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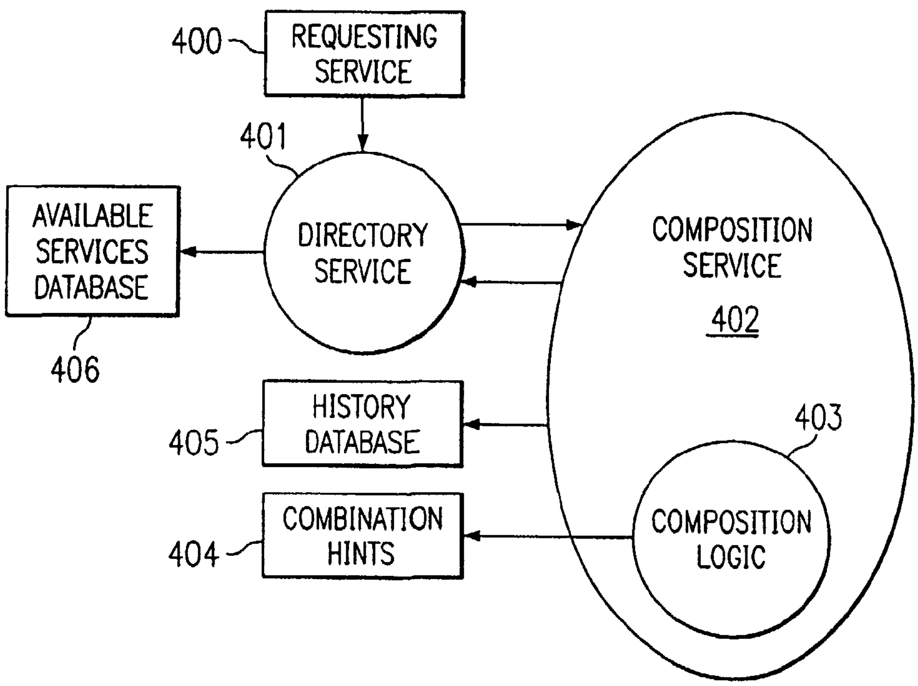

(57) Abstract: A method, computer program product, and data processing system for providing an improved directory service for storing information about hardware and software components is disclosed. The directory service stores not only the information that other hardware and software components require to locate, and make use of, the components listed in the directory, but is also able to dynamically construct 'meta services' that fulfill a client's functionality requirements.

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COMPOSITION SERVICE FOR AUTONOMIC COMPUTING

BACKGROUND OF THE INVENTION

Technical Field

The present invention relates generally to an improved data processing system, and in particular, to a method and apparatus for managing hardware and software components. Still more particularly, the present invention provides a method and apparatus for automatically identifying and combining components to achieve functionality requirements.

Description of Related Art

Modern computing technology has resulted in immensely complicated and ever-changing environments. One such environment is the Internet, which is also referred to as an "internetwork." The Internet is a set of computer networks, possibly dissimilar, joined together by means of gateways that handle data transfer and the conversion of messages from a protocol of the sending network to a protocol used by the receiving network. When capitalized, the term "Internet" refers to the collection of networks and gateways that use the TCP/IP suite of protocols. Currently, the most commonly employed method of transferring data over the Internet is to employ the World Wide Web environment, also called simply "the Web". Other Internet resources exist for transferring information, such as File Transfer Protocol (FTP) and Gopher, but have not achieved the popularity of the Web. In the Web environment, servers and clients effect data transaction using the Hypertext Transfer Protocol (HTTP), a known protocol for handling the transfer of various data files (e.g., text, still graphic images, audio, motion video, etc.). The information in various data files is formatted for presentation to a user by a standard page description language, the Hypertext Markup Language (HTML). The Internet also is widely used to transfer applications to users using browsers. Often times, users of may search for and obtain software packages through the Internet.

Other types of complex network data processing systems include those created for facilitating work in large corporations. In many cases, these networks may span across regions in various worldwide locations. These complex networks also may use the Internet as part of a virtual product network for conducting business. These networks are further complicated by the need to manage and update software used within the network.

As software evolves to become increasingly 'autonomic', the task of installing and configuring software will, more and more, be performed by the computers themselves, as opposed to being performed by administrators. The current installing and configuring mechanisms are moving towards an "autonomic" process. For example, many operating systems and software packages will automatically look for particular software components based on user-specified requirements. These installation and update mechanisms often connect to the Internet at a preselected location to see whether an update or a needed component is present. If the update or other component is present, the message is presented to the user in which the message asks the user whether to download and install the component. An example of such a system is the package management program "dselect" that is part of the open-source Debian GNU/Linux operating system.

A next block towards "autonomic" computing involves identifying and installing/downloading necessary hardware and software components without requiring user intervention. In such a next generation system, an autonomic configuration utility would install components in response to the detection of a need for particular functionality. In such a circumstance, there may not be a single hardware or software component for providing the needed functionality. Thus, it would be desirable for there to be a scheme whereby needed functionality may be obtained in the absence of a single component for providing the necessary functionality.

SUMMARY OF THE INVENTION

Accordingly, the present invention provides a computer-implemented process for storing information about hardware and software components comprising: receiving a request containing a functional requirement; consulting a directory to determine if a single component exists that satisfies the functional requirement; in response to a determination that a single component that satisfies the functional requirements does not exist, identifying a plurality of functionalities that, when combined according to a combination method, would satisfy the functional requirement; and identifying a plurality of components satisfying the plurality of functionalities.

A computer program product comprising instructions for carrying out the inventive process is also provided is a data processing system for implementing the process.

The invention thus offers an improved directory service which stores not only the information that other components require to locate, and make use of, the components listed in the directory, but is also able to dynamically construct 'meta services' that fulfill a client's functionality requirements.

In response to a request from the client for particular functional requirements, the directory service determines a set of hardware and/or software components to provide the needed functionality. The components in the set are then combined and configured to achieve the necessary functionality via logical deduction from domain knowledge. A history mechanism allows for already derived configurations of hardware or software components to be recalled immediately.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the invention are set forth in the appended claims. The invention itself, however, as well as a preferred mode of use, further objectives and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

Figure 1 is a diagram of a networked data processing system in which the present invention may be implemented;

Figure 2 is a block diagram of a server system within the networked data processing system of **Figure 1**;

Figure 3 is a block diagram of a client system within the networked data processing system of **Figure 1**;

Figure 4 is a diagram depicting an overall view of an autonomic composition broker system in accordance with a preferred embodiment of the present invention;

Figure 5 is a flowchart representation of a process of fulfilling a request for a hardware or software component in a preferred embodiment of the present invention;

Figure 6 is a diagram providing a legend for symbols in E-R (entity-relationship diagrams) as used in this document;

Figure 7 is an exemplary E-R diagram representing a database system for use in a preferred embodiment of the present invention;

Figure 8 is a flowchart representation of a process followed by a control logic in accordance with a preferred embodiment of the present invention; and

Figure 9 is a diagram depicting an architectural variation on the present invention in which a remote meta-service provider is used to provide the derived meta-service; and

Figure 10 is a diagram depicting an architectural variation on the present invention in which remote meta-service capability is incorporated into a composition service.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

With reference now to the figures, **Figure 1** depicts a pictorial representation of a network of data processing systems in which the present invention may be implemented. Network data processing system **100** is a network of computers in which the present invention may be implemented. Network data processing system **100** contains a network **102**, which is the medium used to provide communications links between various devices and computers connected together within network data processing system **100**. Network **102** may include connections, such as wire, wireless communication links, or fiber optic cables.

In the depicted example, server **104** is connected to network **102** along with storage unit **106**. In addition, clients **108**, **110**, and **112** are connected to network **102**. These clients **108**, **110**, and **112** may be, for example, personal computers or network computers. In the depicted example, server **104** provides data, such as boot files, operating system images, and applications to clients **108-112**. Clients **108**, **110**, and **112** are clients to server **104**. Network data processing system **100** may include additional servers, clients, and other devices not shown. In the depicted example, network data processing system **100** is the Internet with network **102** representing a worldwide collection of networks and gateways that use the Transmission Control Protocol/Internet Protocol (TCP/IP) suite of protocols to communicate with one another. At the heart of the Internet is a backbone of high-speed data communication lines between major nodes or host computers, consisting of thousands of commercial, government, educational and other computer systems that route data and messages. Of course, network data processing system **100** also may be implemented as a number of different types of networks, such as for example, an intranet, a local area network (LAN), or a wide area network (WAN). **Figure 1** is intended as an example, and not as an architectural limitation for the present invention.

Referring to **Figure 2**, a block diagram of a data processing system that may be implemented as a server, such as server **104** in **Figure 1**, is depicted in accordance with a preferred embodiment of the present invention. Data processing system **200** may be a symmetric multiprocessor (SMP) system including a plurality of processors **202** and **204** connected to system bus **206**. Alternatively, a single processor system may be employed. Also connected to system bus **206** is memory controller/cache **208**, which provides an interface to local memory **209**. I/O bus bridge **210** is connected to system bus **206** and provides an interface to I/O bus **212**. Memory controller/cache **208** and I/O bus bridge **210** may be integrated as depicted.

