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(54) METHOD AND APPARATUS FOR ENABLING LOCATION-INDEPENDENT AND LOCATION-TRANSPARENT INTERACTION BETWEEN PROGRAM AND USER

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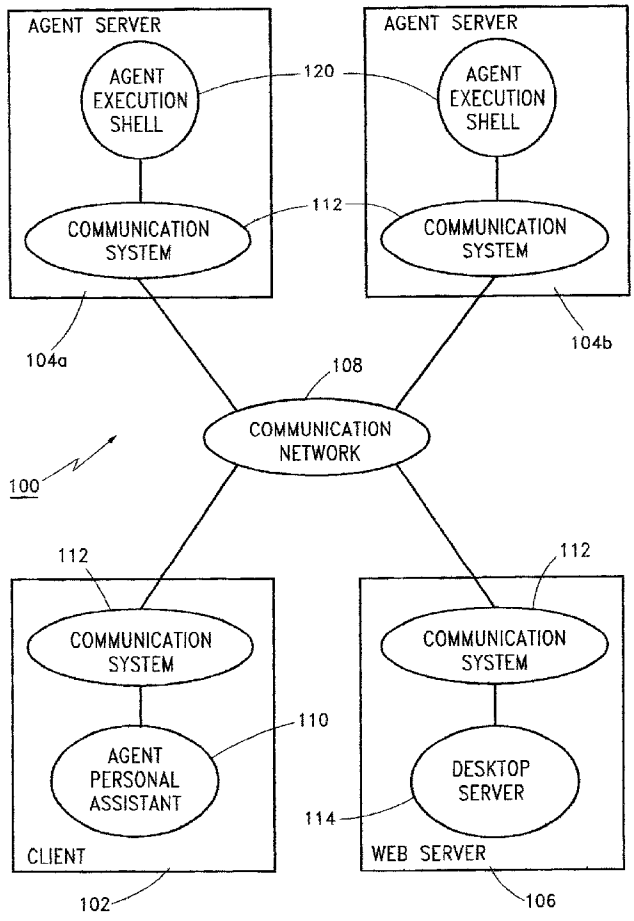
(57) ABSTRACT

A system and method wherein a mobile user or a user interacting with a mobile program, can at any time initiate a program status request. The program status request initiates the sequence of events whereby the current location of the program is determined and/or the current user location is made available to the program without the necessity of either entity changing location. Further, the agent script for the program maintains a composite data structure which includes an input buffer for storing input variables, an output buffer for storing output values to be displayed to the user, a program state data structure, and an optional bag buffer for temporarily storing input variables which the program will need in the course of future execution. By maintaining such a composite data structure, it is assured that all necessary information can be provided at a program location regardless of whether the program or the user has relocated.



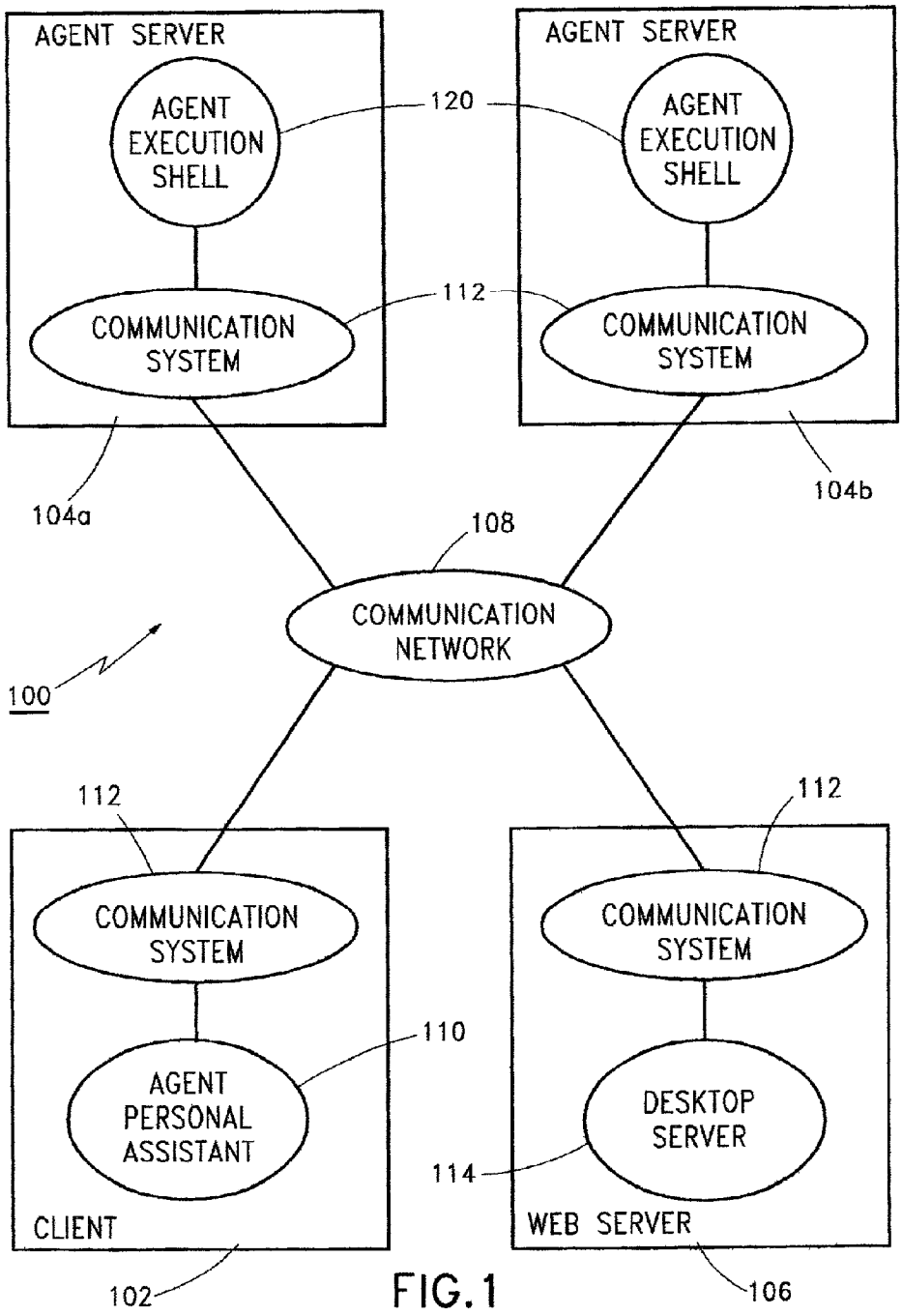

AGENT SERVER
AGENT EXECUTION SHELL
120
AGENT SERVER
AGENT EXECUTION SHELL
112
COMMUNICATION SYSTEM
COMMUNICATION SYSTEM
104a
104b
108
COMMUNICATION NETWORK
100
112
112
COMMUNICATION SYSTEM
COMMUNICATION SYSTEM
110
AGENT PERSONAL ASSISTANT
DESKTOP SERVER
114
CLIENT
WEB SERVER
102
106

