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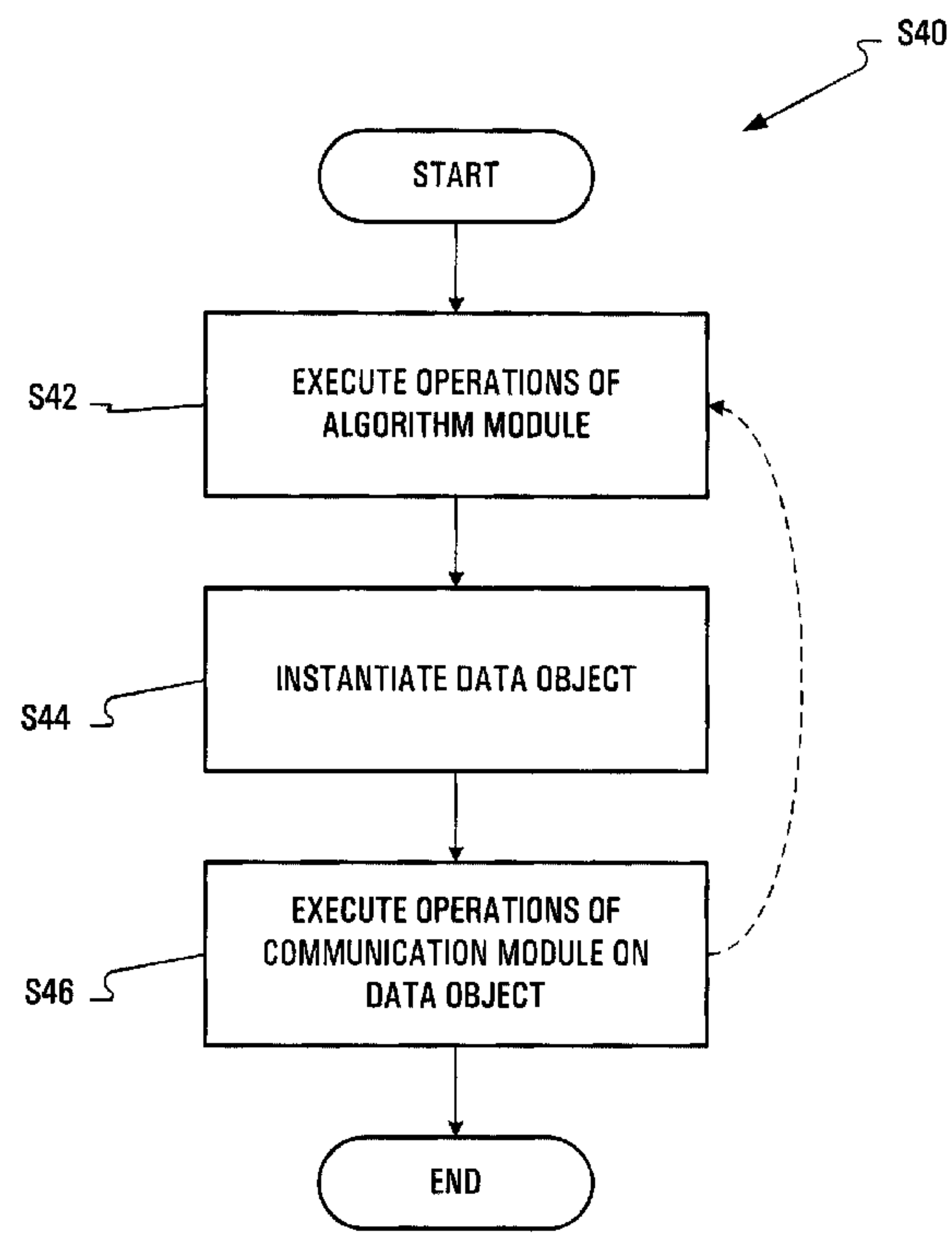
(54) Titre : ENCAPSULATION ET EXECUTION D'ALGORITHMES INFORMATIQUES
(54) Title: ENCAPSULATING AND EXECUTING COMPUTER ALGORITHMS



(57) Abrégé/Abstract:
A computer algorithm is encapsulated in at least two modules: at least one communication operation of the computer algorithm is encapsulated in a communication module, separately from the rest of the operations of the algorithm which may be encapsulated in an algorithm module. The separately encapsulated communication operation is made available to the algorithm module during its execution. Modules for data objects encapsulating data communicated may also be provided. A framework may be provided to ensure compatibility between different modules, wherein a plurality of protocols are provided and each module implements a corresponding protocol. All environment-dependent communication operations may be separately encapsulated so that one of the communication module and the algorithm module may be modified without modifying the other.

