as a customer profile may include one or more attributes **19** corresponding to contact information, demographic information, geographic information, and psychographic characteristics, buying patterns, credit-worthiness, purchase history, or the like or a combination or sub-combination thereof. Accordingly, in selected embodiments, a record **18** may include or contain attributes **19** of one or more names **19***a*, postal addresses **19***b*, telephone numbers **19***c*, email addresses **19***d*, credit card information **12***e* (e.g., codes or index information corresponding to credit card data), identification information **19***f* (e.g., account numbers, customer numbers, membership numbers, or the like), other information **19***g* as desired or necessary, or the like.

[0024] Records **18** in accordance with the present invention may be processed in any suitable manner. As noted hereinabove, in selected embodiments, it may be desirable to identify one or more links between two or more records **18**. Accordingly, an attribute **19** (e.g., telephone number **19***c*) or set of attributes **19** (e.g., set of telephone numbers **19***c*) of one record **18** may be compared to a corresponding attribute **19** or set of attributes **19** of another record **18** to identify those that correspond to the same individual, household, or the like. Such records **10** may then be linked, enabling greater benefit to be obtained thereby.

[0025] For example, records **18** corresponding to customer profiles may be generated by different sources. Certain records **18** may correspond to online purchases. Other records **18** may correspond to membership in a warehouse club. Still other records **18** may correspond to purchases in a brick-and-mortar retail store. Selected customers and/or households may correspond to records **18** from one or more such sources. However, there may not be any hard link (e.g., unifying or universal identification number) linking such records **18** together. Accordingly, a decision tree **10** may be used to identify those records **18** that correspond to the same individual, household, or the like. Once linked together, those records **18** may provide a more complete picture of the individual or household and, as a result, be more useful.

[0026] Referring to FIG. **3**, in selected embodiments, linking two or more records **18** together may require comparing pairs of records **18**. As the number records **18** increases, the number of comparisons grows exponentially. Moreover, each comparison of two records **18** may be computationally expensive. Accordingly, computer systems **20** in accordance with the present invention may employ new methodologies in order to efficiently process one or more large collections **14** of records **18** (e.g., collections **14** of over one million records **18**, five hundred million records **18**, one billion records **18**, or the like).

[0027] Since comparisons between records **18** are independent (e.g., can be conducted without inter-process communication), record linkage may be performed in a parallel computing environment. Accordingly, in selected embodiments, a computer system **20** in accordance with the present invention may provide, enable, or support parallel computing. In certain embodiments, a system **20** may be embodied as hardware, software, or some combination thereof. For example, a system **20** may include one or more computing nodes **22**.

[0028] A computing node **22** may include one or more processors **24**, processor cores **24**, or central processing units (CPUs) **24** (hereinafter "processors **24**"). Each such processor **24** may be viewed an independent computing resource capable of performing a processing workload distributed thereto. Alternatively, the one or more processors **24** of a computing node **22** may collectively form a single computing resource. Accordingly, individual workload shares may be distributed to computing nodes **22**, to multiple processors **24** of computing nodes **22**, or combinations thereof.

[0029] In selected embodiments, a computing node **22** may include memory **26**. Such memory **26** may be operably connected to a processor **24** and include one or more devices such as a hard drive **28** or other non-volatile storage device **28**, read-only memory (ROM) **30**, random access memory (RAM) **32**, or the like or a combination or sub-combination thereof. In selected embodiments, such components **24**, **26**, **28**, **30**, **32** may exist in a single computing node **22**. Alternatively, such components **24**, **26**, **28**, **30**, **32** may be distributed across multiple computing nodes **22**.

[0030] In selected embodiments, a computing node **22** may include one or more input devices **34** such as a keyboard, mouse, touch screen, scanner, memory device, communication line, and the like. A computing node **22** may also include one or more output devices **36** such as a monitor, output screen, printer, memory device, and the like. A computing node **22** may include a network card **38**, port **40**, or the like to facilitate communication through a computer network **42**. Internally, one or more busses **44** may operably interconnect various components **24**, **26**, **34**, **36**, **38**, **40** of a computing node **22** to provide communication therebetween. In certain embodiments, various computing nodes **22** of a system **20** may contain more or less of the components **24**, **26**, **34**, **36**, **38**, **40**, **44** described hereinabove.