FIG. 1

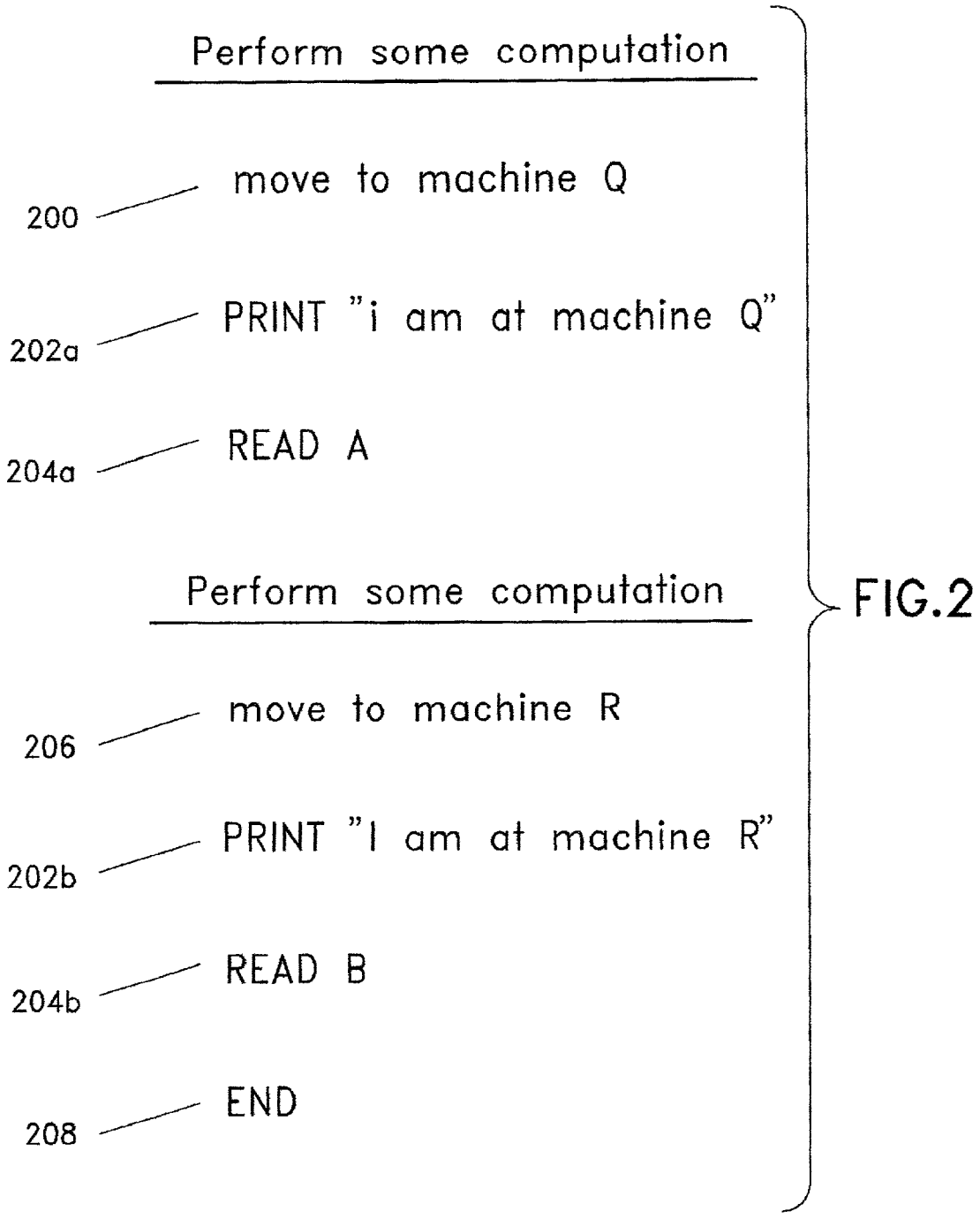

Perform some computation
200
move to machine Q
202a
PRINT "i am at machine Q"
204a
READ A
Perform some computation
206
move to machine R
202b
PRINT "I am at machine R"
204b
READ B
208
END