Peripheral component interconnect (PCI) bus bridge **214** connected to I/O bus **212** provides an interface to PCI local bus **216**. A number of modems may be connected to PCI local bus **216**. Typical PCI bus implementations will support four PCI expansion slots or add-in connectors. Communications links to clients **108-112** in **Figure 1** may be provided through modem **218** and network adapter **220** connected to PCI local bus **216** through add-in boards.

Additional PCI bus bridges **222** and **224** provide interfaces for additional PCI local buses **226** and **228**, from which additional modems or network adapters may be supported. In this manner, data processing system **200** allows connections to multiple network computers. A memory-mapped graphics adapter **230** and hard disk **232** may also be connected to I/O bus **212** as depicted, either directly or indirectly.

Those of ordinary skill in the art will appreciate that the hardware depicted in **Figure 2** may vary. For example, other peripheral devices, such as optical disk drives and the like, also may be used in addition to or in place of the hardware depicted. The depicted example is not meant to imply architectural limitations with respect to the present invention.

The data processing system depicted in **Figure 2** may be, for example, an IBM eServer pSeries system, a product of International Business

Machines Corporation in Armonk, New York, running the Advanced Interactive Executive (AIX) operating system or LINUX operating system.

With reference now to **Figure 3**, a block diagram illustrating a data processing system is depicted in which the present invention may be implemented. Data processing system **300** is an example of a client computer. Data processing system **300** employs a peripheral component interconnect (PCI) local bus architecture. Although the depicted example employs a PCI bus, other bus architectures such as Accelerated Graphics Port (AGP) and Industry Standard Architecture (ISA) may be used. Processor **302** and main memory **304** are connected to PCI local bus **306** through PCI bridge **308**. PCI bridge **308** also may include an integrated memory controller and cache memory for processor **302**. Additional connections to PCI local bus **306** may be made through direct component interconnection or through add-in boards. In the depicted example, local area network (LAN) adapter **310**, SCSI host bus adapter **312**, and expansion bus interface **314** are connected to PCI local bus **306** by direct component connection. In contrast, audio adapter **316**, graphics adapter **318**, and audio/video adapter **319** are connected to PCI local bus **306** by add-in boards inserted into expansion slots. Expansion bus interface **314** provides a connection for a keyboard and mouse adapter **320**, modem **322**, and additional memory **324**. Small computer system interface (SCSI) host bus adapter **312** provides a connection for hard disk drive **326**, tape drive **328**, and CD-ROM drive **330**. Typical PCI local bus implementations will support three or four PCI expansion slots or add-in connectors.

An operating system runs on processor **302** and is used to coordinate and provide control of various components within data processing system **300** in **Figure 3**. The operating system may be a commercially available operating system, such as Windows XP, which is available from Microsoft Corporation. An object oriented programming system such as Java may run in conjunction with the operating system and provide calls to the operating system from Java programs or applications executing on data processing system **300**. "Java" is a trademark of Sun Microsystems, Inc. Instructions for the operating system, the object-oriented operating system, and applications or programs are located on storage devices, such as hard disk drive **326**, and may be loaded into main memory **304** for execution by processor **302**.

Those of ordinary skill in the art will appreciate that the hardware in **Figure 3** may vary depending on the implementation. Other internal hardware or peripheral devices, such as flash read-only memory (ROM), equivalent nonvolatile memory, or optical disk drives and the like, may be used in addition to or in place of the hardware depicted in **Figure 3**. Also, the processes of the present invention may be applied to a multiprocessor data processing system.

As another example, data processing system **300** may be a stand-alone system configured to be bootable without relying on some type of network communication interfaces As a further example, data processing system **300** may be a personal digital assistant (PDA) device, which is configured with ROM and/or flash ROM in order to provide non-volatile memory for storing operating system files and/or user-generated data.

The depicted example in **Figure 3** and above-described examples are not meant to imply architectural limitations. For example, data processing system **300** also may be a notebook computer or hand held computer in addition to taking the form of a PDA. Data processing system **300** also may be a kiosk or a Web appliance.

The present invention is directed toward an improved directory service for storing information about hardware and software components. Throughout this document, the term "service" is used to described both hardware and software components. In an autonomic computing paradigm, services may be procured and combined (bound) dynamically according to functional requirements. Thus, hardware and software components in an autonomic computing environment are referred to as "services" to emphasize the fact that in autonomic computing, the system components are deployed for current functional requirements only. Thus, an autonomic computing system is not statically constructed at build time from a fixed and unchanging set of components, but rather dynamically utilizes available "services" as required.

Sometimes the functionality required of an autonomic computing system cannot be provided by a single service alone. In such cases, the required functionality may be achieved by combining a number of services together. Thus, the directory service provided by the present invention stores not only the information that other components require to locate, and make use of, the services listed in the directory, but is also able to dynamically construct "meta-services" that fulfill a client's request.

For example, if a client asks the directory to provide details for a certain type of service (including, but not limited to, the location or identity of that service) that is not available in the directory, then a simple directory service would simply respond that no such services were available. However, the improved directory service has the capability to derive (or to cause another software entity to derive), either based on pre-programmed knowledge or on-the-fly deduction, a mechanism by which components available in the directory may be combined in order to obtain functionality equivalent to that of the services originally sought by the requesting client.

Consider, for example, a situation where a requesting service (e.g., a software component) asks the directory for information about available services that can provide 1PB (Petabyte) of direct-access storage space. In the case where the directory does not contain information about any such services, but does contain information about ten services, each of which can provide 100 TB (Terabytes) of direct-access storage space, the directory service can then return a response to the requesting service indicating that if the requesting service combined the ten services, it would obtain the equivalent of the service that was originally requested.

Figure 4 is a diagram depicting an overall view of a directory and composition service in accordance with a preferred embodiment of the present invention. A requesting service **400** requests a service meeting particular functionality requirements from directory service **401**, which is itself a service (hardware or software component). Directory service **401** consults available services database **406** to locate a service (hardware or software component) providing the necessary functionality. Should no such single service be available, directory service **401** may utilize composition service **402** (which is also a hardware or software component) to combine individual services into a "meta-service" to provide the necessary functionality.

In a preferred embodiment, directory service **401** may provide directory services through the use of standardized directory service schemes such as Web Services Description Language (WSDL) and systems such as Universal Description, Discovery, and Integration (UDDI), which allow a program to locate entities that offer particular services and to automatically determine how to communicate and conduct transactions with those services. WSDL is a proposed standard being considered by the WorldWide Web Consortium, authored by representatives of companies, such as International Business Machines Corporation, Ariba, Inc., and Microsoft Corporation. UDDI version 3 is the current specification being used for Web service applications and services. Future development and changes to

UDDI will be handled by the Organization for the Advancement of Structured Information Standards (OASIS).

Composition service **402** will first try to fulfill the request via history database **405**, which stores the results of previously-derived combinations of services. If no applicable previously-derived combination is available, composition logic **403** will be employed to derive a new combination of available services that satisfies the functional requirements of the request. Composition logic **403** is, in a preferred embodiment, software that utilizes information about components in available services database **406** information regarding the combinability of components from combination hints **404** to derive a combination of components meeting the functional requirements of requesting service **400**'s original request.

Figure 5 is a flowchart representation of a process for fulfilling requests for services in accordance with a preferred embodiment of the present invention. **Figure 5** is divided into two portions. Directory service portion **500** includes blocks involving identifying and locating individual services (e.g., by directory service **401** in **Figure 4**), and composition service portion **512** includes blocks involving the combination of individual services to form meta-services. One of ordinary skill in the art will recognize that this division of blocks may coincide with different software processes (e.g., the blocks in directory service portion **500** are performed by one software process, while the block in composition service **512** are performed by a different software process), or they may not (e.g., one process executes all blocks, or multiple processes execute differently grouped blocks). **Figure 5** assumes that two separate organizational units of software (e.g., processes, threads, functions, subroutines, etc.) are used (i.e., directory service **401** and composition service **402**), although, as stated above, no such division is necessary in practice.

Turning now to the process flow represented by **Figure 5**, the process begins with a request being received from a client (i.e., a service or component requests additional functionality) (block **501**). Next, a determination is made as to whether the request can be met from available services (i.e., available services database **406**) (block **502**). If so (block **502**:Yes), an appropriate response providing instructions regarding the usage of an appropriate service is retrieved from available services database **406** (block **503**). This response is then returned to the client to allow the client to make use of the chosen service (block **504**).