ABSTRACT

A computer algorithm is encapsulated in at least two modules: at least one communication operation of the computer algorithm is encapsulated in a communication module, separately from the rest of the operations of the algorithm which may be encapsulated in an algorithm module. The separately encapsulated communication operation is made available to the algorithm module during its execution. Modules for data objects encapsulating data communicated may also be provided. A framework may be provided to ensure compatibility between different modules, wherein a plurality of protocols are provided and each module implements a corresponding protocol. All environment-dependent communication operations may be separately encapsulated so that one of the communication module and the algorithm module may be modified without modifying the other.

Encapsulating and Executing Computer Algorithms

[0001] The present invention relates to encapsulating and executing computer algorithms.

[0002] It is desirable that computer programming codes are portable and reusable, i.e, the same code for a computer algorithm can be used for different purposes and in different applications with no or minimal modification. Using portable and reusable codes, development, maintenance, and upgrading costs can be reduced.

[0003] A common technique for improving code portability and reusability is to encapsulate computer algorithms in modules, such as commands, routines, procedures, functions, methods, classes, and other like encapsulations known to a person skilled in the art. A non-communicating module, i.e., one which does not communicate with its external environment during execution, may be completely encapsulated and thus easily ported or reused without changing its code.

[0004] However, a module may need to communicate or interact with its external environment during its execution, such as to report its status and obtain additional instructions. For example, a file-creating routine may need a confirmation from a user before overwriting an existing file. An entity that communicates information with the module is herein referred to as a "communicating partner." A communicating partner can be an information receiver, or an information provider, or both. As can be appreciated, a communicating partner can be a human operator, a physical device, or a software component (such as an object) that interacts with the executing module. A communicating partner forms part of the external environment of the executing module. Thus, the environment changes if one of the communicating partners has been changed. For example, a command procedure receiving input from a batch file or a console input device is considered to be executing in two different environments.

[0005] The need to communicate makes it difficult to encapsulate an algorithm. As can be understood, a module can only properly communicate with a communicating partner if they both communicate in a compatible way. Incompatibility may arise due to the use of incompatible data formats or data types for the same information. Further, with different communicating partners, or, in different environments, different information may need to be communicated or different operations may need to be performed for processing the information. For instance, the file writing routine discussed earlier may receive instructions from a human operator through different devices (such as a keyboard or a mouse) or from a data object (such as a file) that contains pre-stored instructions. In each case, the information provider is different, the data to be transmitted is different, and the operations to be performed may be different. For example, a message of "do not overwrite" may be provided to the routine by one or more key strokes (in the case of keyboard input), by one or more mouse clicks at one or more pre-defined locations on a monitor screen (in the case of mouse input), or by a text string or a numerical value (in the case of an data object).

[0006] Under known programming approaches, code modification is often required when a communicating module is to be used in a new environment. In order to improve code portability and reusability, several programming techniques have been developed to enhance encapsulation of communicating modules. One of the known techniques is to use an intermediate object to convert the formats of communicated data when the data is transmitted between two modules with mismatching internal data formats, so that the modules can communicate with each other without the need to modify the code of either module. Another similar technique is to intercept and translate messages communicated between incompatible objects before relaying the message to the receiving object. However, code modification may still be required under either of these two approaches in cases where a module needs to communicate different information or perform different communication operations in different environments.

[0007] Thus, there is a need to enhance encapsulation of communicating algorithm modules and to improve portability and reusability of module codes encapsulating communicating algorithms.

SUMMARY OF THE INVENTION

[0008] In accordance with the invention, at least one communication operation of a computer algorithm is encapsulated in a communication module, separately from the rest of the operations of the algorithm which may be encapsulated in an algorithm module. The separately encapsulated communication operation is made available to the algorithm module during its execution.

