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(54) **EFFICIENT DATA PROCESSING**

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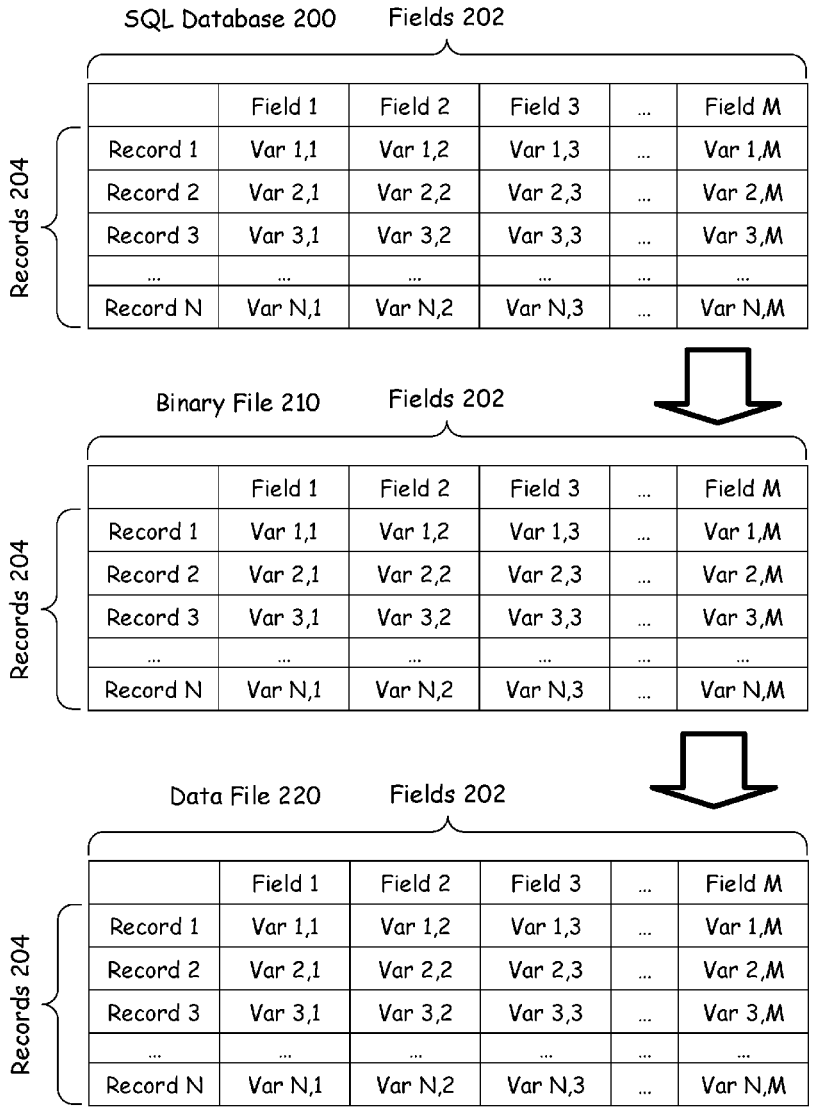
(57) **ABSTRACT**

A method for improving the operation of a computer by transferring data from an SQL database in a storage unit to a memory by copying the data from the SQL database to a binary file in the storage unit, where the binary file having a data structure and a data type. A data file having the data structure and the data type is configured within the memory, and the binary file in the storage unit is copied to the data file in the memory with a single read/write operation.



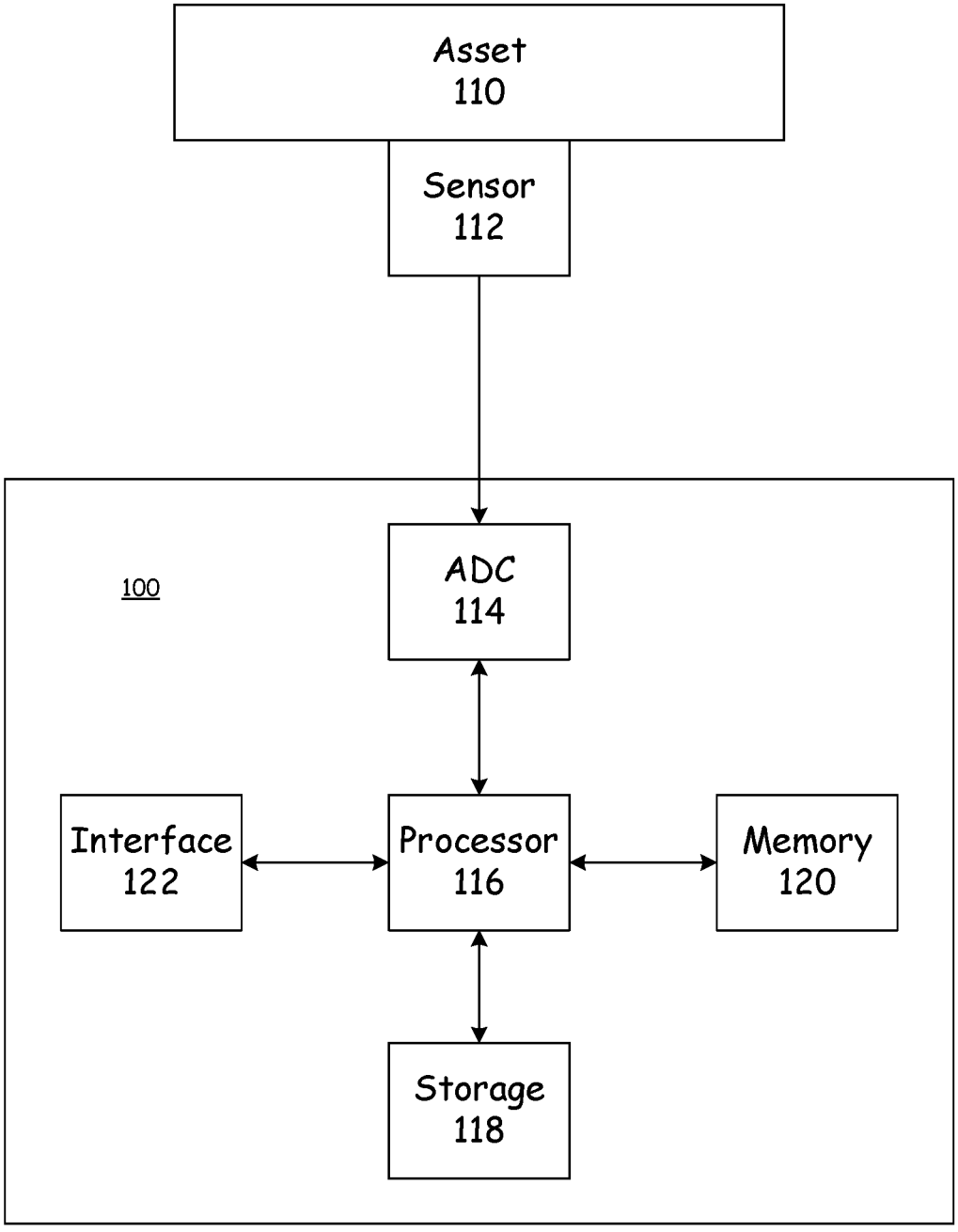

Asset
110
Sensor
112
100
ADC
114
Interface
122
Processor
116
Memory
120
Storage
118