If the request cannot be met from available services (block **502**:No), the request is forwarded to composition service **402** (block **505**). Composition service **402** receives the request (block **506**) and determines whether the request can be satisfied from history database **405** (block **507**). If so (block **507**:Yes), a response from history database **405** is returned (block **509**). If not (block **507**:No), composition logic **403** is used to derive a combination providing the necessary functionality (block **510**). This new combination is entered into history database **405** (block **508**), and a response returned (block **509**). Directory service **401** then receives composition services **402**'s response (block **511**) and returns the response to the client (block **504**).

As can be seen from **Figures 4** and **5**, the task of identifying and/or combining services in response to a request involves retrieving data from one or more databases and applying logic to the data (e.g., composition logic **403**) to derive an appropriate response. **Figures 6** and **7** describe one possible database schema that may be employed to store directory, combination, and history information in a preferred embodiment of the present invention. One of ordinary skill in the art will recognize that many variations on and substitutions for the schema described herein are also applicable without departing from the scope and spirit of the present invention. The database schema depicted in the following Figures is included for illustrative purposes only.

The E-R (entity-relationship) approach to database modeling provides the semantics for the conceptual design of databases. With the E-R approach, database information is represented in terms of entities, attributes of entities, and relationships between entities, where the following definitions apply. The modeling semantics corresponding to each definition is illustrated in **Figure 6**. **Figure 6** is adapted from Elmasri and Navathe, *Fundamentals of Database Systems*, 3rd Ed., Addison Wesley (2000), pp. 41-66, which contains additional material regarding E-R diagrams and is hereby incorporated by reference.

Entity: An entity is a principal object about which information is collected. For example, in a database containing information about personnel of a company, an entity might be "Employee." In E-R modeling, an entity is represented with a box. An entity may be termed weak or strong, relating its dependence on another entity. A strong entity exhibits no dependence on another entity, i.e. its existence does not require the existence of another Entity. As shown in **Figure 6**, a strong entity is represented with a single unshaded box. A weak entity derives its existence from another entity. For example, an entity "Work Time Schedule" derives its existence from an entity "Employee" if a work time schedule can only exist if it is associated with an employee. As shown in **Figure 6**, a weak entity is represented by concentric boxes.

Attribute: An attribute is a label that gives a descriptive property to an entity (e.g., name, color, etc.). Two types of attributes exist. Key attributes distinguish among occurrences of an entity. For example, in the United States, a Social Security number is a key attribute that distinguishes between individuals. Descriptor attributes merely describe an entity occurrence (e.g., gender, weight). As shown in **Figure 6**, in E-R modeling, an attribute is represented with an oval tied to the entity (box) to which it pertains.

In some cases, an attribute may have multiple values. For example, an entity representing a business may have a multivalued attribute "locations." If the business has multiple locations, the attribute "locations" will have multiple values. A multivalued attribute is represented by concentric ovals, as shown in **Figure 6**.

Relationships: A relationship is a connectivity exhibited between entity occurrences. Relationships may be one to one, one to many, and many to many, and participation in a relationship by an entity may be optional or mandatory. For example, in the database containing information about personnel of a company, a relation "married to" among employee entity occurrences is one to one (if it is stated that an employee has at most one spouse). Further, participation in the relation is optional as there may exist unmarried employees. As a second example, if company policy dictates that every employee have exactly one manager, then the relationship "managed by" among employee entity occurrences is many to one (many employees may have the same manager), and mandatory (every employee must have a manager).

As shown in **Figure 6**, in E-R modeling a relationship is represented with a diamond if it relates one or two entities, and is represented with an n-sided polygon if it relates more than two entities. The cardinality ratio (one-to-one, one-to-many, etc.) in a relationship is denoted by the use of the characters "1" and "N" to show 1:1 or 1:N cardinality ratios, or through the use of explicit structural constraints, as shown in **Figure**

6. When all instances of an entity participate in the relationship, the entity box is connected to the relationship diamond by a double line; otherwise, a single line connects the entity with the relationship, as in **Figure 6.**

Figure 7 is an entity-relationship (E-R) diagram of an exemplary database schema that may be applied to a preferred embodiment of the present invention. The schema depicted in **Figure 7** is divided into portions according to the architecture depicted in **Figure 4**, namely directory service portion **700**, history database portion **702**, and combination hints portion **704**. One of ordinary skill in the art will recognize that such division is merely conceptual and is not intended to mandate any physical separation of the information in the different portions from each other.

The "base" entity in **Figure 7** is component entity **706**, representing a basic "atomic" service, meaning an individual component (service) that is not a composition of other components (services). Each component may have multiple requirements, such as certain minimum hardware requirements or dependencies on other services, represented by multi-valued attribute "requirement" **708**.

Ternary relationship "provides1" **710** relates each component (**706**) with one or more base functionalities (**714**) under a particular usage (**712**). Ternary relationship "provides1" **710** denotes that a particular component (**706**), when used in a certain way (**712**), provides one or more base functionalities (**714**).

Ternary relationship "synthesize" **716** relates one or more base functionalities (**714**) with a combination method (combination method entity **718**) and a corresponding derived functionality (derived functionalities entity **720**). Ternary relationship "synthesize" **716** denotes that one or more base functionalities (**714**) may be combined in a certain manner (**718**) to achieve a derived functionality (**720**). For example, converting a graphics file from a "BMP" (bitmap) file to "TIFF" (tagged image file format) file might be a base functionality and converting a TIFF file to a "GIF" (graphics interchange format) may be yet another base functionality. Converting from BMP to GIF format would then be a derived functionality achievable by applying the combination method of feeding the output from a BMP-to-TIFF conversion service into a TIFF-to-GIF conversion service. It should be noted that in **Figure 7** ternary relationship "synthesize" **716** relates *functionalities*, not components. For example, ternary relationship "synthesize" **716** would indicate that *any* BMP-to-TIFF conversion service may be combined with any TIFF-to-GIF conversion service to yield a BMP-to-GIF conversion meta-service; no indication is made in ternary relationship "synthesize" **716** as to which specific BMP-to-TIFF conversion service should be used.

"Combinable" relationship **722** relates a combination method (**718**) with one or more components (**706**). "Combinable" relationship **722** denotes that a particular group of components may be combined according to a particular combination method (**718**). Thus, in the case of the aforementioned graphics file format conversions, "combinable" relationship **722** would store an indication that two particular conversion services could be combined by feeding the output of one into the input of the other. Thus, if a certain functionality must be derived from base functionalities, "combinable" relationship **722** may be consulted to ensure that a particular group of components may be combined in the way necessary to achieve the desired derived functionality.

A combination of components (**706**) combining a set of base functionalities (**714**) into a derived functionality (**720**) is a combination, represented by "combination" entity **724**, which is related to entities **706**, **714**, and **720** via relationships **722**, **728**, and **730**. "Combination scheme" attribute **726** of "combination" entity **724** represents information for forming or using the combination. Combination entity **724** provides a history mechanism for storing already-derived combinations. "Combination scheme" attribute **726** may contain, for example, combination method information (e.g., from "combination method" entity **718**), or any other pertinent information for using or forming a combination (such as instructions for forming the combination from individual components or a copy of a combined software component incorporating the code from individual components).

A database schema such as the schema described in **Figure 7** may be implemented using a database management system, such as a relational, object-oriented, object-relational, or deductive database management system. Other data storage paradigms are also possible within a preferred embodiment of the present invention as are available in the art.

In accordance with a preferred embodiment of the present invention, a database schema such as is described in **Figure 7** is combined with control logic (e.g., such as is provided by directory service **401**, composition service **402**, and composition logic **403** in **Figure 4**) to allow available services to be selected and/or combined in satisfaction of functional requirements. **Figure 8** depicts in flowchart form one possible embodiment of a control logic that may be used in an embodiment of the present invention. The control logic described in **Figure 8** is based on the database schema of **Figure 7** and combines functionalities of directory service **401**, composition service **402**, and composition logic **403**, as described with respect to **Figure 4**. As was stated in conjunction with **Figure 4**, no rigid separation of directory service **401**, composition service **402**, and composition logic **403** is required by the present invention. As with the database schema in **Figure 7**, the process depicted in **Figure 8** is merely intended to serve as an example of how a control logic may function and is not intended to be limiting.

The process depicted in **Figure 8** begins with calling a subroutine to find the components and constraints associated with the specified functional requirements (block **800**). The subroutine called in block **800** is a recursive subroutine to find and/or combine components in satisfaction of each functional requirement specified. As components are incorporated into the solution for each functional requirement, the subroutine is invoked recursively to incorporate additional components and/or combinations in satisfaction of the remaining requirements. When the subroutine is initially invoked, the full list of functional requirements and two empty lists, representing the components and constraints in the solution so far, may be passed into the subroutine as parameters. As the subroutine is repeatedly recursively called, components and constraints are added to the two lists representing the solution so far and functional requirements that have been satisfied by the solution so far are removed from the list of functional requirements.

Each time the subroutine is invoked, a determination is made as to whether any functional requirements remain to be addressed (block **802**). If no additional functional requirements remain (block **802**:No), the solution so far should be returned as the result (block **804**).