[0031] Different computing nodes **22** within a system **20** may perform different functions. For example, one or more

computing nodes **22** within a system **20** may function as or be master computing nodes **22**. Additionally, one or more computing nodes **22** within a system **20** may function as or be worker computing nodes **22**. Accordingly, a system **20** may include one or more master computing nodes **22** distributing work to one or more worker computing nodes **22**. In selected embodiments, a system **20** may also include one or more computing nodes **22** that function as or are routers **46** and the like. Accordingly, one computer network **42** may be connected to other computer networks **48** via one or more routers **46**.

[0032] Referring to FIG. **4**, a system **20** in accordance with the present invention may process records **18** in any suitable manner. In selected embodiments, the nature of the hardware and/or software of a system **20** may reflect the specific processing to be performed. For example, a system **20** configured to link records **18** may include one or more modules providing, enabling, or supporting such functionality.

[0033] A computer system **20** in accordance with the present invention may include any suitable arrangement of modules. In certain embodiments, a computer system **20** may include a data store **50**, tree-generation module **52**, comparison module **54**, one or more other modules **56** as desired or necessary, or the like or a combination or sub-combination thereof.

[0034] In selected embodiments, certain components or modules of a computer system **20** may be associated more with computing nodes **22** of a certain type. For example, a data store **50** may be primarily or exclusively associated with one or more master computing nodes **22**. Conversely, a comparison module **54** may be primarily or exclusively associated with one or more worker computing nodes **22**.

[0035] A data store **50** may contain information supporting the operation of a computing system **20**. In selected embodiments, a data store **50** may contain or store one or more records **18**. For example, a data store **50** may contain one or more records **18** comprising training data **58** (e.g., records **18** used by a tree-generation module **52** in building one or more decision trees **10**), one or more records **18** comprising additional data **60** (e.g., records **18** to be processed for record linkage), or the like or combinations thereof. A data store **50** may also contain data, information, results, or the like produced by a computer system **20** or one or more components or modules thereof. For example, a data store **50** may contain linking data **62** identifying which records **18** correspond to the same individual, household, or the like.

[0036] A tree-generation module **52** may generate and/or train one or more of the decision trees **10** used by a comparison module **54** to process (e.g., link) records **18**. A comparison module **54** may correspond to, enable, or support the processing of one or more records **18** in any suitable manner. In selected embodiments, a comparison module **54** may enable one or more worker computing nodes **22** to compare the records **18** of a particular group amongst themselves using one or more decision trees **10** (e.g., a random forest of probability estimation trees **10**) to identify records **18** that correspond to the same individual, household, or the like.

[0037] A computer system **20** may correspond to or include multiple comparison modules **54**. For example, in a parallel computing environment, a plurality of worker computing nodes **22** may each correspond to, enable, or support a comparison module **54**. Accordingly, the number of comparison modules **54** may correspond to or match the number of worker computing nodes **22**.

[0038] In selected embodiments, a comparison module **54** may include a computation module **64**. A computation module **64** may be programmed to perform one or more computations required by the distinctions of one or more distinction nodes **12**. That is, a decision tree **10** may include one or more distinction nodes **12** corresponding to distinctions requiring completion of selected computations. Due to the fact that the computations may be, in the overall context and/or scale of the process, computationally expensive, they may initially be left uncomputed. Accordingly, if a distinction node **12** requiring such computation is never reached as subject data (e.g., a pair of records **18** being compared) is processed through a corresponding decision tree **10**, no computation time gets wasted. However, if and when the distinction node **12** is reached, a computation module **64** may complete the computation "just-in-time" or "on-demand." Thereafter, a distinction based on results of the computation may be made.

[0039] Embodiments in accordance with the present invention may be embodied as an apparatus, method, or computer program product. Accordingly, the present invention may take the form of an entirely hardware embodiment, an entirely software embodiment (including firmware, resident software, micro-code, etc.), or an embodiment combining software and hardware aspects that may all generally be referred to herein as a "module" or "system." Furthermore, the present invention may take the form of a computer program product embodied in any tangible medium of expression having computer-usable program code embodied in the medium.