FIG.2

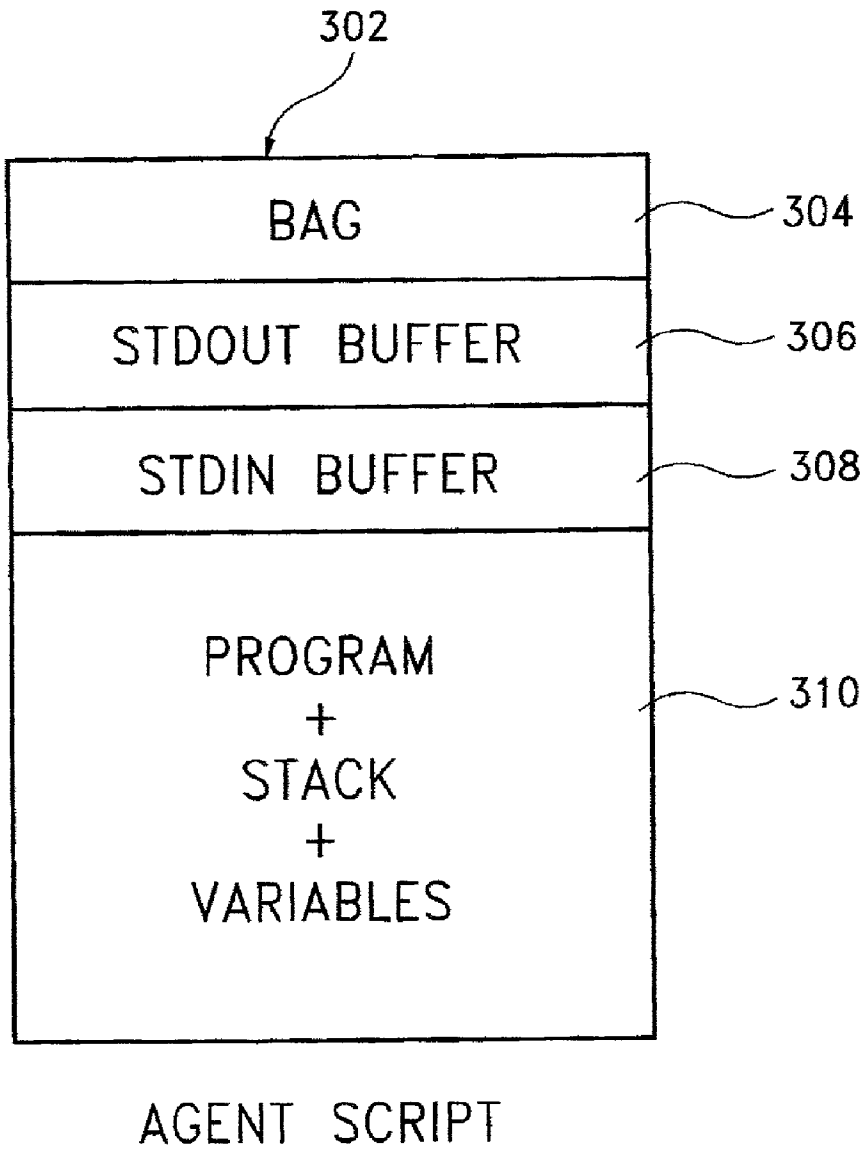

302
BAG
304
STDOUT BUFFER
306
STDIN BUFFER
308
PROGRAM
+
STACK
+
VARIABLES
310
AGENT SCRIPT

FIG.3

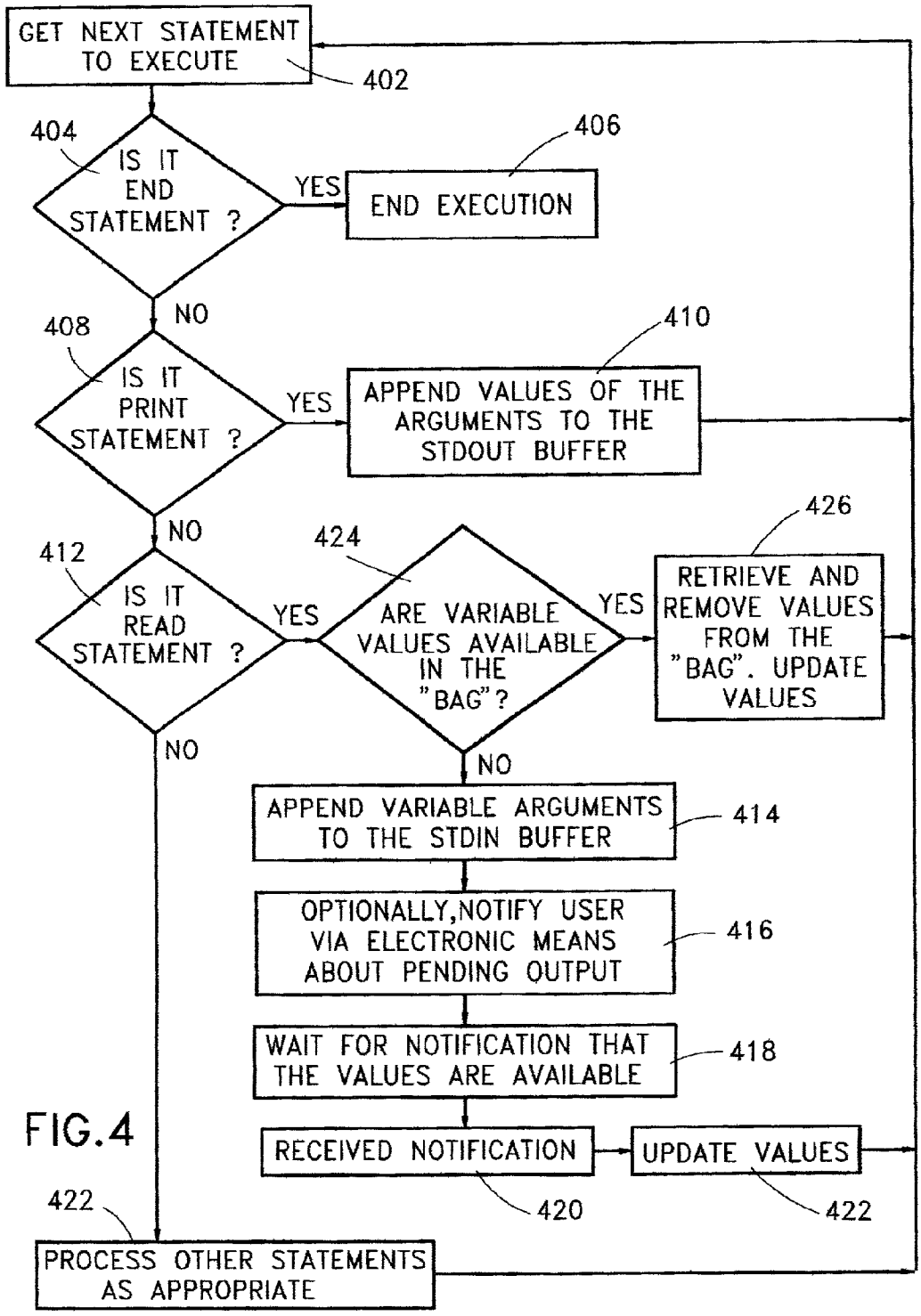

GET NEXT STATEMENT TO EXECUTE
402
404
IS IT END STATEMENT ?
YES
406
END EXECUTION
NO
408
IS IT PRINT STATEMENT ?
YES
410
APPEND VALUES OF THE ARGUMENTS TO THE STDOUT BUFFER
NO
412
IS IT READ STATEMENT ?
YES
424
ARE VARIABLE VALUES AVAILABLE IN THE "BAG"?
YES
426
RETRIEVE AND REMOVE VALUES FROM THE "BAG". UPDATE VALUES
NO
NO
APPEND VARIABLE ARGUMENTS TO THE STDIN BUFFER
414
OPTIONALLY,NOTIFY USER VIA ELECTRONIC MEANS ABOUT PENDING OUTPUT
416
WAIT FOR NOTIFICATION THAT THE VALUES ARE AVAILABLE
418
RECEIVED NOTIFICATION
420
UPDATE VALUES
422
422
PROCESS OTHER STATEMENTS AS APPROPRIATE