If any functional requirements do remain (block **802**:Yes), a determination is made as to whether any components have been selected for inclusion in the solution so far (block **806**). If so (block **806**:Yes), then a determination is made as to whether any of the remaining requirements can be met by components already selected for inclusion in the solution (block **808**). If not (block **808**:No) or if no components have been selected so far, the process continues to block **812**.

If there is a requirement that is met by an already selected component (block **808**:Yes), then usage information (i.e., information that instructs a client on how to use the component in question to achieve the desired functionality) is added to the list of constraints in the solution so far (block **810**). A recursive call is then made to address any remaining functional requirements (block **811**).

In block **812**, a determination is made as to whether there is a requirement that may be met by a single component that has not yet been selected for inclusion in the solution so far. If so (block **812**:Yes), the component is added to the list of components in the solution so far (block **814**), usage information for that component is added to the solution so far (block **810**), and the subroutine is recursively called to handle any remaining functional requirements (block **811**).

If none of the functional requirements may be satisfied by a single component (block **812**:No), a determination is made as to whether a functional requirement may be met with a combination of functions (block **816**). If so (block **816**:Yes), the subroutine is called recursively to find a set of components meeting the functional requirements needed to achieve the necessary derived functional requirement (block **818**). The result of the recursive subroutine call is then checked to see if the components returned by the subroutine may be combined in the necessary way (block **819**). If not (block **819**:No), the process makes additional subroutine calls to find combinable components (block **818**). If a properly combinable set of components is found (block **819**:Yes), the components are added to the solution so far (block **814**), usage information specifying how to combine and use the components is added to the solution so far (block **810**), and the subroutine is called recursively to address any remaining functional requirements (block **811**).

Once a solution is returned by the subroutine, the combination derived is stored in the history database (block **820**). One of ordinary skill in the art will recognize that a history database may be implemented using conventional database storage techniques or by making modifications to program logic in a language that supports tabled logic programming or self-modifying code, such as Prolog, or through any other appropriate means, not limited to a simple database representation.

While the preferred embodiment depicted in **Figures 4-8** assumes that the a directory service or combined directory and composition service will return a response comprising instructions or other information to allow a client to combine and use services (components), a number of other architectural arrangements are also possible. **Figure 9** depicts an embodiment of the present invention utilizing a remote meta-service provider **912**. Remote meta-service provider **912** allows the actual combination of services to be performed remotely from client **900**. Specifically, client **900** issues a request **902** to directory service **904**, which if a combination of services is necessary relays request **906** to composition service **908**. Composition service **908** then forwards combination instructions **910** to remote meta-service provider **912**. Directory service **904** then responds (**914,** not shown) to client **900** to notify client **900** that remote meta-service provider **912** is now available to provide the requested functionality. Client **900** may then utilize remote meta-service provider **912** as if it were an individual service providing the requested functionality. Remote meta-service provider **912**, however, in actuality serves as an interface to the combination of services making up the "meta-service" according to combination instructions **910**.

Figure 10 depicts yet another architectural variation of the present invention in which the remote meta-service provider is incorporated into the composition service used for deriving combinations. Client **1000** issues a request **1002** to directory service **1004**, which if a combination of services is necessary relays request **1006** to composition service **1008**, which then provides the derived meta-service to client **1000** as would remote meta-service provider **912** in **Figure 9**. Directory service **1004** then responds (**1010,** not shown) to client **1000** to notify client **1000** that composition service **1008** is now available to provide the requested functionality. A variation on the architecture in **Figure 10** would be for directory service **1004** to provide the derived meta-service, rather than composition service **1008**.

Additional variations on the present invention are possible. For example, the process of deriving combinations may be done in a distributed fashion, so that multiple solutions are returned from a plurality of composition services operating concurrently and a best solution is chosen from the returned solutions. Another variation is to offer two or more possible combinations to the requesting client, possibly with additional information to be used as selection criteria, and allowing the client to choose one of the possible combinations presented. Another way in which multiple solutions may be supported is for the composition service (or directory service) to query the client for preferences that would aid in choosing a derived combination from a plurality of candidates, so that the composition service (or directory service) could then offer one or more solutions that best fit the client's preferences. For example, the client could be asked whether speed or reliability is a greater concern, and solutions could be offered in which the speed/reliability tradeoff is handled in accordance with the client's needs.

It is important to note that while the present invention has been described in the context of a fully functioning data processing system, those of ordinary skill in the art will appreciate that the processes of the present invention are capable of being distributed in the form of a computer readable medium of instructions or other functional descriptive material and in a variety of other forms and that the present invention is equally applicable regardless of the particular type of signal bearing media actually used to carry out the distribution. Examples of computer readable media include recordable-type media, such as a floppy disk, a hard disk drive, a RAM, CD-ROMs, DVD-ROMs, and transmission-type media, such as digital and analog communications links, wired or wireless communications links using transmission forms, such as, for example, radio frequency and light wave transmissions. The computer readable media may take the form of coded formats that are decoded for actual use in a particular data processing system. Functional descriptive material is information that imparts functionality to a machine. Functional descriptive material includes, but is not limited to, computer programs, instructions, rules, facts, definitions of computable functions, objects, and data structures.

The description of the present invention has been presented for purposes of illustration and description, and is not intended to be exhaustive or limited to the invention in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. The embodiment was chosen and described in order to best explain the principles of the invention, the practical application, and to enable others of ordinary skill in the art to understand the invention for various embodiments with various modifications as are suited to the particular use contemplated.

CLAIMS

1. A computer-implemented process for storing information about hardware and software components comprising:

receiving (501) a request containing a functional requirement;

consulting (502) a directory (401) to determine if a single component exists that satisfies the functional requirement;

in response to a determination that a single component that satisfies the functional requirements does not exist, identifying (816) a plurality of functionalities that, when combined according to a combination method, would satisfy the functional requirement; and

identifying (818) a plurality of components satisfying the plurality of functionalities.

2. The process of claim 1, wherein the functional requirements are service definitions and the directory determines if a defined service is available by consulting a database of available services.

3. The process of claim 1 or claim 2, further comprising:

deriving instructions for combining the plurality of components according to the combination method to achieve the functional requirement.

4. The process of claim 3, wherein the request is made by a client and the process further comprises:

returning the instructions to the client,

whereby the client may utilize the plurality of components to achieve the functional requirement.

5. The process of claim 3, wherein the request is made by a client and the process further comprises:

providing the instructions to a remote meta-service provider so that the remote meta-service provider may provide functionality satisfying the functional requirement to the client by combining the plurality of components into a meta-service.

6. The process of any preceding claim, further comprising:

registering the plurality of components for future use without reidentifying the plurality of components.

7. The process of claim 1, wherein the request is made by a client and the process further comprises:

making an identification of the plurality of components available to services other than the client.

8. The process of claim 1, wherein the request is made by a client and the process further comprises:

identifying a plurality of combinations of components satisfying the plurality of functionalities; and

offering the client a choice of a combination from the plurality of combinations.

9. The process of claim 1, wherein the request is made by a client and the process further comprises:

identifying a plurality of combinations of components satisfying the plurality of functionalities;

querying the client to determine additional preferences; and

choosing, based on the additional preferences, at least one combination from the plurality of combinations to offer to the client.

10. A computer program product comprising instructions, when executed by a computer, cause the computer to carry out the process of:

receiving (501) a request containing a functional requirement;

consulting (502) a directory (401) to determine if a single component exists that satisfies the functional requirement;

in response to a determination that a single component that satisfies the functional requirements does not exist, identifying (816) a plurality of functionalities that, when combined according to a combination method, would satisfy the functional requirement; and

identifying (818) a plurality of components satisfying the plurality of functionalities.

11. The computer program product of claim 10, wherein the functional requirements are service definitions and the directory determines if a service is available by consulting a database of available services.

12. The computer program product of claim 10 or claim 11, wherein the process carried out by the computer further includes:

deriving instructions for combining the plurality of components according to the combination method to achieve the functional requirement.

13. The computer program product of claim 12, wherein the request is made by a client and the process carried out by the computer includes:

returning the instructions to the client,

whereby the client may utilize the plurality of components to achieve the functional requirement.

14. The computer program product of claim 12, wherein the request is made by a client and the process carried out by the computer includes:

providing the instructions to a remote meta-service provider so that the remote meta-service provider may provide functionality satisfying the functional requirement to the client by combining the plurality of components into a meta-service.

15. The computer program product of any of claims 10 to 14 wherein the process carried out by the computer includes:

registering the plurality of components for future use without reidentifying the plurality of components.

16. The computer program product of claim 10, wherein the request is made by a client and the process carried out by the computer includes:

making an identification of the plurality of components available to services other than the client.

17. The computer program product of claim 10, wherein the request is made by a client and the process carried out by the computer includes:

identifying a plurality of combinations of components satisfying the plurality of functionalities; and

offering the client a choice of a combination from the plurality of combinations.