[0009] Thus, the encapsulation of the algorithm is enhanced in the sense that its communication operation(s) can be modified without changing the algorithm module code. When all environment-dependent communication operations of the algorithm are encapsulated in the communication module code, the algorithm module code can be ported to different environments without changing its code. As many communication operations in a particular environment are common to various algorithms, common communication module codes may be developed so as to further reduce, and sometimes avoid, code modification.

[0010] In accordance with one aspect of the invention there is provided a method of executing a computer algorithm. The method comprises executing a first module encapsulating the computer algorithm except at least one communication operation of the algorithm and executing a second module encapsulating the at least one communication operation of the algorithm, such that the at least one communication operation is available to the first module.

[0011] In accordance with another aspect of the invention there is provided a computer readable medium storing thereon computer executable instruction code. The code when executed by a processor of a computer causes the processor to execute a first module encapsulating a computer algorithm except at least one communication operation of the algorithm and execute a second module encapsulating the at least one communication operation of the algorithm, such that the at least one communication operation is available to the first module.

[0012] In accordance with yet another aspect of the invention there is provided a method of encapsulating a computer algorithm. The method comprises encapsulating, in a first module code, the computer algorithm except at least one communication operation of the computer algorithm, and encapsulating the at least one communication operation in a second module code, so that one of the first and second module codes can be modified without changing the other one of the first and second module code.

[0013] Other aspects, features and advantages of the invention will become apparent to those of ordinary skill in the art upon review of the following description of specific embodiments of the invention in conjunction with the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] In the figures, which illustrate exemplary embodiments of the invention,

[0015] **FIG. 1** is a schematic diagram illustrating a computer system;

[0016] **FIG. 2A** and **2B** schematically illustrates methods of executing a computer algorithm which communicates with a communicating partner;

[0017] **FIG. 3** is a flowchart diagram illustrating executing the computer algorithm coded in **FIG. 2B**;

[0018] **FIG. 4** is a class diagram illustrating the relationships between exemplary interfaces and classes of a Java framework for coding an algorithm as illustrated in **FIG. 2B**; and

[0019] **FIG. 5** is a flowchart diagram illustrating the operation of example codes implementing the framework of **FIG. 4**.

DETAILED DESCRIPTION

[0020] In overview, to enhance the encapsulation of a computer algorithm, a communication operation of the algorithm is encapsulated in a communication module, separate from an algorithm module that encapsulate the rest of the algorithm's operations. The operation of the communication module is available to the algorithm module during the execution of the algorithm.

[0021] As can be understood, when environment-dependent communication operations are separately encapsulated in one or more communication modules, the algorithm module can be used, without modification, in different environments.

[0022] **Fig. 1** illustrates computer **10** on which computer algorithms can be executed in one or more computing environments. As is typical, computer **10** has a processor **12**, which communicates with memory **14**, input **16** and output **18**. Memory **14** may store both computer executable instruction codes **20** and data **22**. Computer **10** may optionally communicate with a network **24**.

[0023] Memory **14** includes a primary electronic storage for processor **12** and may include one or more secondary stores, each of which comprises a computer readable medium. A computer readable medium can be any available media accessible by a computer, either removable or non-removable, either volatile or non-volatile, including any magnetic storage, optical storage, or solid state storage devices, or any other medium which can embody the desired computer executable instructions and can be accessed, either locally or remotely, by a computer or computing device. Any combination of the above should also be included in the scope of computer readable medium.

[0024] Input device **16** may comprise, for example, a keyboard, a mouse, a microphone, a scanner, a camera, and the like. It may also include a computer readable medium and the corresponding device for accessing it.

[0025] Output device **18** may comprise, for example, display devices, printers, speakers, and the like. It may also include a computer writable medium and the device for writing to it.

[0026] Computer **10** may communicate with other computer systems (not shown) on network **24**. Network **24** may be embodied using conventional network technologies and may include one or more of the following: local area networks, wide area networks, intranets, the Internet, wireless networks, and the like. For clarity and conciseness, aspects of the present invention are illustrated using only computer **10** throughout the description herein. However, as will be appreciated by those of ordinary skill in the art, aspects of the invention may be distributed amongst one or more networked computing devices, which communicate and interact with computer system **10**, via one or more data networks such as network **24**.