FIG.4

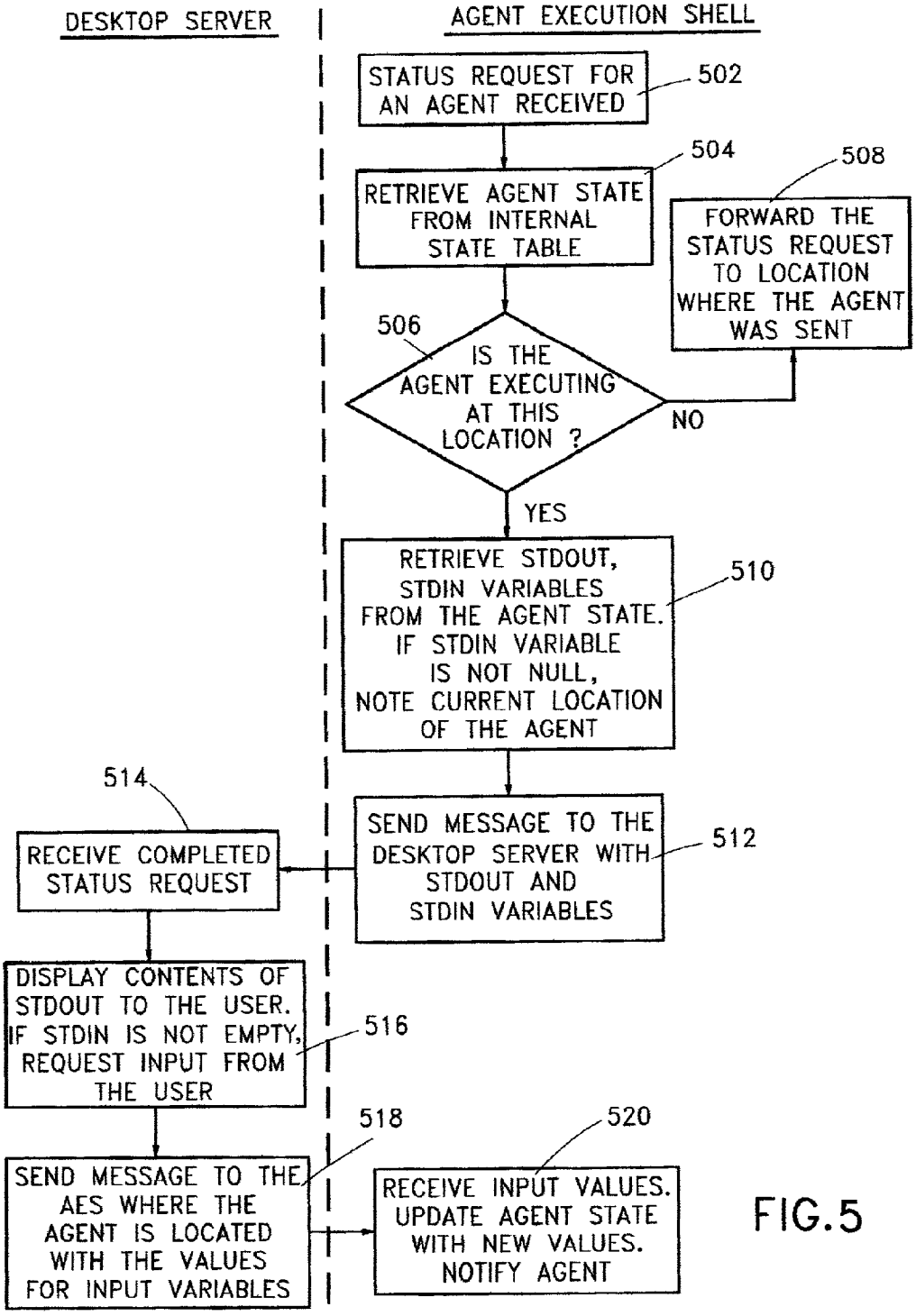

DESKTOP SERVER
AGENT EXECUTION SHELL
STATUS REQUEST FOR AN AGENT RECEIVED
502
RETRIEVE AGENT STATE FROM INTERNAL STATE TABLE
504
FORWARD THE STATUS REQUEST TO LOCATION WHERE THE AGENT WAS SENT
508
IS THE AGENT EXECUTING AT THIS LOCATION ?
506
NO
YES
RETRIEVE STDOUT, STDIN VARIABLES FROM THE AGENT STATE. IF STDIN VARIABLE IS NOT NULL, NOTE CURRENT LOCATION OF THE AGENT
510
SEND MESSAGE TO THE DESKTOP SERVER WITH STDOUT AND STDIN VARIABLES
512
RECEIVE COMPLETED STATUS REQUEST
514
DISPLAY CONTENTS OF STDOUT TO THE USER. IF STDIN IS NOT EMPTY, REQUEST INPUT FROM THE USER
516
SEND MESSAGE TO THE AES WHERE THE AGENT IS LOCATED WITH THE VALUES FOR INPUT VARIABLES
518
RECEIVE INPUT VALUES. UPDATE AGENT STATE WITH NEW VALUES. NOTIFY AGENT
520

FIG.5

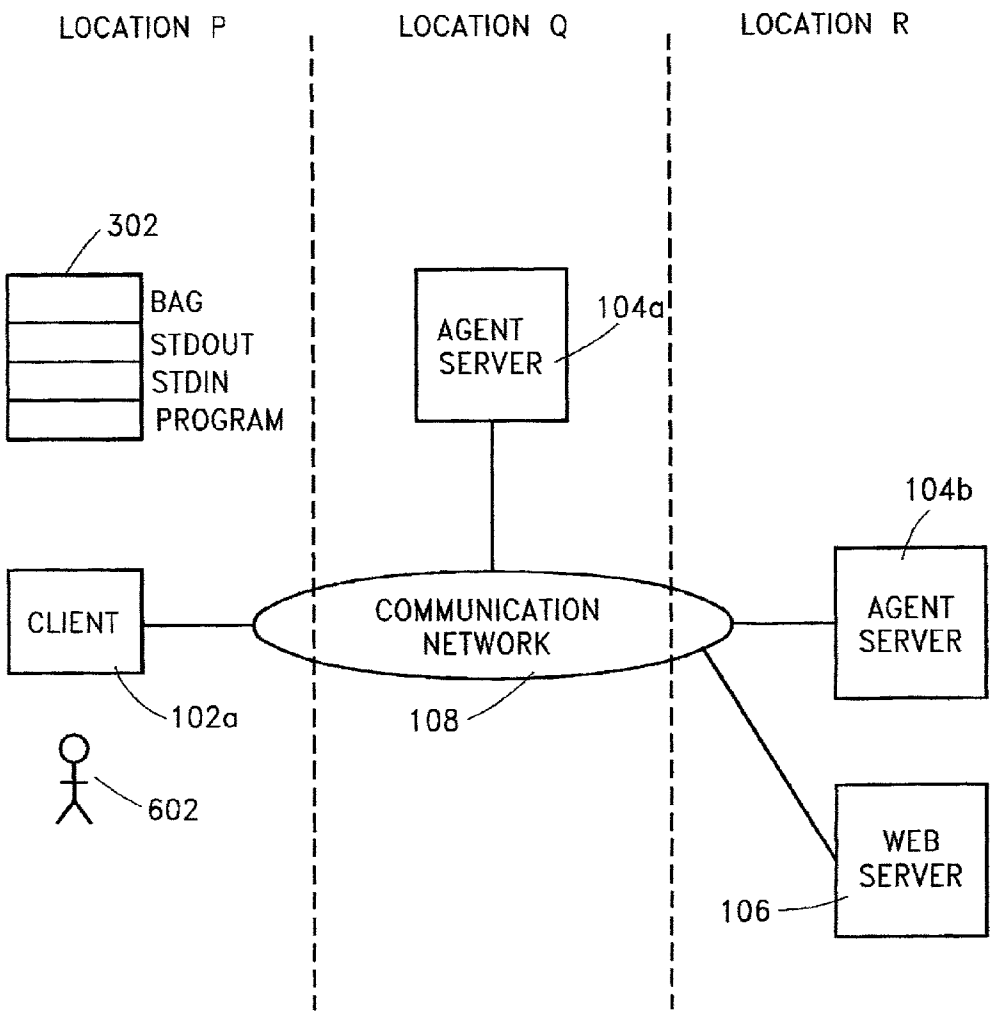

LOCATION P
LOCATION Q
LOCATION R
302
BAG
STDOUT
STDIN
PROGRAM
AGENT SERVER
104a
104b
CLIENT
COMMUNICATION NETWORK
AGENT SERVER
102a
108
602
WEB SERVER
106