18. The computer program product of claim 10, wherein the request is made by a client and the process carried out by the computer includes:

identifying a plurality of combinations of components satisfying the plurality of functionalities;

querying the client to determine additional preferences; and

choosing, based on the additional preferences, at least one combination from the plurality of combinations to offer to the client.

19. A data processing system comprising:

means (501) for receiving a request containing a functional requirement;

means (502) for consulting a directory (401) to determine if a single component exists that satisfies the functional requirement;

means (816), responsive to a determination that a single component that satisfies the functional requirements does not exist, for identifying a plurality of functionalities that, when combined according to a combination method, would satisfy the functional requirement; and

means (818) for identifying a plurality of components satisfying the plurality of functionalities.

20. A data processing system as claimed in claim 19 wherein the functional requirements are service definitions, the system further including a database of service definitions consultable by directory.

21. The data processing system of either claim 19 or claim 20, further comprising:

means for deriving instructions for combining the plurality of components according to the combination method to achieve the functional requirement.

22. The data processing system of claim 21, wherein the request is made by a client and the data processing system further comprises:

means for returning the instructions to the client,

whereby the client may utilize the plurality of components to achieve the functional requirement.

23. The data processing system of claim 21, wherein the request is made by a client and the data processing system further comprises:

means for providing the instructions to a remote meta-service provider so that the remote meta-service provider may provide functionality satisfying the functional requirement to the client by combining the plurality of components into a meta-service.

24. The data processing system of any one of claims 19-23, further comprising:

means for registering the plurality of components for future use without reidentifying the plurality of components.

25. The data processing system of claim 19, wherein the request is made by a client and the data processing system further comprises:

means for making an identification of the plurality of components available to services other than the client.

26. The data processing system of claim 19, wherein the request is made by a client and the data processing system further comprises:

means for identifying a plurality of combinations of components satisfying the plurality of functionalities; and means for offering the client a choice of a combination from the plurality of combinations.

27. The data processing system of claim 19, wherein the request is made by a client and the data processing system further comprises:

means for identifying a plurality of combinations of components satisfying the plurality of functionalities;

means for querying the client to determine additional preferences; and

means for choosing, based on the additional preferences, at least one combination from the plurality of combinations to offer to the client.

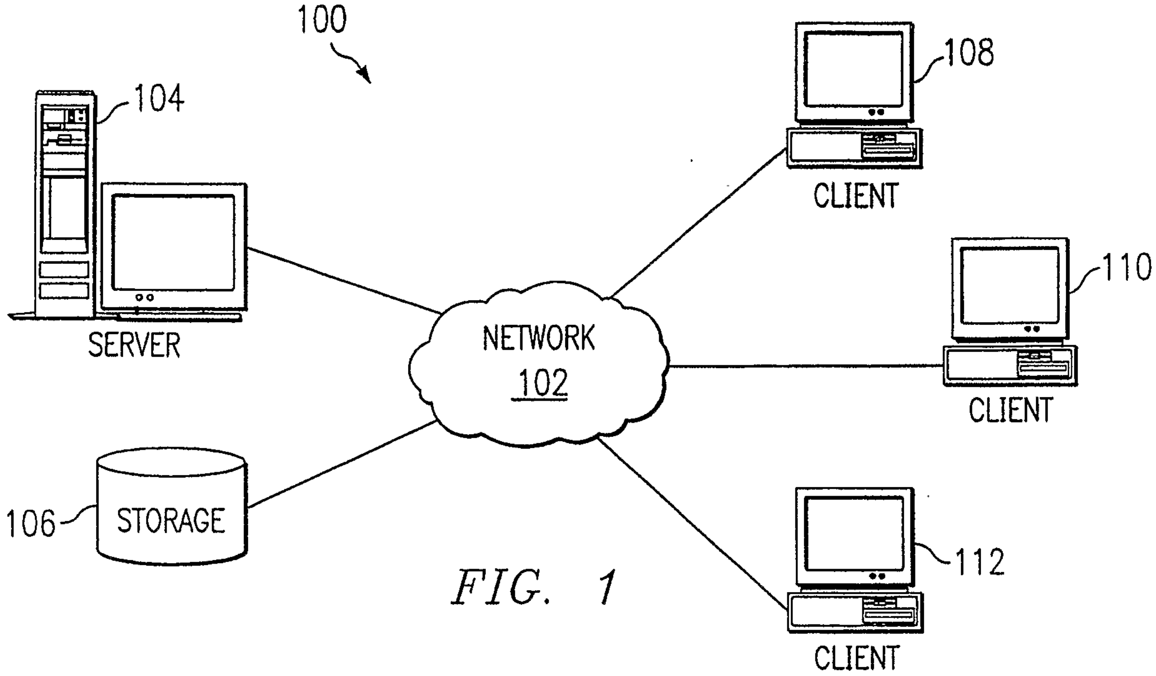

100
104
SERVER
106
STORAGE
NETWORK
102
108
CLIENT
110
CLIENT
112
CLIENT

FIG. 1

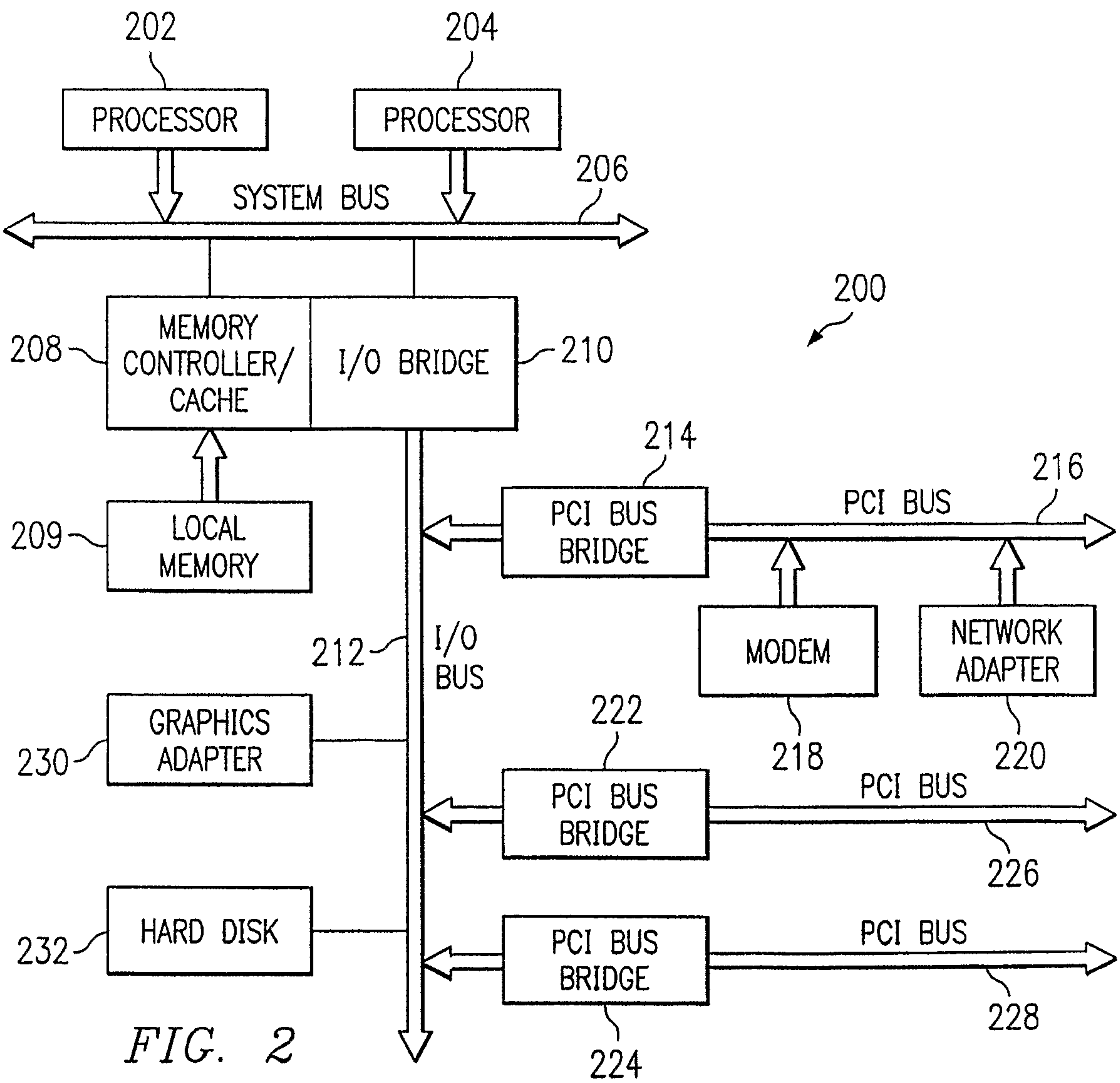

202
PROCESSOR
204
PROCESSOR
SYSTEM BUS
206
200
208
MEMORY
CONTROLLER/
CACHE
I/O BRIDGE
210
209
LOCAL
MEMORY
214
PCI BUS
BRIDGE
PCI BUS
216
212
I/O
BUS
MODEM
218
NETWORK
ADAPTER
220
230
GRAPHICS
ADAPTER
222
PCI BUS
BRIDGE
PCI BUS
226
232
HARD DISK
PCI BUS
BRIDGE
224
PCI BUS
228