[0027] It will be understood by those of ordinary skill in the art that computer system **10** may also include other, either necessary or optional, components not shown in the figure. By way of example, such other components may include elements of a CPU; network devices and connections, such as modems, telephone lines, network cables, and wireless connections; additional processors; additional memories; additional input and output devices; and so on. Further, two or more components of the computer system **10** may be embodied in one physical device. For example, a CPU chip may also have built-in memory. A memory storage such as a disk can be part of the memory **14**, input device **16**, and output device **18**.

[0028] **Fig. 2A** schematically illustrates an exemplary method of executing a computer algorithm **26** which communicates with a communicating partner **28**. As mentioned earlier, communicating partner **28** can be an information receiver, or an information provider, or both. Further, communicating partner **28** can be a human operator, a physical device, or a software module. Algorithm **26** has both environment-dependent communication operations and other operations (referred to as algorithm operations herein). The algorithm operations are encapsulated in algorithm module **30**.

The environment-dependent communication operations are encapsulated in communication module **32**.

[0029] Optionally, one or more data objects may be instantiated during execution to encapsulate data communicated between algorithm module **30** and communicating partner **28**. For instance, as illustrated in **Fig. 2B**, data object **34** may be used to encapsulate all data communicated from algorithm **30** and data object **36** may be used to encapsulate all data communicated to algorithm module **30**.

[0030] Each one of the modules and objects may be instantiated from a module code. Thus, an exemplary method of coding algorithm **26** is to encapsulate algorithm **26** in at least two module codes. The environment-dependent communication operations are encapsulated in a communication module code and the algorithm operations are encapsulated in an algorithm module code. Optionally, data module codes may be provided for encapsulating data to be communicated.

[0031] In operation, referring to **Fig. 2A** to **Fig. 3**, one or more operations of algorithm module **30** are executed (**S42**) in a given environment. When a need to communicate arises, one or both of data objects **34** and **36** are instantiated (**S44**), and one or more operations of communication module **32** are executed on at least one of the instantiated data object(s) (**S46**). As can be appreciated, an object of communication module **32** can be instantiated any time before it is used. After the execution of the operation(s) of communication module **32** (**S46**), one or more operations of algorithm module **30** may be further executed, or the process from **S42** to **S46** may be repeated for either the same or different operations.

[0032] To execute algorithm **26** in a new environment, a different communication module code suitable for use in the new environment may be provided. During execution, the operation(s) of the new communication module is (are) made available to the executing algorithm module **30**. Thus, the code for algorithm module **30** does not need to be modified.

[0033] As common codes for environment-specific operations can be developed and made available, algorithm **26** can be executed in different environments without any code-modification. All that may be required is to choose a particular suitable module encapsulating environment-specific operations. In this regard, it is advantageous to ensure that all the module codes encapsulating algorithm **26** are compatible with each other. To do so, coding protocols (also known as interfaces in Java programming parlance) may be provided and individual modules can be coded in compliance with one or more respective protocols.

[0034] To further illustrate how algorithm **26** can be coded, an exemplary set of codes is described below. It should be understood that although the example codes are in Java language, any other suitable programming language may be used to implement an algorithm as taught herein. It is also understood that only relevant parts of the codes are listed and described. The omitted parts, either necessary or optional, can be readily added by those skilled in the art.

[0035] Referencing **Fig. 4**, in an exemplary embodiment of the invention, a Java framework is provided. The framework comprises four abstract interfaces: Command interface **50**, Environment interface **52**, Status interface **54**, and Response interface **56**. Each of abstract interfaces **50** to **56** defines a protocol, i.e., certain methods and data types that each compliant class must implement, as well as method behavior. As is typical, method behavior may be described in a documentation such as a JavaDoc. Exemplary codes for these interfaces are listed in **Table I**.