Fig. 1

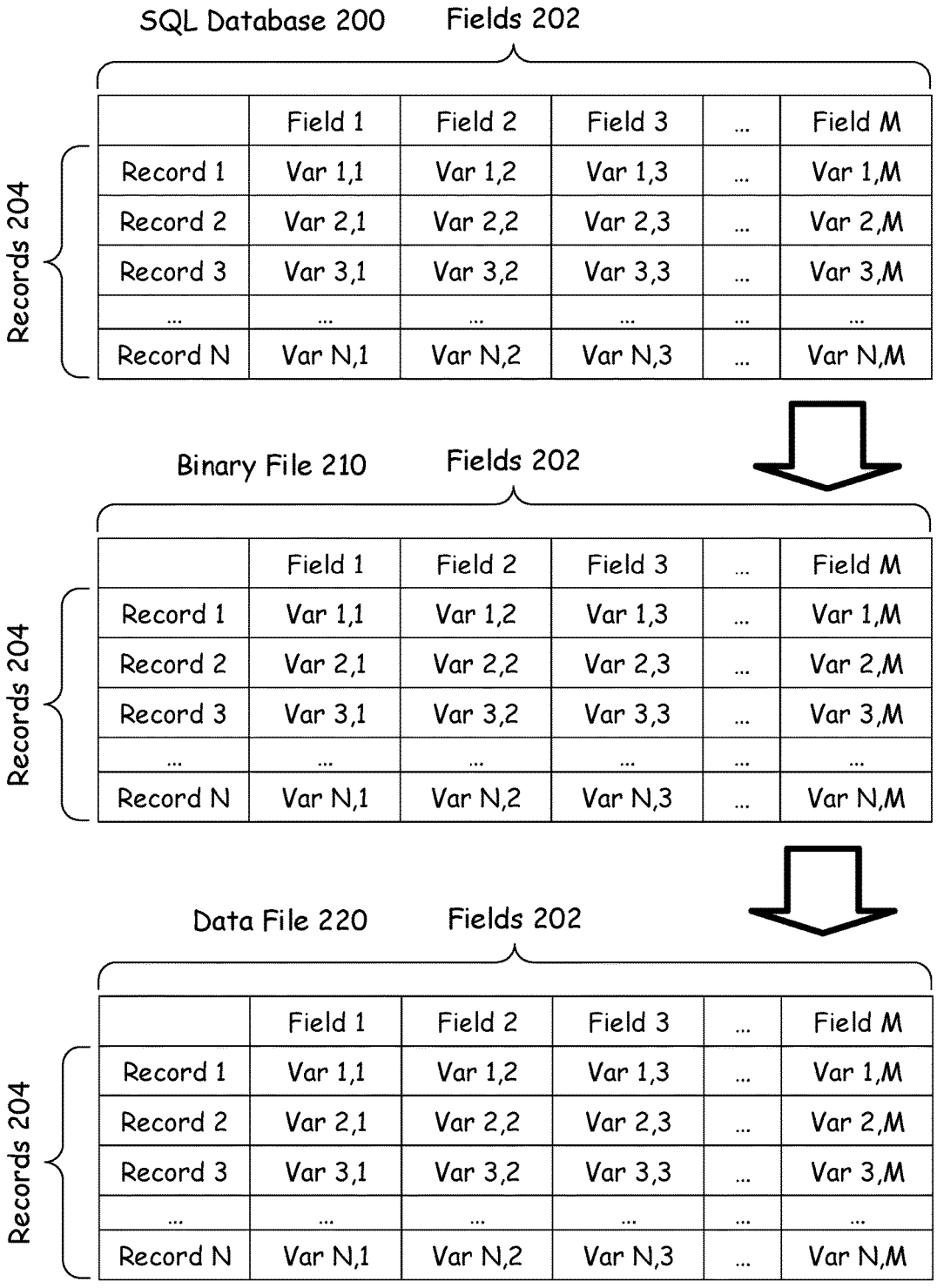

SQL Database 200
Fields 202
Records 204
Field 1
Field 2
Field 3
...
Field M
Record 1
Var 1,1
Var 1,2
Var 1,3
Var 1,M
Record 2
Var 2,1
Var 2,2
Var 2,3
Var 2,M
Record 3
Var 3,1
Var 3,2
Var 3,3
Var 3,M
Record N
Var N,1
Var N,2
Var N,3
Var N,M
Binary File 210
Data File 220

Fig. 2

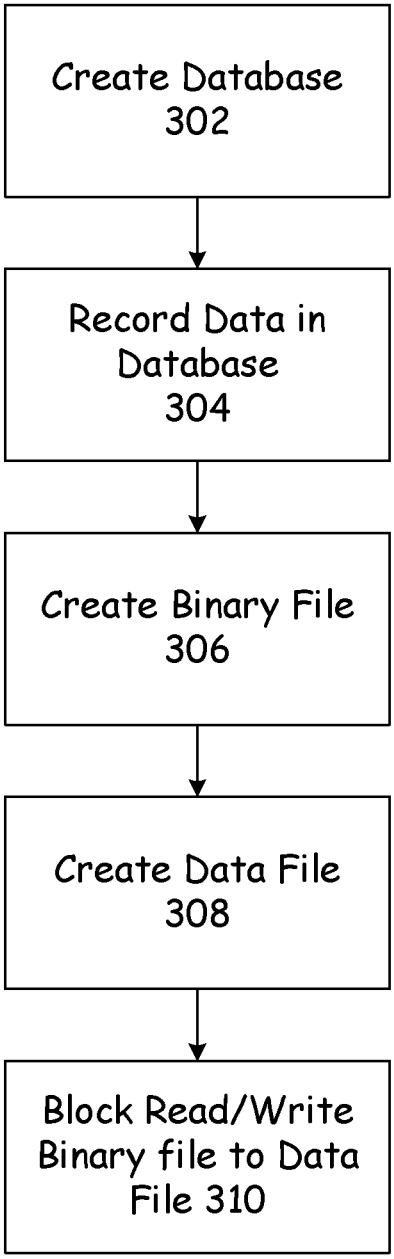

Create Database
302
Record Data in
Database
304
Create Binary File
306
Create Data File
308
Block Read/Write
Binary file to Data
File 310