FIG. 2

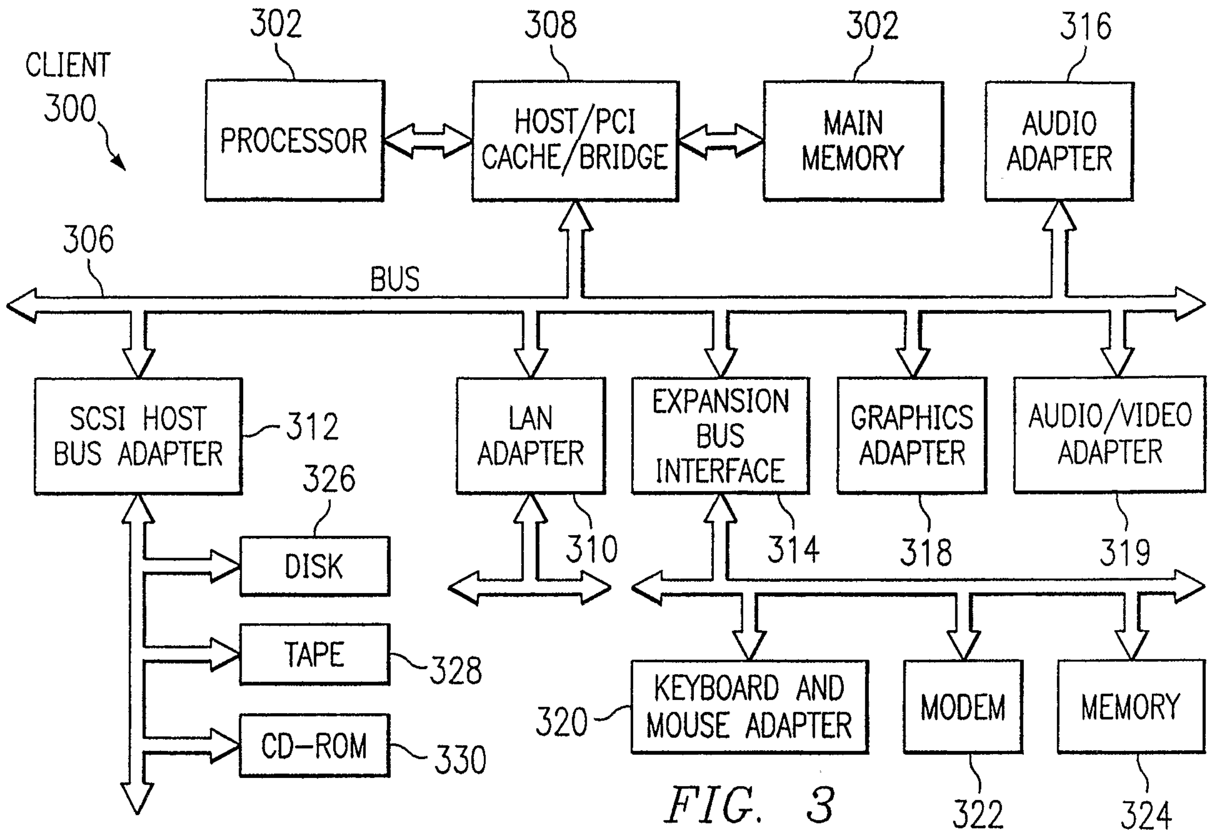

CLIENT
300
302
PROCESSOR
308
HOST/PCI CACHE/BRIDGE
302
MAIN MEMORY
316
AUDIO ADAPTER
306
BUS
SCSI HOST BUS ADAPTER
312
326
DISK
TAPE
328
CD-ROM
330
LAN ADAPTER
310
EXPANSION BUS INTERFACE
314
GRAPHICS ADAPTER
318
AUDIO/VIDEO ADAPTER
319
320
KEYBOARD AND MOUSE ADAPTER
MODEM
322
MEMORY
324

FIG. 3

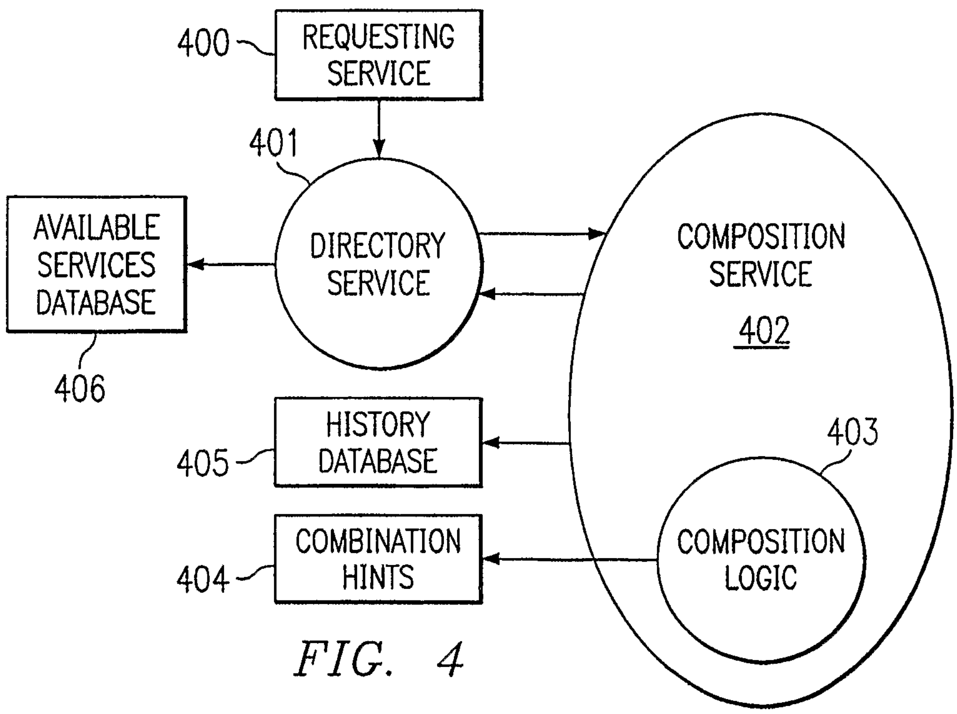
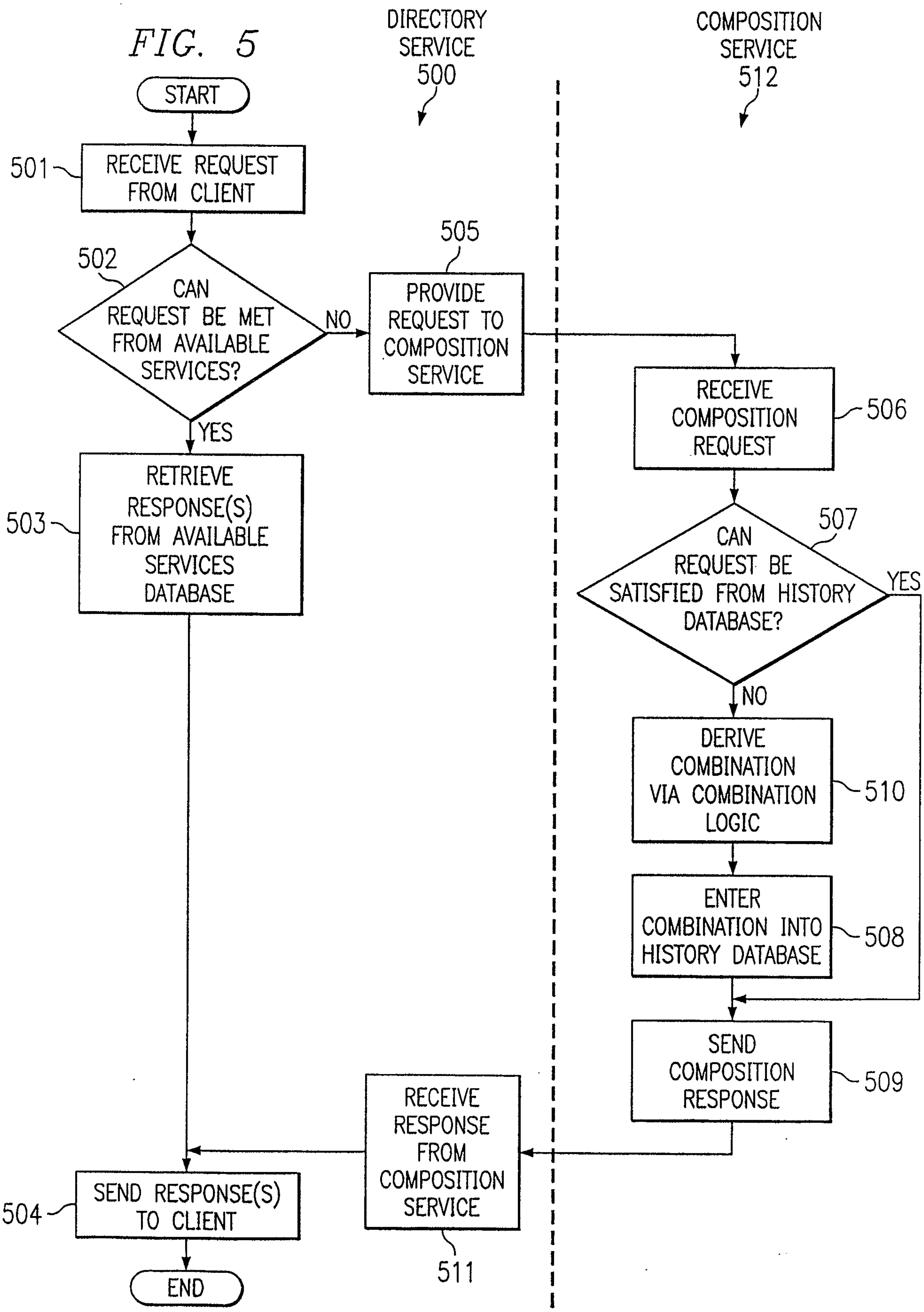