FIG.6A

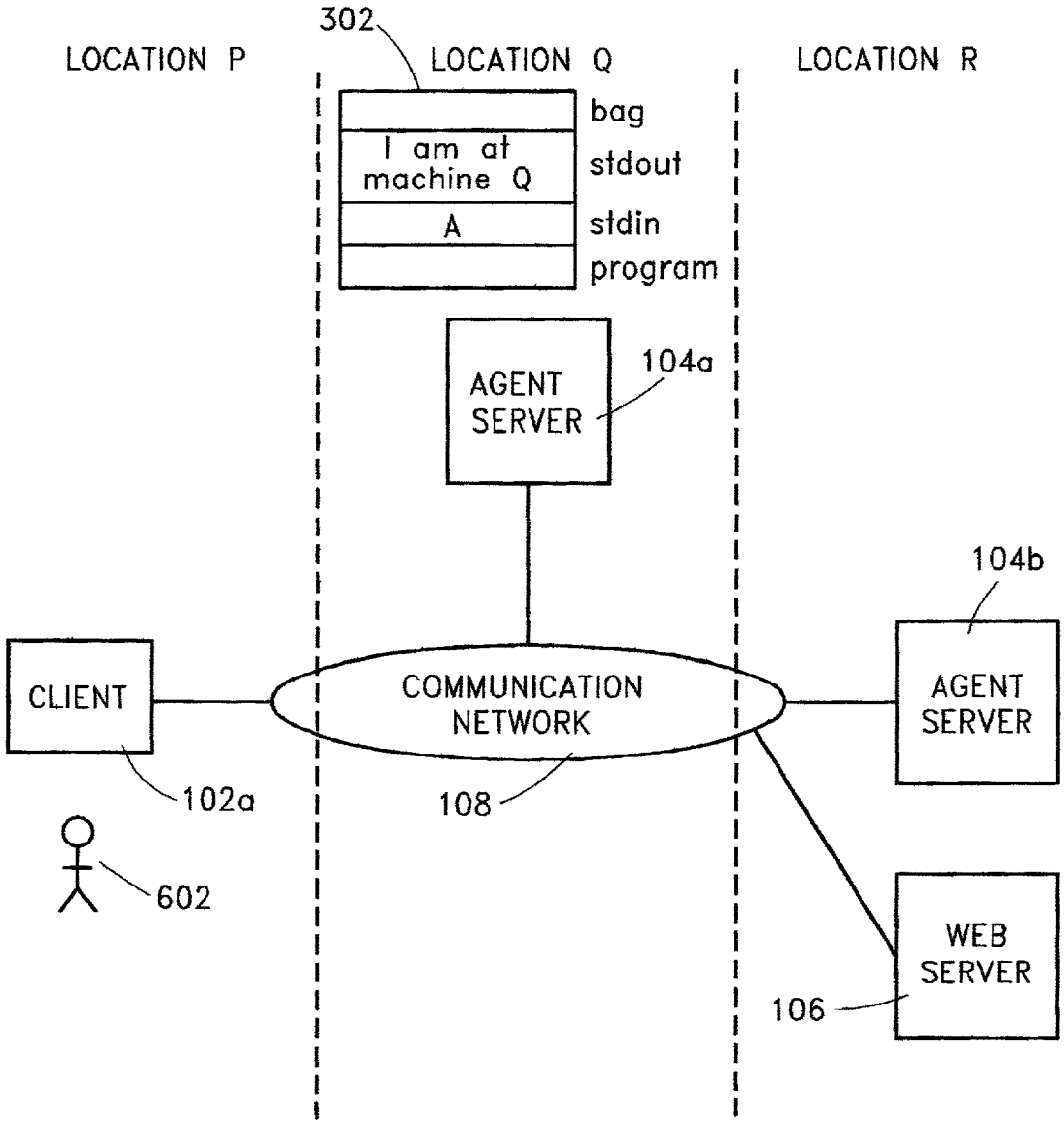

302
LOCATION P
LOCATION Q
LOCATION R
bag
I am at machine Q
stdout
A
stdin
program
AGENT SERVER
104a
104b
CLIENT
COMMUNICATION NETWORK
AGENT SERVER
102a
108
602
WEB SERVER
106

FIG.6B

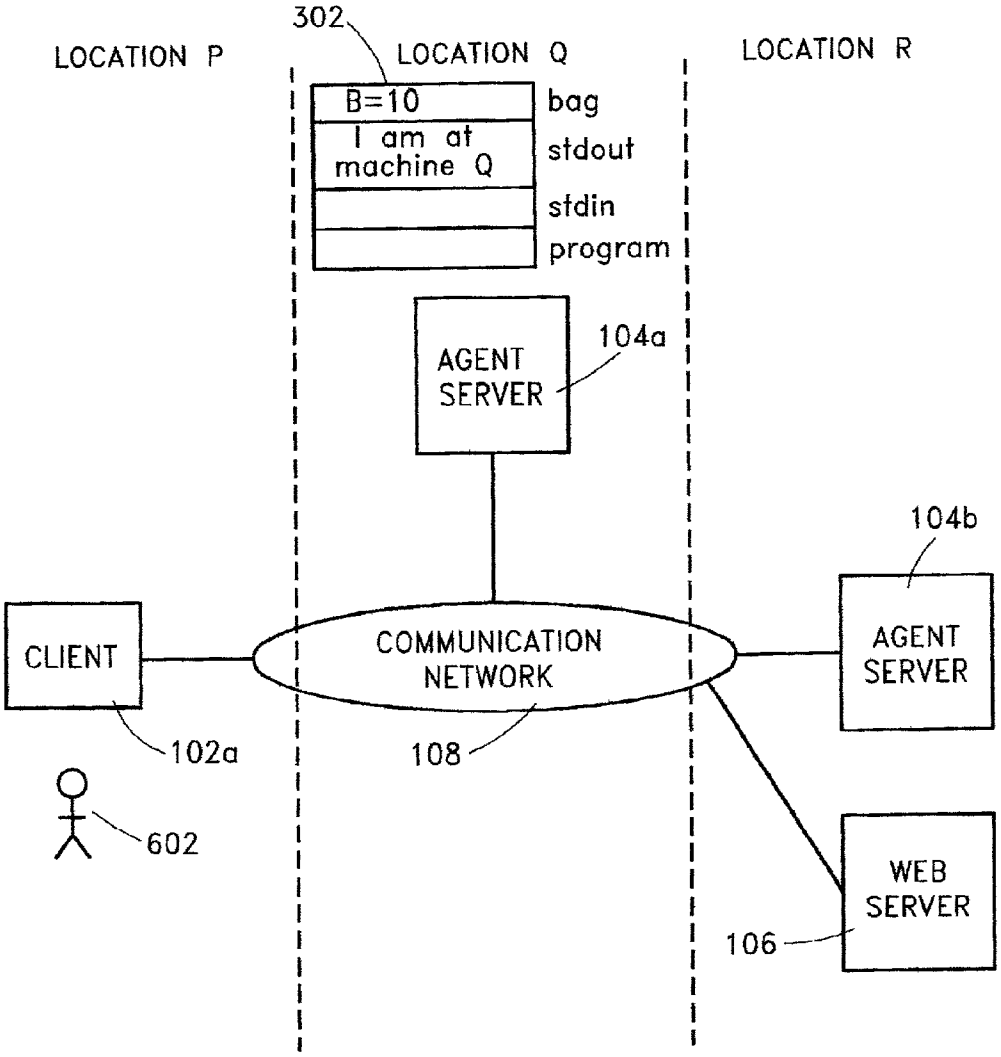

302
LOCATION P
LOCATION Q
LOCATION R
B=10
bag
I am at machine Q
stdout
stdin
program
AGENT SERVER
104a
104b
CLIENT
COMMUNICATION NETWORK
AGENT SERVER
102a
108
602
WEB SERVER
106