Fig. 3

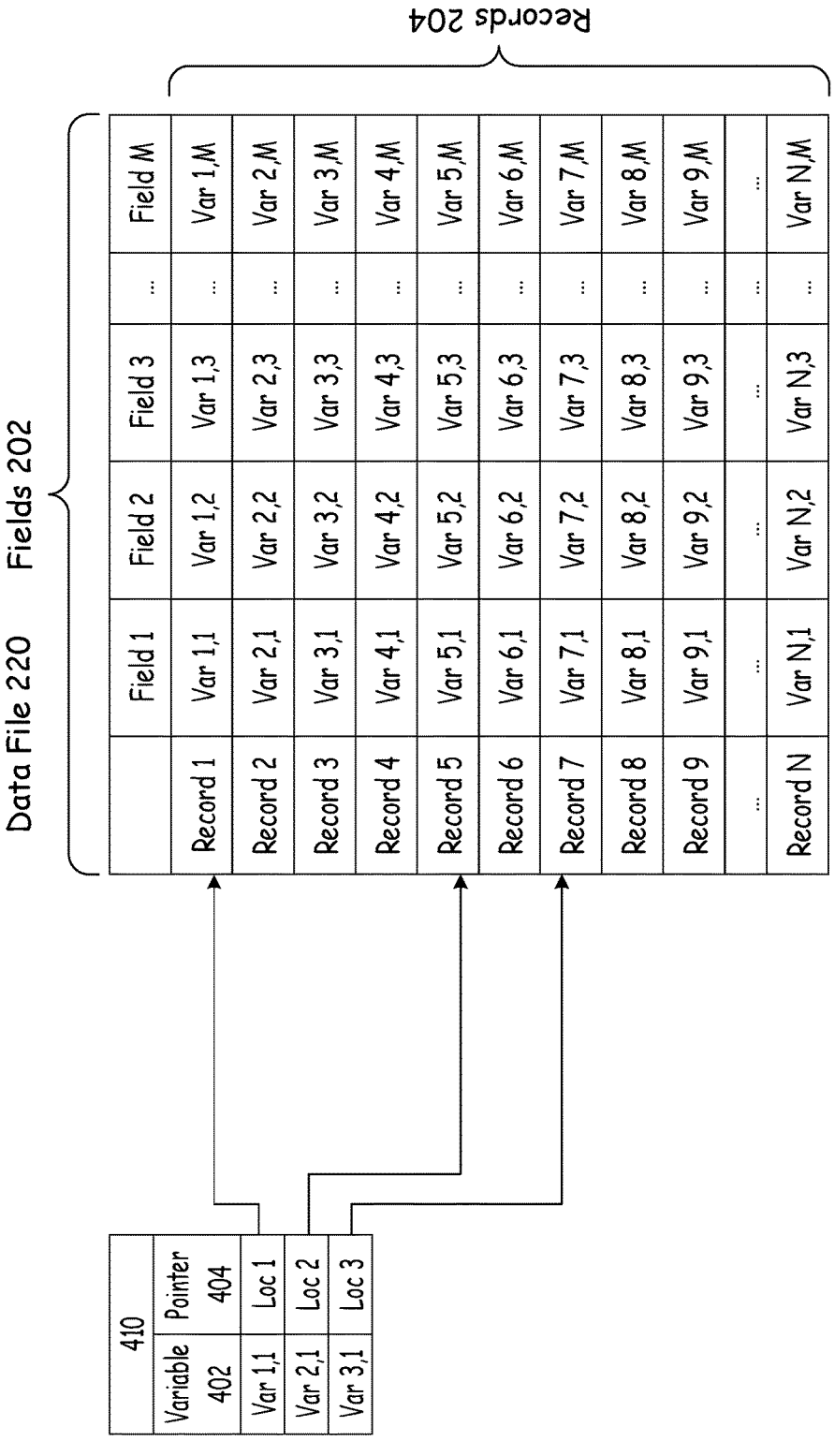

Records 204
Data File 220
Fields 202
Field 1
Field 2
Field 3
...
Field M
Record 1
Var 1,1
Var 1,2
Var 1,3
...
Var 1,M
Record 2
Var 2,1
Var 2,2
Var 2,3
...
Var 2,M
Record 3
Var 3,1
Var 3,2
Var 3,3
...
Var 3,M
Record 4
Var 4,1
Var 4,2
Var 4,3
...
Var 4,M
Record 5
Var 5,1
Var 5,2
Var 5,3
...
Var 5,M
Record 6
Var 6,1
Var 6,2
Var 6,3
...
Var 6,M
Record 7
Var 7,1
Var 7,2
Var 7,3
...
Var 7,M
Record 8
Var 8,1
Var 8,2
Var 8,3
...
Var 8,M
Record 9
Var 9,1
Var 9,2
Var 9,3
...
Var 9,M
...
...
...
...
...
Record N
Var N,1
Var N,2
Var N,3
...
Var N,M
410
Variable 402
Pointer 404
Var 1,1
Loc 1
Var 2,1
Loc 2
Var 3,1
Loc 3

Fig. 4

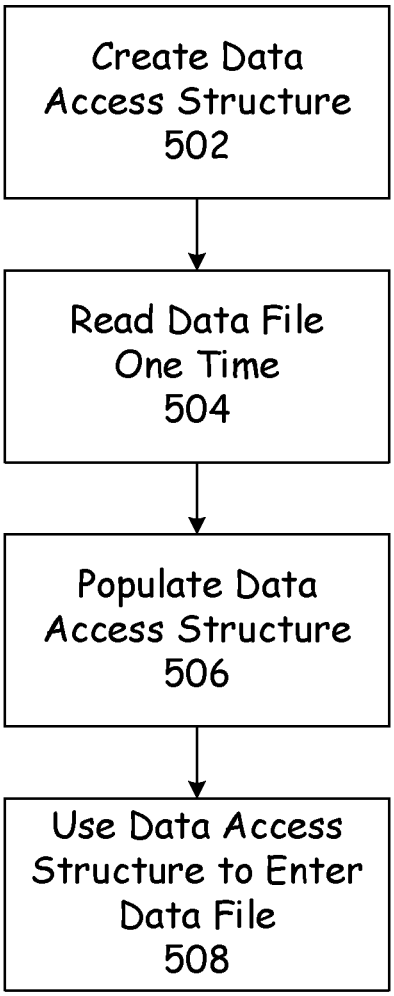

Create Data Access Structure 502
Read Data File One Time 504
Populate Data Access Structure 506
Use Data Access Structure to Enter Data File 508