[0040] Any combination of one or more computer-usable or computer-readable media may be utilized. For example, a computer-readable medium may include one or more of a portable computer diskette, a hard disk, a random access memory (RAM) device, a read-only memory (ROM) device, an erasable programmable read-only memory (EPROM or Flash memory) device, a portable compact disc read-only memory (CDROM), an optical storage device, and a magnetic storage device. In selected embodiments, a computer-readable medium may comprise any non-transitory medium that can contain, store, communicate, propagate, or transport the program for use by or in connection with the instruction execution system, apparatus, or device.

[0041] Computer program code for carrying out operations of the present invention may be written in any combination of one or more programming languages, including an object-oriented programming language such as Java, Smalltalk, C++, or the like and conventional procedural programming languages, such as the "C" programming language or similar programming languages. The program code may execute entirely on one or more master computing nodes **22**, worker computing nodes **22**, or combinations thereof. In selected embodiments, one or more master and/or worker computing nodes **22** may be positioned remotely with respect to one another. Accordingly, such computing nodes **22** may be connected to one another through any type of network, including a local area network (LAN) or a wide area network (WAN), or the connection may be made through the Internet using an Internet Service Provider.

[0042] Embodiments can also be implemented in cloud computing environments. In this description and the following claims, "cloud computing" is defined as a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned via virtualization and released

with minimal management effort or service provider interaction, and then scaled accordingly. A cloud model can be composed of various characteristics (e.g., on-demand self-service, broad network access, resource pooling, rapid elasticity, measured service, etc.), service models (e.g., Software as a Service ("SaaS"), Platform as a Service ("PaaS"), Infrastructure as a Service ("IaaS"), and deployment models (e.g., private cloud, community cloud, public cloud, hybrid cloud, etc.).

[0043] Selected embodiments in accordance with the present invention may be described with reference to flowchart illustrations and/or block diagrams of methods, apparatus (systems) and computer program products according to embodiments of the invention. It will be understood that each block of the flowchart illustrations and/or block diagrams, and combinations of blocks in the flowchart illustrations and/or block diagrams, can be implemented by computer program instructions or code. These computer program instructions may be provided to a processor of a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

[0044] These computer program instructions may also be stored in a computer-readable medium that can direct a computer or other programmable data processing apparatus to function in a particular manner, such that the instructions stored in the computer-readable medium produce an article of manufacture including instruction means which implement the function/act specified in the flowchart and/or block diagram block or blocks.

[0045] The computer program instructions may also be loaded onto a computer or other programmable data processing apparatus to cause a series of operational steps to be performed on the computer or other programmable apparatus to produce a computer implemented process such that the instructions which execute on the computer or other programmable apparatus provide processes for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

[0046] Referring to FIG. **5**, in selected embodiments, one or more computations corresponding to or performed by a computation module **64** may be distinguishable from distinctions made at distinction nodes **12**. In general, computations performed by a computation module **64** may be more computationally intensive than distinctions. Alternatively, or in addition thereof, computations performed by a computation module **64** may be prerequisites for distinctions. That is, the distinctions of the corresponding distinction nodes **12** cannot be meaningfully attempted until one or more corresponding computations of the computation module **64** are complete.

[0047] For example, a distinction of a distinction node **12** may question whether the normalized Levenshtein distance for two compared character strings is less than 0.02. Thus, the distinction may be a simple comparison to see whether the particular normalized Levenshtein distance is less than 0.02. However, such a distinction cannot be meaningfully attempted or made until the normalized Levenshtein distance for the two compared character strings has been computed. Such prerequisite computation may be the domain of a computation module **64** in accordance with the present invention.

[0048] A computation module **64** in accordance with the present invention may include any suitable arrangement of sub-components or modules. The nature of such sub-components or modules may depend on the nature of the distinctions of one or more corresponding decision trees **10**. In certain embodiments, a computation module **64** may include a transformation module **66**, metric module **68**, frequency module **70**, equality module **72**, set-size module **74**, one or more other modules **76** performing other prerequisite computations as desired or necessary, or the like or a combination or sub-combination thereof.

[0049] A transform module **66** may support, enable, or provide the computation associated with transformations of attributes **19**. For example, a transform module **66** may enable a transformation of a particular character string into a phonetic representation thereof. Accordingly, a transformation module **66** may support or enable distinctions and distinction nodes **12** based on phonetic representations or the like. In certain embodiments, a transform module **66** may include, support, or enable an identify transform **78**, Soundex transform **80**, Double Metaphone transform **82**, one or more other transforms **84** as desired or necessary, or the like or a combination or sub-combination thereof.