FIG.6C

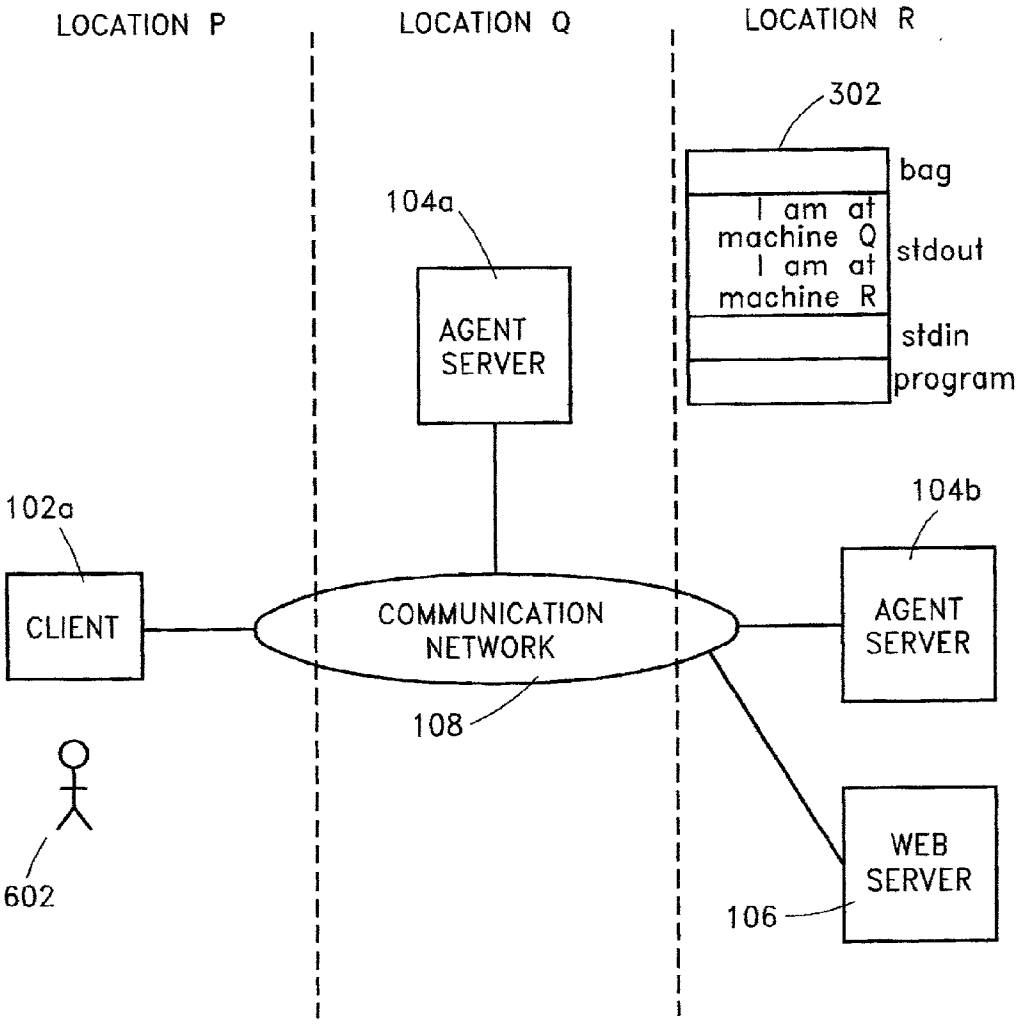

LOCATION P
LOCATION Q
LOCATION R
302
bag
I am at machine Q
I am at machine R
stdout
stdin
program
104a
AGENT SERVER
102a
CLIENT
COMMUNICATION NETWORK
108
104b
AGENT SERVER
WEB SERVER
106
602

FIG.6D

METHOD AND APPARATUS FOR ENABLING LOCATION-INDEPENDENT AND LOCATION-TRANSPARENT INTERACTION BETWEEN PROGRAM AND USER

FIELD OF INVENTION

[0001] The present invention relates to input and output functions of computer programs. More specifically, the present invention is related to enabling location independent and location transparent interaction between a program and a user, one or both of which is mobile.

BACKGROUND OF THE INVENTION

[0002] To support interaction between a user and a program, current systems require the program and the user to be constantly aware of each other's location. If a program, such as a mobile agent program, moves to a different host, it must return to the user location or communicate through another program at the user location, to receive input or display output to the user. This is a problem when the user is mobile (e.g., using a laptop or handheld device) and, therefore, usually not in the original location from which the program was launched. Similarly, if a user chooses to move to another location on a network, that user must access the machine at which the program is executing in order to provide input or to receive output from the program.

[0003] In prior art systems, interactions between a program and a user are handled using standard input and output constructs. For example, in C programming language the input construct is the "scarf( )" function and the output construct is the "printf( )" function. In Java language, the input is performed using methods in classes such as "java.io.InputStreamReader" and "Java.io.InputStream," while output is performed using methods in classes such as "java.io.PrintWriter" and "java.io.PrintStream." For such programs, both the user and the program must be at the same location.

[0004] In conventional mobile agent systems, such as those described in U.S. Pat. No. 5,603,031, issued Feb. 11, 1997, entitled "System and Method for Distributed Computation Based Upon the Movement, Execution, and Interaction of Processes in a Network," by White et al. and "IBM Aglets Workbench—Programming Mobile Agents in Java", Proceedings of 1997 World Wide Computing and Its Applications, Japan, pp. 253-266 by Lange et al., the program executes part of its code at one host location, then moves to another host location where it executes a next portion of code, and so on. Interaction between a mobile agent and a user in such a system is achieved by the agent moving to and executing at the user's machine when display of data to the user and/or receipt of input from the user is required.

[0005] The conventional systems have three main limitations. First, both the program and the user have to be aware of each others' location at all times. Second, in situations where a program must move to the location of a user, the user's machine must have a program execution environment available to host and execute the program at any time. Third, while mechanisms exist to supply initialization parameters to a program before it begins execution, after the program has started execution, there are no mechanisms in these systems to permit a user to both determine the status of the program and to provide input to the program during program execution and/or before the program asks for them.

[0006] An object of the present invention is to provide a system and method for permitting input and output between a user and a program without the requirement of each entity constantly maintaining knowledge of the other entity's location.

[0007] Another object of the present invention is to provide a system and method for permitting input and output between a user and a program without requiring the user's machine to have an execution environment available in which the program can run.

[0008] Another object of the present invention is to provide for a user to both determine the status of a mobile program during execution and supply input to a program during execution and before input is actually needed.

SUMMARY OF THE INVENTION

[0009] These and other objects of the invention are realized by the present invention comprising a system and method wherein a mobile user, or a user interacting with a mobile program, can at any time initiate a program status request. The program status request initiates the sequence of events whereby the current location of the program is determined and/or the current user location is made available to the program without the necessity of either entity changing location. Further, the agent script for the program maintains a composite data structure which includes an input buffer for storing input variables, an output buffer for storing output values to be displayed to the user, a program state data structure, and an optional bag buffer for temporarily storing input values which the program will need in the course of future execution. By maintaining such a composite data structure, it is assured that all necessary information can be provided at a program location regardless of whether the program or the user has relocated.

BRIEF DESCRIPTION OF THE DRAWING

[0010] The present invention will be understood by reference to the drawing, wherein:

[0011] **FIG. 1** shows a networked system into which the present invention can be incorporated;

[0012] **FIG. 2** shows an example of an agent script with input and output statements;

[0013] **FIG. 3** shows an embodiment of the relevant data structures of a mobile agent script according to an aspect of the present invention;

[0014] **FIG. 4** shows an embodiment of the logic of the present invention for handling input and output by the Agent Execution Shell of the system of **FIG. 1**;

[0015] **FIG. 5** shows an embodiment of the logic of the present invention for processing a user's request for status; and

[0016] **FIGS. 6***a*, **6***b*, **6***c* and **6***d* show an example scenario in which a user launches the script from one geographic location and, while moving, continually monitors the program, views results of the program and supplies input values as needed.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0017] The following are definitions of some of the terms used in this specification:

[0018] A host or host machine is a computing system, such as a mainframe, desktop personal computer, portable laptop computer or handheld device on which a program is executing.