Fig. 5

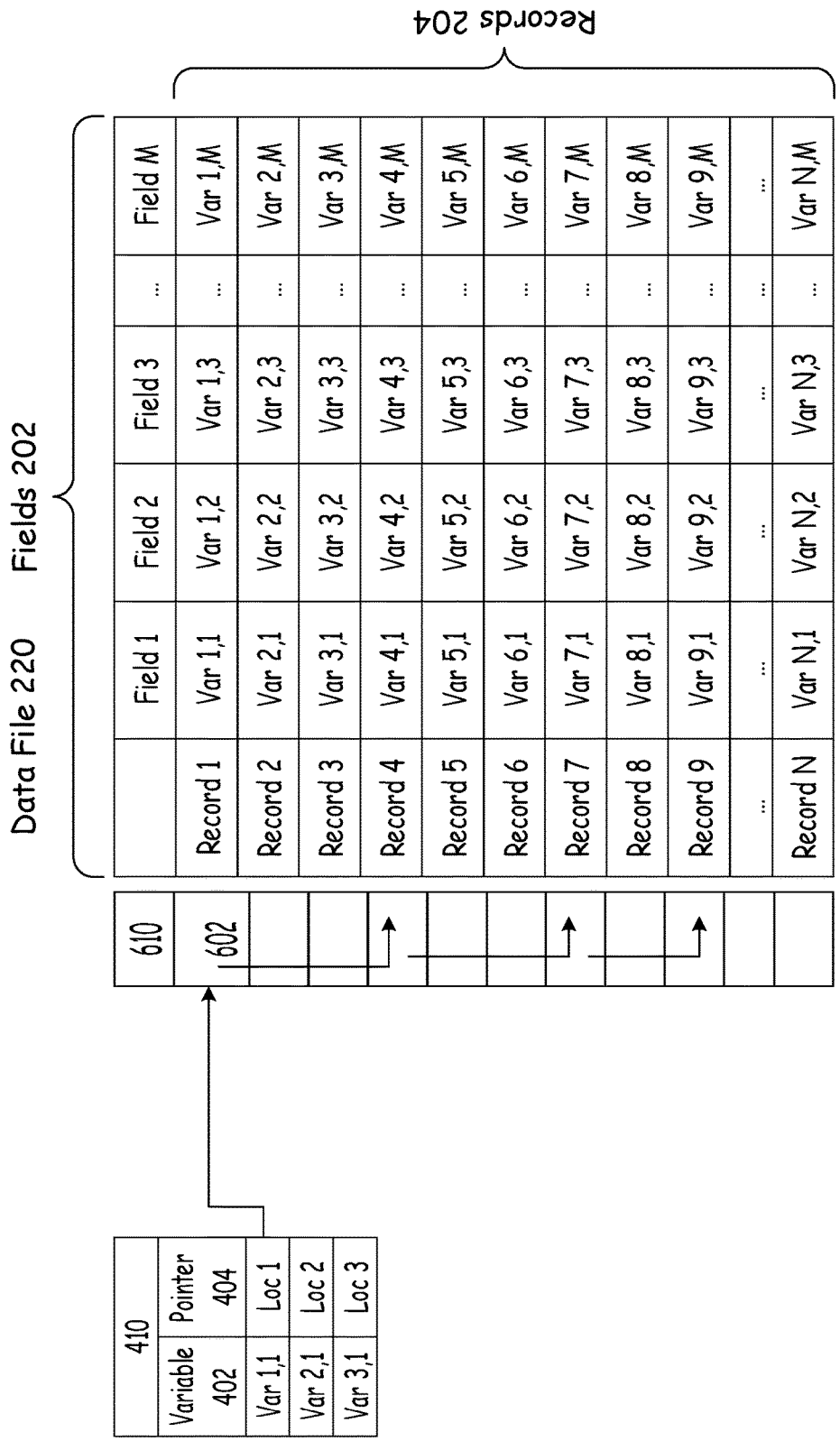

Records 204
Data File 220
Fields 202
Field 1
Field 2
Field 3
...
Field M
Record 1
Var 1,1
Var 1,2
Var 1,3
...
Var 1,M
Record 2
Var 2,1
Var 2,2
Var 2,3
...
Var 2,M
Record 3
Var 3,1
Var 3,2
Var 3,3
...
Var 3,M
Record 4
Var 4,1
Var 4,2
Var 4,3
...
Var 4,M
Record 5
Var 5,1
Var 5,2
Var 5,3
...
Var 5,M
Record 6
Var 6,1
Var 6,2
Var 6,3
...
Var 6,M
Record 7
Var 7,1
Var 7,2
Var 7,3
...
Var 7,M
Record 8
Var 8,1
Var 8,2
Var 8,3
...
Var 8,M
Record 9
Var 9,1
Var 9,2
Var 9,3
...
Var 9,M
...
...
...
...
...
Record N
Var N,1
Var N,2
Var N,3
...
Var N,M
610
602
410
Variable 402
Pointer 404
Var 1,1
Loc 1
Var 2,1
Loc 2
Var 3,1
Loc 3

Fig. 6

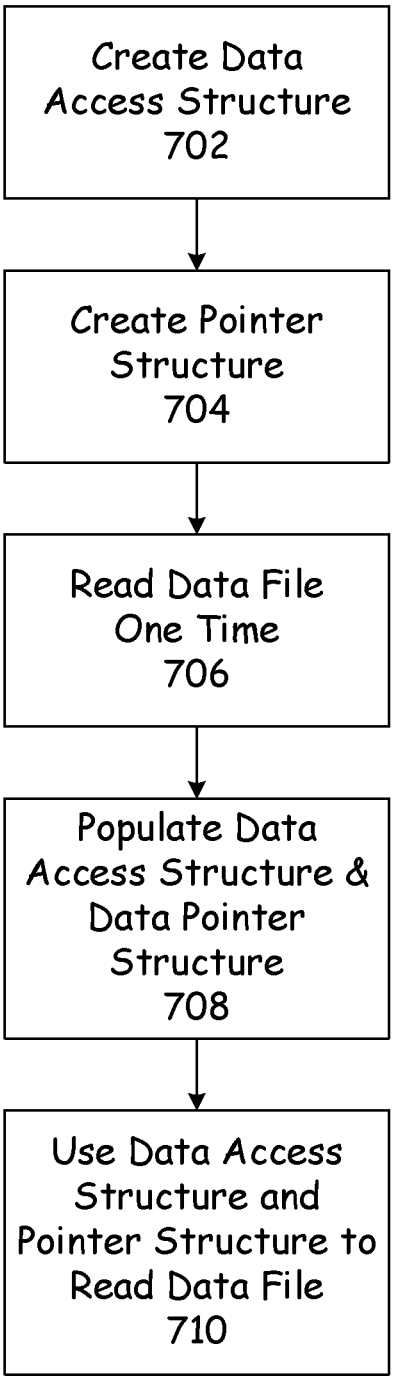

Create Data Access Structure 702
Create Pointer Structure 704
Read Data File One Time 706
Populate Data Access Structure & Data Pointer Structure 708
Use Data Access Structure and Pointer Structure to Read Data File 710

Fig. 7

	X = Var 1	X = Var 2	X = Var 3	X = Var ...	X = Var *M*
Y = Var 1	Unity	$\frac{\sum_t (x_t - \bar{x})(y_t - \bar{y})}{\sqrt{\sum_t (x_t - \bar{x})^2}\sqrt{\sum_t (y_t - \bar{y})^2}}$	$\frac{\sum_t (x_t - \bar{x})(y_t - \bar{y})}{\sqrt{\sum_t (x_t - \bar{x})^2}\sqrt{\sum_t (y_t - \bar{y})^2}}$	$\frac{\sum_t (x_t - \bar{x})(y_t - \bar{y})}{\sqrt{\sum_t (x_t - \bar{x})^2}\sqrt{\sum_t (y_t - \bar{y})^2}}$	$\frac{\sum_t (x_t - \bar{x})(y_t - \bar{y})}{\sqrt{\sum_t (x_t - \bar{x})^2}\sqrt{\sum_t (y_t - \bar{y})^2}}$
Y = Var 2	Duplicate	Unity	$\frac{\sum_t (x_t - \bar{x})(y_t - \bar{y})}{\sqrt{\sum_t (x_t - \bar{x})^2}\sqrt{\sum_t (y_t - \bar{y})^2}}$	$\frac{\sum_t (x_t - \bar{x})(y_t - \bar{y})}{\sqrt{\sum_t (x_t - \bar{x})^2}\sqrt{\sum_t (y_t - \bar{y})^2}}$	$\frac{\sum_t (x_t - \bar{x})(y_t - \bar{y})}{\sqrt{\sum_t (x_t - \bar{x})^2}\sqrt{\sum_t (y_t - \bar{y})^2}}$
Y = Var 3	Duplicate	Duplicate	Unity	$\frac{\sum_t (x_t - \bar{x})(y_t - \bar{y})}{\sqrt{\sum_t (x_t - \bar{x})^2}\sqrt{\sum_t (y_t - \bar{y})^2}}$	$\frac{\sum_t (x_t - \bar{x})(y_t - \bar{y})}{\sqrt{\sum_t (x_t - \bar{x})^2}\sqrt{\sum_t (y_t - \bar{y})^2}}$
Y = Var ...	Duplicate	Duplicate	Duplicate	Unity	$\frac{\sum_t (x_t - \bar{x})(y_t - \bar{y})}{\sqrt{\sum_t (x_t - \bar{x})^2}\sqrt{\sum_t (y_t - \bar{y})^2}}$
Y = Var *M*	Duplicate	Duplicate	Duplicate	Duplicate	Unity

810

Fig. 8

EFFICIENT DATA PROCESSING

FIELD

[0001] This invention relates to the field of data processing. More particularly, this invention relates to improving the operation of a computer by providing more efficient reading and locating of data, particularly database data stored in a storage unit of a computer.