[0050] A metric module **68** may support, enable, or provide the computation associated with one or more metrics. For example, a metric module **68** may enable a computation of one or more metrics that numerically characterize the similarity or dissimilarity between two compared character strings. Accordingly, a metric module **68** may support or enable distinctions and distinction nodes **12** based on string similarity. In certain embodiments, a metric module **68** may include, support, or enable a Levenshtein metric **86** for calculating a Levenshtein distance, a normalized Levenshtein metric **88** for calculating a normalized Levenshtein distance, a trigram metric **90** based on the presence or absence of selected trigrams (e.g., a trigram ratio corresponding to the number of trigrams found in both compared character strings, divided by the number of trigrams found in either compared character string), one or more other metrics **92** as desired or necessary, or the like or a combination or sub-combination thereof.

[0051] A frequency module **70** may support, enable, or provide the computation associated with one or more occurrence patterns or frequencies. For example, a frequency module **70** may enable a computation of a value characterizing how common a particular name is in a given population or set. Accordingly, a frequency module **70** may support or enable distinctions and distinction nodes **12** based on occurrence patterns or frequencies.

[0052] An equality module **72** may support, enable, or provide the computation associated with a determination of whether two compared attributes **19** are equal, interchangeable, match, or the like. For example, an equality module **72** may enable a "just-in-time" determination of whether one character string identifying a state of residence (or synonyms, abbreviations, or the like thereof) matches another character string identifying a state of residence. Accordingly, an equality module **72** may support or enable distinctions and distinction nodes **12** based on whether one character string is equal to another character string.

[0053] A set-size module **74** may support, enable, or provide the computation associated with determining the size of one or more sets of attributes **19**. For example, a set-size module **74** may enable a computation of the quantity of tele-

phone numbers **19***c* corresponding to a particular record **18**. Accordingly, a set-size module **74** may support or enable distinctions and distinction nodes **12** based on the size of one or more sets of attributes **19**.

[0054] Referring to FIG. **6**, in selected embodiments, a method **94** for processing of a collection of computerized records **18** may begin with building **96** one or more decision trees **10** and receipt **98** of a collection of records **18** (or access thereto) by a system **20** in accordance with the present invention. Sometime subsequent thereto, the collection of records **18** may be divided into groups and distributed among a plurality of worker computing nodes **22**, where processing the records through a decision tree **10** may begin **100**. Accordingly, the number of groups may correspond to the number of worker computing nodes **22** that are to process the records **18**.

[0055] At some point during the processing of the records **18**, subject data (e.g., a pair of records **18** being compared to one another) may arrive **102** at a distinction node **12**. The distinction node **12** may correspond to a particular computation. As yet, that computation may be uncomputed. However, the computation may be a prerequisite for the distinction corresponding to the distinction node **12**. Accordingly, after the arrival **102** of the subject data at the distinction node **12**, the computation may be performed **114** (e.g., by a computation module **64**).

[0056] The exact nature of the computation may depend on the nature of the distinction of the distinction node **12**. In selected embodiments, the computation may include one or more transformations, metric calculations, frequency calculations, equality calculations, set-size calculations, or the like or combinations or sub-combinations thereof.

[0057] The computation may be uncomputed at the time of arrival at the distinction node **12** because, in selected embodiments or situations, the computation may not be needed. That is, as subject data passes through a decision tree **10**, it will not reach every distinction node **12**. Any time spent on computations corresponding to missed distinction nodes **12** will be wasted. Accordingly, a computer system **20** (e.g., a computation module **64**) may improve efficiency by performing **114** computations just-in-time or on demand as necessary.

[0058] Once the computation has been completed, the distinction of the corresponding distinction node **12** may be made **116**. The processing of the records **18** through the decision tree **10** may then continue until it is finished **118** or completed **118**. In selected embodiments, continuing through the decision tree **10** may include arriving at another distinction node **12** requiring completion of an as yet uncomputed computation. Accordingly, selected steps **102**, **114**, **116** of a method **94** in accordance with the present invention may be repeated.