[0019] A network is a set of hosts, interconnected by some physical and logical communications infrastructure.

[0020] A user is a human user of the network environment.

[0021] A client is the user's interface to a network and may be a computer, handheld portable device, or other device having communication capabilities.

[0022] A program is a sequence of instructions that execute on a host machine.

[0023] A mobile program is a program, such as a mobile agent, that moves from one host machine to another, executing some of its instructions at each host machine.

[0024] An Agent Server is a host machine having the execution environment for a mobile agent.

[0025] An Agent Execution Shell (AES) is a software subsystem at a host's Agent Server in which a mobile agent executes part of its instructions.

[0026] The preferred embodiment is described in the context of a program that is mobile such as a mobile agent.

[0027] **FIG. 1** depicts a system into which the features of the present invention can be incorporated. Here, a networked system **100** connects computers that have distinct roles in the system. The computers **102**, **104***a*, **104***b* and **106**, which can be running conventional operating systems such as OS/2, UNIX, AIX or Windows NT, are interconnected by way of a communication network **108** in conjunction with a communication protocol. The communication protocol can be, for example, Sun Microsystems RPC, which can run on UDP/IP or TCP/IP. The network **108** can be a LAN, Internet or intranet. The client **102** and Agent Servers **104***a*, **104***b* can be embodied by conventional personal computers (PCs) such as IBM PCs. On each computer, there is a conventional communication system **112**, such as the TCP/IP stack in the operating system, that is used to communicate over the network **108**. Alternatively, clients also can be embodied as handheld portable mobile devices, such as a PalmPilot or a smart cellular telephone. These mobile devices can run proprietary operating systems using cellular telephone technology, infrared communication means, or other equivalent means, to connect to the communication network **108**. Note that the distinction between a client **102** and an Agent Server **104***a*, **104***b* may be logical or physical and that the client need not be able to provide an execution environment for the relevant program.

[0028] Although only one client is shown in **FIG. 1**, there can be many clients in the system **100**. An agent program is launched from a client machine **102**, using a subsystem called the Agent Personal Assistant (APA) **110**. In addition to agent launch, this subsystem is capable of debugging, updating and checking agent status. Such a subsystem is disclosed in U.S. patent application Ser. No. 08/847,079 of Devarakonda et al, entitled, "Dynamic Mobile Agents," filed May 1, 1997. In the present invention, it is preferable that the APA **110** be embodied as an application with a web interface. The APA **110** interacts with a Desktop Server **114**, located within a Web Server **106**, to perform these tasks.

[0029] There can be a plurality of Agent Servers in the system **100**. Each of the Agent Servers **104***a*, **104***b* supports an execution environment that includes a software subsystem referred to as an Agent Execution Shell (AES) **120**. This AES **120** acts as the single coordinator for agent execution and maintains an internal table containing the state of all currently active agents. Each Agent Server additionaly maintains at least one routing table for recording the locations(s) from and to which mobile agents move.

[0030] **FIG. 2** shows a typical example of agent code to be used with the present invention. After performing some computation on a machine, the agent moves to the next host machine Q at step **200**. The next host may be specified in the code or may be dynamically determined as discussed in the aforementioned patent application, the disclosure of which is hereby incorporated by reference. The agent code may contain the construct PRINT for providing output and the construct READ for reading input values from machine Q. As illustrated, at step **202***a*, the PRINT construct enables the agent to display results to a user, while the READ construct, at step **204***a*, enables the agent to request input from a user. After performing its computation as required, such as executing the READ, PRINT or other instruction, the agent moves to machine R at line **206**. Again, the agent code may contain a PRINT construct and a READ construct, which may be executed at **204***a* and **204***b*, respectively. The code completes execution at step **208**.

[0031] **FIG. 3** shows a composite data structure associated with an agent script **302** as it moves through the network **108** in accordance with the present invention. While the contents of the components of the composite data structure change as the agent script moves, the data structure components, including bag **304**, STDOUT **306**, STDIN **308**, and program state **310** remain available. A "bag"**304** is a buffer that contains a set of variable name/value pairs which have been preset or input dynamically for future program usage. When the program requires input, the agent script examines the contents of the bag to locate values for variables and then retrieve the values. The value for a particular variable name could be a set of values that would be returned sequentially for successive requests for the same name. If the bag does not contain a value for the needed variable, the agent script blocks and waits for the user to input the needed data. The bag buffer may be implemented as an array, hash table, tuple space, or other equivalent data structure. "STDOUT" buffer **306** contains all the output generated by an agent. The contents of the STDOUT buffer **306** are displayed to the user when requested. "STDIN" buffer **308** contains the variable names for which an agent script is awaiting input values from the user. The "STDIN" buffer **308** is used by the AES **120** to communicate values for input variables to the agent script. Finally, program, stack and variable data structures are included for representing the program state **310** of the agent script.

[0032] **FIG. 4** shows the method steps performed by an embodiment of the AES **120** when executing program statements of the agent. Only statements relevant to the

present invention are shown in **FIG. 4**. In step **402**, the AES **120** examines the next statement to execute. In step **404**, the AES **120** determines if the statement is the END statement. If it is the END statement, the AES terminates execution of the agent at step **406**. If the next statement is not the END statement, the AES **120** determines if the statement is a PRINT statement at step **408**. If the next statement is a PRINT statement, the AES **120** retrieves values for the arguments to the PRINT statement from the program state **310** and appends the values to the STDOUT buffer **306** in a pre-determined format in step **410**. A STDOUT buffer **306** is associated with each agent. The AES **120** then continues with the execution of the agent by returning to step **402**.

[**0033**] If, in step **408**, it is concluded that the statement is not a PRINT statement, the AES **120** next determines, in step **412**, if the statement is a READ statement. If, in step **412**, it is determined that the statement is a READ statement, then the AES **120** checks whether the needed variable values are available in the bag **304** in step **424**. If the values are available, the values are retrieved and removed from the bag **304** in step **426**. The variables are updated, and the AES **120** continues execution of the program by returning to step **402**. If, in step **424**, it is determined that the values are not available, the AES **120** appends the names of the arguments for the READ statement to the STDIN buffer **308** in step **414**. Optionally, in step **416**, the AES **120** then notifies the user via electronic means such as pager/beeper/electronic mail that input is required. The preference to be notified can be specified by the user when the agent script is launched.

[**0034**] In step **418**, the AES **120** suspends execution of the program and waits for notification that the input values are available. The logic for notifying the AES **120** about input values is shown in **FIG. 5**, described hereinbelow. After the AES **120** receives notification in step **420**, the AES **120** updates the program state **310** with new values in step **422**, and continues with execution of the program by returning to step **402**. The AES may additionally update the bag contents if the user has provided input which the user knows will be required by the program in succeeding steps. If, in step **412**, it is determined that the statement is not a READ statement, the AES **120** processes other statements as appropriate, in step **422**, and continues execution of the program by returning to step **402**. In one optmized embodiment, the entire contents of the bag could be consumed at one time (assuming that the bag contains more than just the immediately-required input) and utilizes the consumed input as required without having to re-examine the bag content at each input juncture of program execution.