INTRODUCTION

[0002] Many systems and methods produce the collection and storage of large amounts of data. With modern relational databases, the preservation of large quantities of data within a storage unit, such as on magnetic or optical storage media, is not a problem. However, accessing this data can be very time consuming. For example, reading six million records from a structured query language (SQL) database on a storage unit can take as long as thirty seconds. Thirty seconds might not seem too long, but if there were 600 million records it would take fifty minutes to read all the data, which in many applications is too long.

[0003] When only a relatively small number of records are needed, this length of time is acceptable, and a standard SQL management system can be used to interrogate the database. However, when analyses are to be performed on large blocks of data, or when different configurations of the data are required, the standard interrogation of a database is much too slow, and the issues described above become more pronounced.

[0004] As a specific example, it is common to gather vibration information on rotating equipment so that problems that are manifested with vibration signatures can be quickly detected and resolved. Capturing a live stream of such information produces large amounts of data for even a single asset. However, for companies that have many such assets, the amount of information that is produced is extremely large. That large amount of information is then further compounded by keeping and adding to the data over long periods of time.

[0005] Because these databases of information are so large and take so long to interrogate, many who would otherwise desire to do so are dissuaded from accessing them unless the need is dire or the amount of data to be read is relatively small, and so they do not interrogate them for all the analyses that might be of use to them.

[0006] What is needed, therefore, are computer systems improvements that tend to reduce issues such as those described above, at least in part.

SUMMARY

[0007] The above and other needs are met by a method for transferring data from an SQL database in a storage unit to a memory by copying the data from the SQL database to a binary file in the storage unit, where the binary file having a data structure and a data type. A data file having the data structure and the data type is configured within the memory, and the binary file in the storage unit is copied to the data file in the memory with a single read/write operation.

[0008] In some embodiments according to this aspect of the invention, the data structure includes records and fields, with a number of records and a number of fields for each record. In some embodiments, the data type comprises at least one of real, integer, and word length.

[0009] When the records of the data file are sorted, some embodiments also include reading through the entire data file only once to find record positions for data containing predetermined data characteristics. A pointer table is created in the memory, where the pointer table includes a single record position for a first instance of each of the predetermined data characteristics within the data file. The data file is read starting at the record position in the pointer table that corresponds to a desired one of the predetermined data characteristics.

[0010] When the records of the data file are unsorted, some embodiments also include reading through the entire data file only once to find record positions for data containing predetermined data characteristics. A first pointer table is created in the memory, where the first pointer table includes a single record position for a first instance of each of the predetermined data characteristics within the data file. A second pointer table is created in the memory, where the second pointer table includes, in association with the record position for the first instance of each of the predetermined data characteristics, a subsequent record position for a next subsequent instance of each of the predetermined data characteristics within the data file. The data file is read starting at the record position in the first pointer table that corresponds to a desired one of the predetermined data characteristics, and if the data in the record position does not contain the desired data, the data file is iteratively read at the record position associated with the next subsequent instance in the second pointer table, until the desired data is found.

[0011] Some embodiments for correlating variables in the data file include the steps of reading the data file a first time to determine averages $\bar{x}$ and $\bar{y}$ for each x and y variable pair to be correlated. The data file is read a second time to determine, for each x_i and y_i variable, the following three values, where i represents the number of variables,

$$\Sigma_i(x_i-\bar{x})(y_i-\bar{y}),$$

$$\sqrt{\Sigma_i(x_i-\bar{x})^2}, \text{ and}$$

$$\sqrt{\Sigma_i(y_i-\bar{y})^2}.$$

[0012] Each of the three values is stored in a cell of an array designated for the x_i and y_i variable pair. Using the three values in the array for each combination of x_i and y_i variables, the correlation value r is computed according to the formula

$$r = \frac{\sum_i (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_i (y_i - \bar{y})^2}\sqrt{\sum_i (y_i - \bar{y})^2}}.$$

[0013] According to another aspect of the invention there is described a method for reading a data file of records in a memory by reading through the entire data file only once to find record positions for data containing predetermined data characteristics. A pointer table is created in the memory, the pointer table including a single record position for a first instance of each of the predetermined data characteristics within the data file. The data file is read starting at the record position in the pointer table that corresponds to a desired one of the predetermined data characteristics.

[0014] In some embodiments, each record in the data file includes a plurality of fields, and all the fields are sorted

according to a predetermined order. In some embodiments, each record of the data file includes a plurality of fields, all the fields are sorted according to a predetermined order, and the pointer table includes, for each of the fields, a single record position associated with a first instance for each of the predetermined data characteristics for each field.

[0015] According to another aspect of the present invention there is described a method for reading a data file of unsorted records to locate desired data by reading through the entire data file only once to find record positions for data containing predetermined data characteristics. A first pointer table is created in the memory, where the first pointer table includes a single record position for a first instance of each of the predetermined data characteristics within the data file. A second pointer table is created in the memory, where the second pointer table includes, in association with the record position for the first instance of each of the predetermined data characteristics, a subsequent record position for a next subsequent instance of each of the predetermined data characteristics within the data file. The data file is read starting at the record position in the first pointer table that corresponds to a desired one of the predetermined data characteristics, and if the data in the record position does not contain the desired data, iteratively reading the data file at the record position associated with the next subsequent instance in the second pointer table, until the desired data is found.

[0016] In some embodiments according to this aspect of the present invention, a first pointer table and a second pointer table are created for each field within the data file.

[0017] According to yet another aspect of the present invention there is described a method for correlating variables in a data file by reading the data file a first time to determine averages $\bar{x}$ and $\bar{y}$ for each x and y variable pair to be correlated. The data file is read a second time to determine, for each x_i and y_i variable the following three values, where i represents the number of variables,

$\Sigma_i(x_i-\bar{x})(y_i-\bar{y})$,

$\sqrt{\Sigma_i(x_i-\bar{x})^2}$, and

$\sqrt{\Sigma_i(y_i-\bar{y})^2}$.

[0018] Each of the three values is stored in a cell of an array designated for the x_i and y_i variable pair. Using the three values in the array for each combination of x_i and y_i variables, the correlation value r is computed according to the formula,

$$r = \frac{\sum_i (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_i (y_i - \bar{y})^2}\sqrt{\sum_i (y_i - \bar{y})^2}}.$$

[0019] In some embodiments, the correlation value r is only calculated for unique combinations of the x_i and y_i variables.

DRAWINGS

[0020] Further advantages of the invention are apparent by reference to the detailed description when considered in conjunction with the figures, which are not to scale so as to more clearly show the details, wherein like reference numbers indicate like elements throughout the several views, and wherein:

[0021] FIG. **1** is a schematic representation of a computer system for collecting and analyzing vibrational data from a machine.