[0059] The flowchart in FIG. **6** illustrates the architecture, functionality, and operation of possible implementations of systems, methods, and computer program products according to certain embodiments of the present invention. In this regard, each block in the flowchart may represent a module, segment, or portion of code, which comprises one or more executable instructions for implementing the specified logical function(s). It will also be noted that each block of the flowchart illustration, and combinations of blocks in the flowchart illustration, may be implemented by special purpose hardware-based systems that perform the specified functions or acts, or combinations of special purpose hardware and computer instructions.

[0060] It should also be noted that, in some alternative implementations, the functions noted in the blocks may occur out of the order noted in the Figure. In certain embodiments, two blocks shown in succession may, in fact, be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved. Alternatively, certain steps or functions may be omitted if not needed.

[0061] The present invention may be embodied in other specific forms without departing from its spirit or essential characteristics. The described embodiments are to be considered in all respects only as illustrative, and not restrictive. The scope of the invention is, therefore, indicated by the appended claims, rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

What is claimed is:

1. A computer-implemented method for efficiently processing a large number of records, the method comprising:
- obtaining, by a computer system, a plurality of records;
- obtaining, by the computer system, a decision tree;
- processing, by the computer system, the plurality of records through the decision tree; and
- the processing comprising
  - arriving at a distinction node of the decision tree, the distinction node corresponding to a distinction requiring completion of an as yet uncomputed computation,
  - completing, by the computer system after the arriving, the computation, and
  - making the distinction based on results of the computation.

2. The method of claim **1**, wherein the decision tree is programmed to perform record linkage.

3. The method of claim **2**, wherein each record of the plurality of records comprises a customer profile.

4. The method of claim **3**, wherein the decision tree is programmed to identify records with the plurality of records that are likely to correspond to a common customer or household.

5. The method of claim **4**, wherein the distinction corresponds to a metric characterizing a similarity between attributes of compared records of the plurality of records.

6. The method of claim **5**, wherein the computation comprises calculation of the metric.

7. The method of claim **6**, wherein the metric is selected from the group consisting of a Levenshtein distance, normalized Levenshtein distance, trigram score, and trigram ratio.

8. The method of claim **1**, wherein the computing system provides a parallel computing environment.

9. The method of claim **8**, wherein the computer system comprises a plurality of worker nodes.

10. The method of claim **9**, wherein the processing is conducted by the plurality of worker nodes.

11. The method of claim **1**, wherein the distinction corresponds to a metric characterizing a similarity between attributes of compared records of the plurality of records.

12. The method of claim **11**, wherein the computation comprises calculation of the metric.

13. The method of claim **12**, wherein the metric is selected from the group consisting of a Levenshtein distance, normalized Levenshtein distance, trigram score, and trigram ratio.

14. The method of claim **1**, wherein:
- each record of the plurality of records comprises a customer profile; and

the plurality of records comprises at least five hundred million records.

15. A computer-implemented method for efficiently processing a large number of records, the method comprising:

obtaining, by a computer system, a plurality of records, each record of the plurality of records comprises a customer profile;

obtaining, by the computer system, a decision tree programmed to identify records with the plurality of records that are likely to correspond to a common customer or household;

processing, by the computer system, the plurality of records through the decision tree; and

the processing comprising

arriving at a distinction node of the decision tree, the distinction node corresponding to a metric characterizing a similarity between character strings of compared records of the plurality of records,

calculating, by the computer system after the arriving, a value corresponding to the metric, and

making the distinction based on the value.

16. The method of claim **15**, wherein the metric is selected from the group consisting of a Levenshtein distance, normalized Levenshtein distance, trigram score, and trigram ratio.

17. The method of claim **15**, wherein the computing system provides a parallel computing environment.

18. The method of claim **17**, wherein the computer system comprises a plurality of worker nodes.

19. The method of claim **18**, wherein the processing is conducted by the plurality of worker nodes.

20. A computer system comprising:

a plurality of processors;

one or more memory devices operably connected to one or more processors of the plurality of processors; and

the one or more memory devices collectively storing

a plurality of records,

a plurality of comparison modules, each programmed to process records of the plurality of records through a decision tree comprising a distinction node making a distinction based on a value corresponding to a metric characterizing a similarity between character strings of compared records of the plurality of records,

the plurality of comparison modules, each further programmed to calculate the value corresponding to the metric only after the distinction node is reached, and

the plurality of comparison modules, each further programmed to make the distinction based on the value.

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