[**0035**] **FIG. 5** shows the steps through which a user interacts with an agent in an embodiment of the present invention. A user initiates a status request for an agent from the APA **110**. The request is forwarded by the APA **110** to the Desktop Server **114** at the Web Server. The Desktop Server **114** then forwards the request as a STATUS request to the AES **120** at the Agent Server where the agent was initially launched. The AES **120**, in step **502**, receives the STATUS request forwarded by the Desktop Server **114**. The AES **120** next retrieves the agent state from the internal state table, in step **504**. The AES **120** then determines if the agent is still executing at the present location, in step **506**. If the agent is no longer executing at the present location, the AES **120** checks its routing table and then, in step **508**, forwards the STATUS request to the site where the agent was sent (and the method resumes with step **502** at the next machine).

[**0036**] If it is determined, in step **506**, that the agent is currently executing at the present site, the AES **120** retrieves, in step **510**, the STDOUT buffer **306** and the STDIN buffer **308**, each associated with the agent state. If the STDIN buffer is not empty, such that input is required, the AES additionally notes the current logical address of the agent. In step **512**, the AES **120** sends a message to the Desktop Server **142** containing the STDOUT and STDIN buffers **306**, **308**. If the STDIN buffer **308** is not empty, the AES **120** also sends the current logical address of the agent in the message, so that user input can be properly routed.

[**0037**] In step **514**, the Desktop Server **114** receives a reply for the STATUS request. The Desktop Server **114** extracts the contents of the STDOUT and STDIN buffers from the message. In step **516**, the Desktop Server **114** displays the contents of the STDOUT buffer to the user via the APA **110**. If the STDIN buffer was not empty, the Desktop Server **114** also requests input from the user. Upon receipt of user input, the Desktop Server **114** sends a message to the AES **120** where the agent is currently located, at step **518**. The AES **120** receives the message, at step **520**, notifies the agent of the new values, and updates the buffers as necessary. As described in **FIG. 4**, the agent resumes execution after receiving the notification.

[**0038**] **FIGS. 6***a-d* show a representative process flow for the present invention based upon the sample script in **FIG. 2**. In **FIG. 6***a*, a user **602** at Location P launches a mobile script **302** from client machine **102***a* onto the communication network **108** which spans Locations P, Q, and R. The Agent Server **104***a* is disposed at Location Q. The Agent Server **104***b* and the Web Server **106** are disposed in Location R. After performing some computation, the mobile script **302** moves to location Q.

[**0039**] In **FIG. 6***b*, the script executes the PRINT statement at location Q. As a result of execution, the output of the PRINT statement, "I am at machine Q", is added to the STDOUT buffer. Next, the script **302** executes the statement "READ A." Since the value of A is not available in the bag, the script **302** optionally sends notification to the user **602** and waits for a reply. The user notification can be implemented using technology such as a beeper, pager, e-mail, smart phone or handheld portable mobile device. After the user checks the status of the script **302** (as explained with reference to **FIG. 5**.), the user **602** supplies a value for variable A to the script **302**. Additionally, under one optional optimization, the user also supplies a value for variable B to the script **302**. Upon receiving these values, the script **302** resumes executions immediately consuming the value for variable A. Since the value for variable B is not yet needed by the script **302**, it is placed in the bag associated with the script **302** (see **FIG. 6***c*). The script **302** then moves to the Agent Server **104***b* at Location R.

[**0040**] In **FIG. 6***d*, the script **302** generates the output "I am at machine R" as a result of executing the PRINT statement, at location R. The output is attached to the STDOUT buffer of script **302**. Next, the script **302** executes the statement "READ B". Since the value for variable B is already available in the bag, the program retrieves the value from the bag and completes execution, without the need for preparing and sending notification to the user. Clearly, more

than one additional value can be input by the user and stored in the bag buffer for subsequent use by the program.

[0041] Now that the invention has been described by way of a preferred embodiment, various modifications and improvements will occur to those of skill in the art. Thus, it should be understood that the preferred embodiment is provided as an example and not as a limitation. For instance, along with the notification, the contents of the STDOUT buffer **306** can be transmitted to the user's device, assuming the device is capable of receiving such data (e.g., pager or smart phone). In addition, a user, using the system of the present invention, can optionally communicate with a particular AES via e-mail. The scope of the invention is defined by the appended claims.

We claim:

1. A method for enabling location independent and location transparent interaction between a program and a user, the program having been launched at a first location and having a program state data structure for storing at least the program state, the method comprising the steps of:

initiating a program status request by the user;

determining the current location of the program;

checking the program state to ascertain program status; and

interacting with said program based upon said program status.

2. The method of claim 1 wherein said interacting with said program comprises:

retrieving, from the program, output contents to display to the user; and

displaying the output contents to said user.

3. The method of claim 1 wherein said interacting with said program comprises:

requesting input variables from said user;

sending any received input values to the current location; and

incorporating the received input values into said program state data structure.

4. The method of claim 1 wherein the program is a mobile agent.

5. The method of claim 1 wherein the program is a mobile script.

6. The method of claim 1 where the user is a mobile user.

7. The method of claim 2 further comprising the step of maintaining an output buffer and wherein said retrieving comprises the step of retrieving the output contents from said output buffer.

8. The method of claim 1 wherein the initiating step comprises the steps of:

initiating the status request at a client machine; and

forwarding the status request to the first location at which said program was launched.

9. The method of claim 8 wherein said program comprises a mobile program which executes a portion of its code at each of a plurality of execution servers and wherein the determining step comprises the steps of:

transmitting the status request to each execution server at which the program has executed a portion of its code; and

determining, at each execution server, whether the program is currently running locally.

10. The method of claim 9 wherein each of said plurality of execution servers maintains routing information for said program and wherein said determining further comprises the step, if said program is not currently running locally, of consulting said routing information to ascertain at least one successive execution server to which the program has been routed.

11. A method for enabling a user to provide input values to a running program before the program needs the input values, comprising the steps of:

maintaining a bag buffer of variable/value pairs in the program;

receiving a communication, including input values, from the user; and

temporarily storing said input values in said bag buffer.

12. The method of claim 11 wherein said program subsequently searches through contents of the bag buffer to locate needed input values before requesting input from said user.

13. The method of claim 2 further comprising the step of maintaining a bag buffer in the program and wherein the retrieving step comprises the steps of:

searching, in the bag buffer, for input values associated with the input variables;

updating, if found, the input variables with the input values;

disposing, in an input buffer, the input variables, if not found; and

optionally notifying the user via electronic means if no suitable values are found in the bag buffer.

14. The method of claim 13 wherein the electronic means is a pager.

15. The method of claim 13 wherein the electronic means is a beeper.

16. The method of claim 13 wherein the electronic means is electronic mail.

17. The method of claim 13 wherein the electronic means is a smart telephone.

18. A computer program data structure comprising;

an output buffer for storing output values to be displayed to a user;

an input buffer for storing values for which user input of variables is required; and

program state buffer for storing at least the present state of said program.

19. The data structure of claim 18 further comprising a bag buffer for storing input variables.

20. The data structure of claim 19 wherein the bag buffer is a array data structure.

21. The data structure of claim 19 wherein the bag buffer is a hash table data structure.

22. The data structure of claim 19 wherein the bag buffer is a tuple space data structure.

23. An execution shell for a mobile program comprising:

a routing component for maintaining routing information regarding said mobile program;

a processor component for processing user status requests related to said program; and

an execution component for executing at least part of said program.

24. The execution shell of claim 23 further comprising a data handling component for receiving user input and storing same in at least one data structure for said program.

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