[0022] FIG. **2** is a graphical illustration of a method for transferring data from a database in a storage unit to a data file in a computer memory in a single read/write step.

[0023] FIG. **3** is a flow chart for the method illustrated in FIG. **2**.

[0024] FIG. **4** is a graphical illustration of a method for selecting data for analysis according to a second embodiment of the disclosure.

[0025] FIG. **5** is a flow chart for the method illustrated in FIG. **4**.

[0026] FIG. **6** is a graphical illustration of a method for selecting data for analysis according to a third embodiment of the disclosure.

[0027] FIG. **7** is a flow chart for the method illustrated in FIG. **6**.

[0028] FIG. **8** is a two-dimensional array for calculating correlation coefficients for pairs of variables in a data file according to an embodiment of the disclosure.

DESCRIPTION

Apparatus

[0029] FIG. **1** illustrates, schematically, a computer system **100** according to an embodiment of the present invention. In some embodiments, the computer system **100** is one of an imbedded computing device such as a Raspberry Pi, a handheld computer such as a phone or PDA, a portable computer such as a tablet or laptop, a desktop computer such as a PC, and a main frame computer. In the embodiment depicted, the computer system **100** receives data from a sensor **112**, such as might be reading vibration data from an asset **110**, such as a machine with a rotating element. In one embodiment, the computer system **100** and sensor **112** constitute a handheld vibration analyzer. In other embodiments, the computer system **100** and sensor **112** constitute a remote vibration analyzer that is mounted on the asset **110**. Other embodiments are also comprehended.

[0030] In some embodiments, the computer system **100** includes an analog to digital converter (ADC) **114** for receiving analog sensor data and converting it to digital data, a processor **116** for performing operations on the data and for controlling the other elements of the computer system **100**, a storage device **118** for storing data (such as on magnetic or optical media), a memory **120** for storing instructions for the operation of the computer system **100**, and for the temporary storage of data when there are operations to be performed on the data by the processor **116** (such as DRAM), and an interface **112** for presenting visual or audible information or communicating with other systems.

[0031] As used herein, the term database refers to a data structure that is stored on the data storage unit **118**, and is in a format that is configured for reading and writing by the database management program, such as an SQL database program. The term binary file refers to a data file that is stored on the data storage unit **118** and is in a flat file configuration of records and fields. The term data file refers

to data that is stored on the memory **120**, and is in a flat file configuration of records and fields.

[0032] To overcome the lengthy read times for databases disposed on the storage unit **118**, as described above, all or a portion of the data can be written into and optionally maintained as a structured binary file in the storage **118** for rapid transfer into the memory **120**. In one embodiment, the time required to copy the structured binary file from the storage **118** to the memory **120** was 2,000 time faster than using an SQL management program to read an SQL database on the storage unit **118** into the memory **120**. For example, if reading the SQL database takes thirty seconds to copy the data, copying the data from the binary file of the same data on the storage unit **118** only takes fifteen milliseconds to read. This is accomplished with a single block read/write operation from the binary file to the data file. Thus, if there were 100 times more data than this, the binary file approach would only take 1.5 seconds, which would be far more practical than the fifty minutes needed to read the SQL database.

[0033] As a part of this process, the data file in the memory **120** and the binary file in the storage unit **118** are both configured according to the properties of the data that is extracted from the SQL database. It is appreciated that in some embodiments all the data in the SQL database is to be extracted, and in other embodiments only a portion of the data in the SQL database is to be extracted. However, as the amount of data to be extracted increases, the benefits of the embodiments of the present invention are more fully realized.

Data Transfer

[0034] FIG. **2** graphically illustrates a method for copying the data in the SQL database **200** on the storage unit **118** to the binary file **210** on the storage unit **118** and then into the data file **220** in the memory **120**. In this example, the database **200** on the storage unit **118** is comprised of a number N of records **204** that include a number M of fields **202**, in which different variables are recorded. It is appreciated that the SQL database **200** can include any number of records **204** and fields **202**, and that the numbers M and N depicted in FIG. **2** are representative only. The data as depicted in the SQL database **200** of FIG. **2** is formatted as a flat file. However, this depiction is used for clarity in the description, and such flat file formatting would typically not be used in an SQL database **200**, but rather a relational formatting would typically be used.

[0035] In addition to the actual data that is contained in the SQL database **200**, there is also metadata. That metadata includes, for example, the number N of records **204**, the number M of fields **202** in each record **204**, the type of data in each field **202**, and the length of each field **202**. The type of data includes designations such as integer, small integer, real, and so forth. The length of each field **202** is, in most embodiments, measured in bytes of data. As used herein, data structure refers to such metadata as the number N of records **204** and the number M of fields **202** in each record **204**. As used herein, data type refers to such metadata as the type of data in each field **202**, and the length of each field **202**.

[0036] The metadata from the SQL database **200** is used to construct both the binary file **210** on the storage unit **118** and the data file **220** in the memory **120**. This involves a configuration processes such as mapping out a block in the memory **120** of the appropriate size, so that when data is eventually read into the data file **220**, it can all be done in one continuous read/write operation. In some embodiments the structure of the binary file **210** is constructed first, and in other embodiments the structure of the data file **220** is constructed first.

[0037] The data is then read out from the SQL database **200** and into the binary file **210**. During this process, the structure of data as contained in the SQL database **200** is modified to the flat file structure of the binary file **210**. This might take some length of time, but it only need be done once, and then the binary file **210** can be retained and even updated on the storage unit **118**, as desired. As new data is entered into the SQL database **200**, it can also be added to the binary file **210**.

[0038] When the data from the SQL database **200** needs to be loaded into the memory **120** for analysis, such as might be determined by some sort of event driven trigger, the numbers N and M of records **204** and fields **202** are determined and an array of the required size is created in the memory **120** as the starting point for the data file **220**. Using a single read/write operation, the data in the binary file **210** is read directly into the array of the data file **220** in the memory **120**. As the structure of the data in the binary file **210** and the data file **220** are the same, no additional data conversion is required. This makes for a very efficient transfer of the data in the binary file **210** into the data file **220** and saves a considerable amount of time in acquiring the data.

[0039] The overall system flow **300** is shown in FIG. **3**. As given in block **302**, the database **200** is first created on the storage unit **118**, and data is recorded in the database **200** as given in block **304**. In various embodiments, the data is vibrational data that is received from one or more of different sources, such as a portable vibration analyzer and an online vibration analyzer. The binary file **210** is created in the storage unit **118**, as given in block **306**. At a desired point in time, the data file **220** is created in the memory **120**, and is created to have the same characteristics as the binary file **210**, such as by using the metadata. Finally, the data from the binary file **210** is copied into the data file **220** in the memory **120** with a single continuous read/write operation, as given in block **310**. The number N of records and number M of fields in the binary file **210** may also recorded as an entry in the binary file **210** and the data file **220**.

[0040] In this manner there is provided a method for performing a much quicker read of data from the storage unit **118** to the memory **120**.

Data Access I

[0041] Some data sets can be sorted in one manner or another according to one or more fields, and this makes them more easily analyzed than does the order in which the data was originally generated. This first data access method is in regard to such data sets.