400
REQUESTING SERVICE
401
DIRECTORY SERVICE
AVAILABLE SERVICES DATABASE
406
COMPOSITION SERVICE
402
403
COMPOSITION LOGIC
405
HISTORY DATABASE
404
COMBINATION HINTS

FIG. 4

FIG. 5


DIRECTORY SERVICE 500
COMPOSITION SERVICE 512
START
501
RECEIVE REQUEST FROM CLIENT
502
CAN REQUEST BE MET FROM AVAILABLE SERVICES?
NO
YES
505
PROVIDE REQUEST TO COMPOSITION SERVICE
RECEIVE COMPOSITION REQUEST
506
503
RETRIEVE RESPONSE(S) FROM AVAILABLE SERVICES DATABASE
507
CAN REQUEST BE SATISFIED FROM HISTORY DATABASE?
YES
NO
DERIVE COMBINATION VIA COMBINATION LOGIC
510
ENTER COMBINATION INTO HISTORY DATABASE
508
SEND COMPOSITION RESPONSE
509
RECEIVE RESPONSE FROM COMPOSITION SERVICE
511
504
SEND RESPONSE(S) TO CLIENT
END

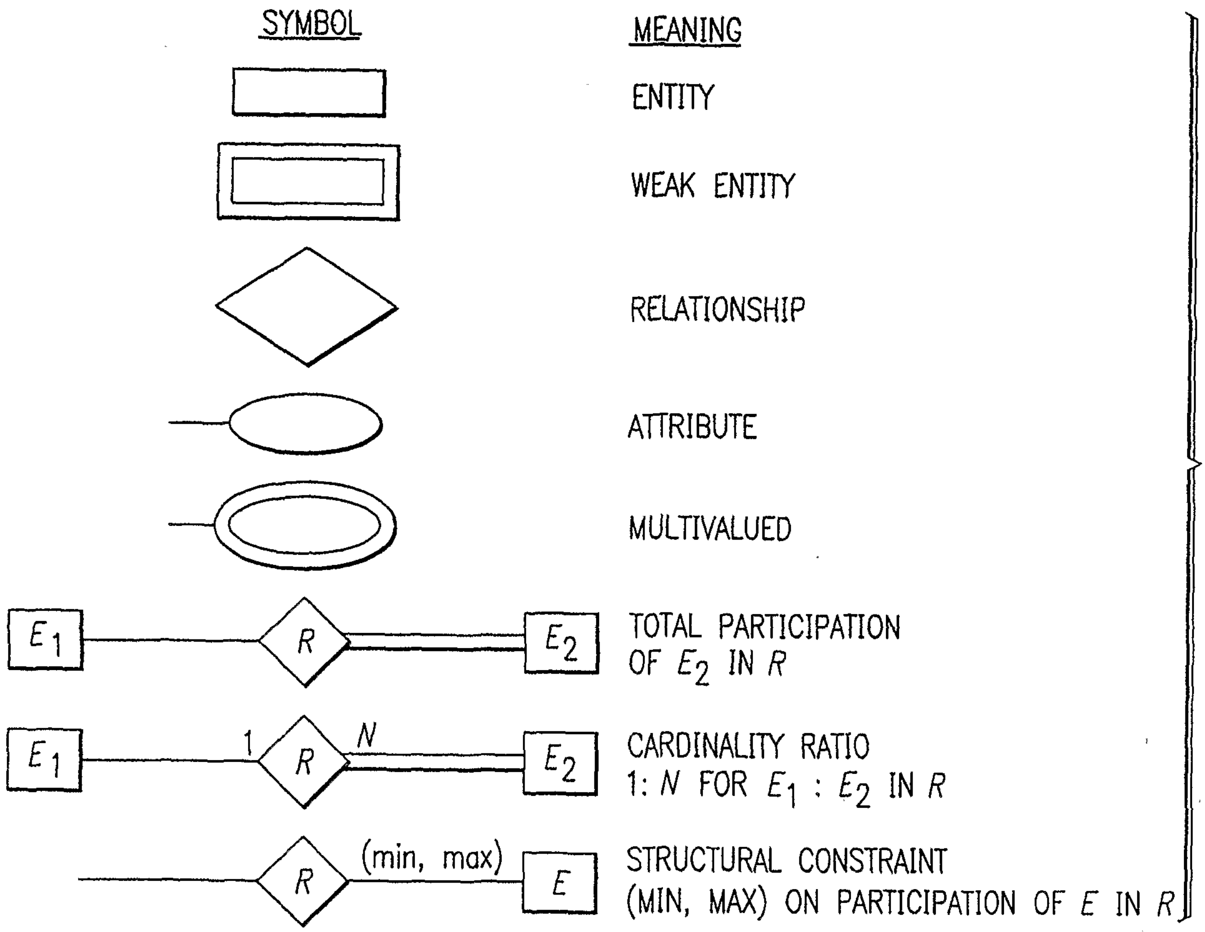


FIG. 6

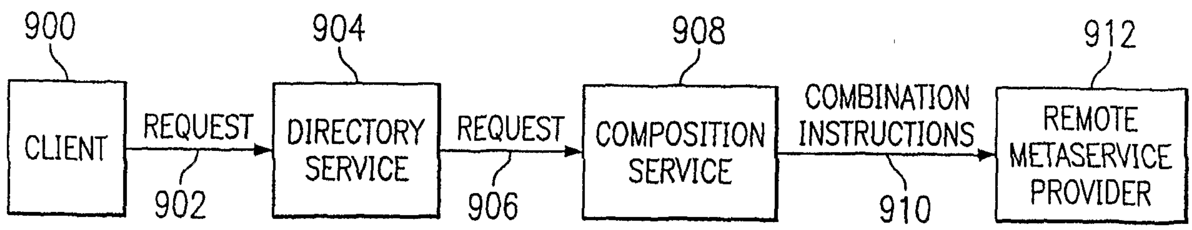
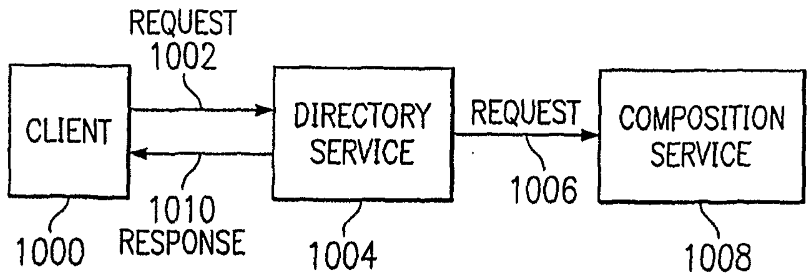