[0042] According to this method, the data file **220** in the memory **120** is sorted according to some desired criteria, such as numerically ascending values of the variable in the first field **202**. For example, if the variables in the first field of the data file **220** were four-digit integers, the sorting operation described above would result in all of the variables that started with the number 1 being first in the data file **220**, then all of the variables that started with 2 being next, and

so forth. Likewise, there would be some number of variables starting with 1, another number of variables starting with 2, and so on.

[0043] If it were desired to perform an analysis on those records **204** having variables in the first field **202** that started with the number 8, for example, a prior art system would have to read down through the records **204** in the data file **220** until the 8's were encountered in the first field **202**. If there were millions of records **204** in the data file **220**, this might waste a tremendous amount of time, in relative terms, especially if this operation needed to be performed multiple times.

[0044] Therefore, according to an embodiment according to the present invention, the data file **220** is read through one time, and an indexing pointer table **410** is created, as depicted in FIG. **4**. The pointer table **410** contains, for example, a minimum of two fields for each record in the pointer table **410**. In the first field **402** are the various indexed values of the variables of the first field **202** of the data file **220**, to continue the example from above. Thus, this portion **402** of the pointer table **410** would contain one of the numbers 0-9 in each of the records. In a field **404** of the pointer table **410** are descriptions of the position of the first instance in the data file **220** of the desired value. This position descriptor can be something such as the number of a record **204** or an address in the memory **120** at which the first instance of the desired data is stored. The lines from table **410** to data file **220** are graphical indications of the location of the records that include the first instance of the desired variable.

[0045] Again continuing the example from above, if variables starting with the number 8 are desired for analysis, the pointer table **410** is interrogated to find the number 8 in the first column, and then the memory location for the first instance of the desired variable is read from the pointer table **410**, and then that information is used to start a read of the data file **220**. In this manner, the time associated with reading through unwanted data is saved.

[0046] In a further embodiment, the pointer table **410** is also read to determine the memory location of the first instance of the next succeeding variable value, which to continue the example would be the number 9. With this memory location know, the read of the data file **220** can automatically be stopped when the last 8 variable has been read. In this manner, the knowledge of the exact size of the read prior to the start of the read can have some benefits, such as an elimination of the analysis of the data as it is read out to determine the stop of the read, and also such as mapping out in advance a portion of the memory **120** with a predetermined size in which to place the read variables, as desired.

[0047] FIG. **5** provides a simplified flow chart of this method. The first step is to create the data access structure **410**, as given in block **502**. As discussed above, this can be accomplished with a single read of the data file **220**, as given in block **504**. The data access structure **410** is then populated with the information gathered from the data file **220**, as given in block **506**. Thereafter, the data access structure **410** is used to enter the data file **220**, as given in block **508**, which removes the need to read down through the data file **220** starting at the top whenever new data is to be retrieved from the data file **220**.

Data Access II

[0048] In some embodiments, however, the data might be received according to multiple contiguous sequences having structures that are not immediately reflected in the received data. For example, different variables **202** are received in records **204**, but neither the variables **202** nor the records **204** reflect the sequence into which the data is organized, otherwise referred to herein as a data trend, and there might be value in analyzing different data trends separately, without disturbing the order in which the data is received.

[0049] In such an embodiment, a marker such as a trend identification can be added to the data to identify the data trends one from another. For example, all of the records **204** belonging to the first data trend could be identified with a 1, all the records **204** in the second data trend identified with a 2, and so forth, with the data trend identification stored, for example, in a new variable **202** field. Then the pointer table **410** is constructed with the data trend identifier in column **402**, which is used to enter a desired data trend in the same manner as described above.

[0050] The pointers **404** in table **410** enable a computer to rapidly sequence through the data in the data file **220**, and can also be used to provide an order in which the data is to be processed. Using this approach, trend data may be accessed in a very efficient and timely manner. Computer performance tests using six million records of vibrational trend data, according to the embodiment of FIGS. **4** and **5**, produced a one order of magnitude increase in computer performance on a standalone computer system. A network with multiple users could be expected to provide an even greater performance improvement using these methods.

Data Access III

[0051] In some applications, it may be necessary to analyze the data in the order in which it is received, and so the data cannot be sorted according to the embodiments of Data Access I. The goal is to find and access all instances of a particular variable value. One embodiment, as depicted in FIG. **6**, is to leave the data file **220** in the order in which the data was originally created, such as a time series, read the data file **220** through once, and while so doing, create the pointer table **410** as given above that includes in field **404** the first instance for given variables **202** and the associated memory position in field **402** for each.

[0052] A second pointer table **610** is created in memory **120** to provide a subsequent record position or memory location that is associated with a subsequent instance of the desired variable **602**. This is represented in FIG. **6** as pointer table **610**, where arrows represent additional entry points into the data file **220** in which subsequent instances of the desired variable **602** are located. Thus, there would be a separate table **610** for each of the variables indexed in the data access structure **410**. In this manner, data that is associated with the desired variable value can be relatively quickly located in an unsorted data file **220**, without the need to read the data file **220** down from the top multiple times.

[0053] FIG. **7** depicts a method for this embodiment, where a memory location for the data access structure **410** is created, as given in block **702**. A memory location for the pointer table **610** is also created, as given in block **704**. The data file **220** is read through a single time, as given in block **706**, and the data access structure **410** and the data pointer table **610** are populated with the data as described above, as

given in block **708**. Thereafter, the data file **220** is interrogated using the data access structure **410** and the pointer table **610**, as given in block **710**.

Variable Correlation

[0054] Finding the correlation that might exist between one variable **202** in a given set of records **204** and another variable **202** in the given set of records **204** enables an analyst to discover additional insight into the behavior of the system that created the data. The variables **202** may include vibration data characteristics for a machine, machine characteristics, or a combination of machine and vibration characteristics for the machine.

[0055] With reference to FIG. **8**, there is depicted a graphical depiction for how this is done. Such a task can be visualized by listing each of the variables **202** across the top of the matrix **810**, and then also listing those same variables **202** down the left side of the matrix **810**. The variables **202** across the columns are designated as x_i, where i varies from one to M (the total number of variables being analyzed), and the variables **202** down the rows are designated as y_i. The box at the intersection of a given row and column represents the correlation between the two variables **202** represented by the intersecting row and column.

[0056] Obviously, each of the variables **202** correlates perfectly with itself, and so the boxes on the chart that are at the intersection of a row and column that each represent the same variable **202** (x_1 and y_1, for example) are represented by unity, and so no computation for correlation for that intersection need be made. Further, all of those boxes on one side of the unity diagonal represent the exact same correlation as those boxes on the other side of the unity line (the correlation between x_1 and y_2 is the same as the correlation between x_2 and y_1), and thus are duplicates that need not be calculated. Therefore, if there are M variables **202** to be correlated, one need only do the computations for

$$\left(\left(\frac{M^2}{2}\right)-M\right)$$

unique variable **202** pairs.

[0057] The correlation r between each unique combination of two variables **202** *x* and *y* is determined by solving the following equation:

$$r=\frac{\sum_i (x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum_i (y_i-\bar{y})^2}\sqrt{\sum_i (y_i-\bar{y})^2}}.$$

[0058] However, this equation has traditionally required several passes through every record of the database in order to compute the value for one given correlation pair. Thus, computing the correlation coefficients for a large number of records **204**, where each record **204** has a large number of variables **202**, can be very time consuming. For example, calculating the correlations for six million records **204** with 274 variables **202** each took 1.5 hours, which is far too long for many applications.

[0059] According to one embodiment, all correlation coefficients between two unique pairs of variables **202** can be determined by using only two passes through the database. In the first pass through the database, average values $\bar{x}$ and $\bar{y}$ for each x and y variable **202** pair to be correlated are determined. The database is then read a second time to determine for each x_i and y_i variable the following three values:

$$\Sigma_i(x_i-\bar{x})(y_i-\bar{y}),$$

$$\sqrt{\Sigma_i(x_i-\bar{x})^2},$$

$$\sqrt{\Sigma_i(y_i-\bar{y})^2}.$$

[0060] Each of the three values for the above formulas is independently stored in the memory **120** in an array designated for each x_i and y_i variable pair as shown in FIG. **8**. After these three portions of the overall correlation equation have been computed individually and stored in the memory **120** in association with a given x_i and y_i variable **202** pair, the three portions are combined for each combination of x_i and y_i variables **202** to produce the correlation value r according to the standard formula given below, with no further passes down through the records of the data:

$$r=\frac{\sum_i (x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum_i (y_i-\bar{y})^2}\sqrt{\sum_i (y_i-\bar{y})^2}}.$$

[0061] In a test case of 274 variables **202** (fields) and six million data points (records **204**), calculations according to the prior art (FIG. **7**) required reading down through all the data 274×274 times. However, using the procedure described above, the data was read down through only twice. The first approach took 1.5 hours to calculate all the correlation coefficients, while the second approach only took eighteen seconds, which is an increase of over 2,000 times in computer performance. It will be appreciated that the foregoing procedure may be adapted for evaluating correlation coefficients for more than two variables **202** (higher order interactions), with even greater savings in computational efficiency.

[0062] The foregoing description of embodiments for this invention has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed. Obvious modifications or variations are possible in light of the above teachings. The embodiments are chosen and described in an effort to provide illustrations of the principles of the invention and its practical application, and to thereby enable one of ordinary skill in the art to utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated. All such modifications and variations are within the scope of the invention as determined by the appended claims when interpreted in accordance with the breadth to which they are fairly, legally, and equitably entitled.

1. A method for improving the operation of a computer by transferring data from an SQL database in a storage unit to a memory, the method comprising the steps of:

copying the data from the SQL database to a binary file in the storage unit, the binary file having a data structure and a data type,

configuring within the memory a data file having the data structure and the data type, and

copying the binary file in the storage unit to the data file in the memory with a single read/write operation.

2. The method of claim **1**, wherein the data structure comprises records and fields, with a number of records and a number of fields for each record.

3. The method of claim **1**, wherein the data type comprises at least one of real, integer, and word length.

4. A method for reading the data file produced by the method of claim **1**, when the records of the data file are sorted, comprising:

reading through the entire data file only once to find record positions for data containing predetermined data characteristics,

creating a pointer table in the memory, the pointer table including a single record position for a first instance of each of the predetermined data characteristics within the data file, and

reading the data file starting at the record position in the pointer table that corresponds to a desired one of the predetermined data characteristics.

5. A method for reading the data file produced by the method of claim **1** to locate desired data, when the records of the data file are unsorted, comprising:

reading through the entire data file only once to find record positions for data containing predetermined data characteristics,

creating a first pointer table in the memory, the first pointer table including a single record position for a first instance of each of the predetermined data characteristics within the data file,

creating a second pointer table in the memory, the second pointer table including, in association with the record position for the first instance of each of the predetermined data characteristics, a subsequent record position for a next subsequent instance of each of the predetermined data characteristics within the data file, and

reading the data file starting at the record position in the first pointer table that corresponds to a desired one of the predetermined data characteristics, and if the data in the record position does not contain the desired data, iteratively reading the data file at the record position associated with the next subsequent instance in the second pointer table, until the desired data is found.

6. A method for correlating variables in the data file produced by the method of claim **1**, the method comprising the steps of:

reading the data file a first time to determine averages $\bar{x}$ and $\bar{y}$ for each x and y variable pair to be correlated,

reading the data file a second time to determine for each x_i and y_i variable the following three values, where i represents the number of variables,

$\Sigma_i(x_i-\bar{x})(y_i-\bar{y})$,

$\sqrt{\Sigma_i(x_i-\bar{x})^2}$,

$\sqrt{\Sigma_i(y_i-\bar{y})^2}$,

storing each of the three values in a cell of an array designated for the x_i and y_i variable pair, and

using the three values in the array for each combination of x_i and y_i variables, computing the correlation value r according to the formula

$$r = \frac{\sum_i (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_i (y_i - \bar{y})^2}\sqrt{\sum_i (y_i - \bar{y})^2}}.$$

7. A method for improving the operation of a computer by reading a data file of records in a memory, the method comprising:

reading through the entire data file only once to find record positions for data containing predetermined data characteristics,

creating a pointer table in the memory, the pointer table including a single record position for a first instance of each of the predetermined data characteristics within the data file, and

reading the data file starting at the record position in the pointer table that corresponds to a desired one of the predetermined data characteristics.

8. The method of claim **7**, wherein each record in the data file comprises a plurality of fields, and all the fields are sorted according to a predetermined order.

9. The method of claim **7**, wherein each record of the data file comprises a plurality of fields, all the fields are sorted according to a predetermined order, and the pointer table includes, for each of the fields, a single record position associated with a first instance for each of the predetermined data characteristics for each field.

10. A method for improving the operation of a computer by reading a data file of unsorted records to locate desired data, the method comprising:

reading through the entire data file only once to find record positions for data containing predetermined data characteristics,

creating a first pointer table in the memory, the first pointer table including a single record position for a first instance of each of the predetermined data characteristics within the data file,

creating a second pointer table in the memory, the second pointer table including, in association with the record position for the first instance of each of the predetermined data characteristics, a subsequent record position for a next subsequent instance of each of the predetermined data characteristics within the data file, and

reading the data file starting at the record position in the first pointer table that corresponds to a desired one of the predetermined data characteristics, and if the data in the record position does not contain the desired data, iteratively reading the data file at the record position associated with the next subsequent instance in the second pointer table, until the desired data is found.

11. The method of claim **11**, wherein a first pointer table and a second pointer table are created for each field within the data file.

12. A method for improving the operation of a computer by correlating variables in a data file, the method comprising the steps of:

reading the data file a first time to determine averages $\bar{x}$ and $\bar{y}$ for each x and y variable pair to be correlated,

reading the data file a second time to determine for each x_i and y_i variable the following three values, where i represents the number of variables,

$\Sigma_i(x_i-\bar{x})(y_i-\bar{y})$,

$\sqrt{\Sigma_i(x_i-\bar{x})^2}$,

$\sqrt{\Sigma_i(y_i-\bar{y})^2}$,

storing each of the three values in a cell of an array designated for the x_i and y_i variable pair, and

using the three values in the array for each combination of x_i and y_i variables, computing the correlation value r according to the formula,

$$r = \frac{\sum_i (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_i (y_i - \bar{y})^2}\sqrt{\sum_i (y_i - \bar{y})^2}}.$$

13. The method of claim **12**, wherein the correlation value r is only calculated for unique combinations of the x_i and y_i variables.

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