FIG. 9

FIG. 10



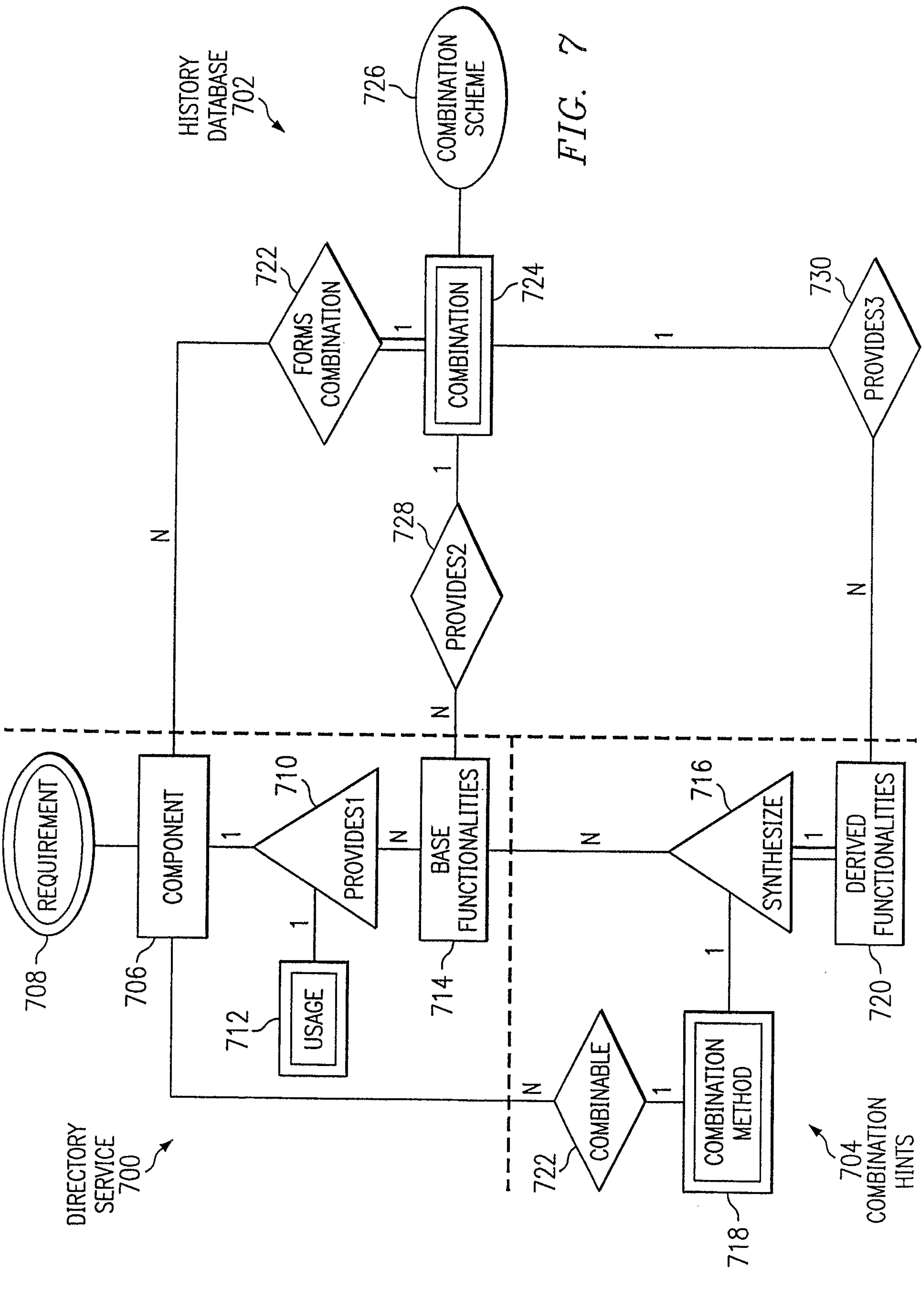

HISTORY DATABASE 702
DIRECTORY SERVICE 700
704 COMBINATION HINTS
REQUIREMENT
708
COMPONENT
706
PROVIDES1
710
USAGE
712
BASE FUNCTIONALITIES
714
SYNTHESIZE
716
DERIVED FUNCTIONALITIES
720
COMBINABLE
722
COMBINATION METHOD
718
FORMS COMBINATION
722
COMBINATION
724
COMBINATION SCHEME
726
PROVIDES2
728
PROVIDES3
730

FIG. 7

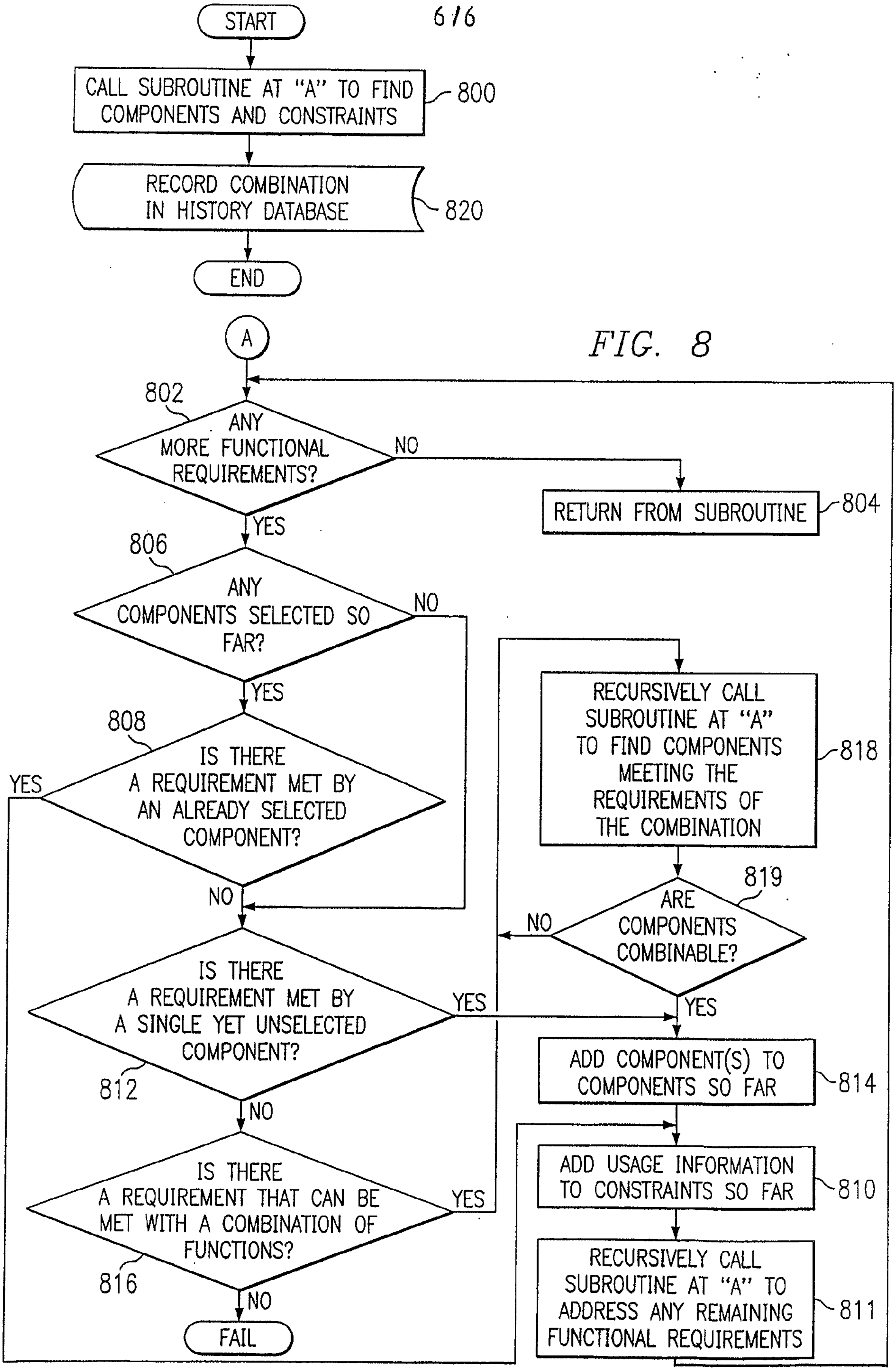

START
CALL SUBROUTINE AT "A" TO FIND COMPONENTS AND CONSTRAINTS
800
RECORD COMBINATION IN HISTORY DATABASE
820
END
A
802
ANY MORE FUNCTIONAL REQUIREMENTS?
NO
RETURN FROM SUBROUTINE
804
YES
806
ANY COMPONENTS SELECTED SO FAR?
NO
YES
808
IS THERE A REQUIREMENT MET BY AN ALREADY SELECTED COMPONENT?
YES
NO
RECURSIVELY CALL SUBROUTINE AT "A" TO FIND COMPONENTS MEETING THE REQUIREMENTS OF THE COMBINATION
818
819
ARE COMPONENTS COMBINABLE?
NO
YES
IS THERE A REQUIREMENT MET BY A SINGLE YET UNSELECTED COMPONENT?
YES
812
NO
ADD COMPONENT(S) TO COMPONENTS SO FAR
814
IS THERE A REQUIREMENT THAT CAN BE MET WITH A COMBINATION OF FUNCTIONS?
YES
ADD USAGE INFORMATION TO CONSTRAINTS SO FAR
810
816
NO
FAIL
RECURSIVELY CALL SUBROUTINE AT "A" TO ADDRESS ANY REMAINING FUNCTIONAL REQUIREMENTS
811

FIG. 8