Table I

Interface	Sample Code

Command	Public Interface Command
	{
	    public void execute (Environment environment);
	}

Environment	Public interface Environment
	{
	    public Response getResponse (Status status, Response[] responses);
	
	    public Status reportStatus (Status status);
	}

Status	Public interface Status
	{
	    public string getMessage ();
	}

Response	Public interface Response
	{
	    public string getLabel ();
	}

[0036] In Java language, computer algorithms are encapsulated in classes. Within the exemplary framework, algorithm module **30** can be implemented in class ACommand **60**, which implements Command interface **50**; communication module **32** can be implemented in class AnEnvironment **62**, which implements Environment interface **52**; modules for data objects can be respectively implemented in classes AStatus **64** (for encapsulating data send by an instance of ACommand **60**) and AResponse **66** (for encapsulating data received by an instance of ACommand **60**), which in turn respectively implement interfaces Status **54** and Response **56**. To illustrate, exemplary codes for these classes are listed below.

ACommand:

```
public class ACommand implements Command
{
    ...

    public void execute ( Environment environment )
    {
        // some operations of the algorithm

        if (AConditionExists)
        {
            Status status = new AStatus("ACondition exists, What to do?");
            response = environment.getResponse(status, new Response[]  responses);
        }

        // some operations of the algorithm depending on the returned response

        environment.reportStatus(new AStatus("A Status Message"));
    }
}
```

AnEnvironment:

```
    ...
    public class AnEnvironment implements Environment
    {
        public void reportStatus( Status status)
        {
            // some environment-dependent communication operations for
            // reporting status via method "status.getMessage()"
        }

        public Response getResponse ( Status status, Response[] responses )
        {
            // some environment-dependent communication operations including
            // output operations making use of method "status.getMessage()" and
            // input operations making use of method "response.getLabel()" for each
            // response in the array.
        }
    }
```

AStatus:

```
...
public class AStatus implements Status
{
        private String message;

        public AStatus (String message )
        {
                this.message = message;
        }

        public String getMessage ()
        {
                return message;
        }
}
```

AResponse:

```
...
public class AResponse implements Response
{
        private String label;

        public AResponse ( String label )
        {
                this.label = label;
        }

        public String getLabel ()
        {
        return label;
        }
}
```

[0037] As is typical, to actually execute the algorithm implemented in the above classes, a main class may be implemented, for example as follows:

Main:

```
public class Main
{
    public static void main ()
    {
        Command c = new ACommand();
        Environment e = new AnEnvironment();
        c.execute(e);
    }
}
```

[0038] The execution of the above exemplary codes in operation is illustrated in **Fig. 5**. When class Main is instantiated (**S72**), an instance of ACommand **60** and an instance of AnEnvironment **62** are respectively instantiated (**S74** and **S76**). The "execute" method of ACommand **60** is then executed (**S78**) where a parameter ("e") is passed to indicate that the communication module in this execution is an "Environment" module, AnEnvironment **62**. Thus, the methods in the object of AnEnvironment **62** are available to the algorithm module. Some algorithm operations may be performed (**S80**). When a condition arises which requires some input from a communicating partner, an object of AStatus **64** is instantiated (**S82**) which holds a message indicating the condition (e.g., as illustrated "ACondtionExists. What to do?"). The "getResponse" method of AnEnvironment **62** is called, by which time an object of AResponse **64** is instantiated (**S84**) which will hold the response from the communicating partner. The "getResponse" method is executed (**S86**) to get a response from a communicating partner. After obtaining a response, some further algorithm operations can be executed (**S88**) based on the return value of the response. Finally, a new object of AStatus **64** is instantiated to hold a new status message (**S90**) and the status message is reported by executing the "reportStatus" method of the environment object (**S92**).

[0039] As is now clear, and advantageously, the Command class does not need to be modified when a new kind of an Environment class needs to be used.

[0040] As can be understood, the above codes are for illustration purposes only and can be modified as appropriate for a particular algorithm or environment. For example, Environment interface **52** may specify a method for reporting execution progress or for logging results of the operations of the algorithm. These methods can be implemented according to known programming techniques.

[0041] Further, the timing and the order in which some objects are instantiated may change. For example, the order in which Command object and Environment object are instantiated may be reversed, so long as during execution of the operations of the algorithm, the methods of Environment object are available to Command object. The order in which the operations of various modules are executed may also vary. For example, an operation of a communication module may be executed before any operation of an algorithm module is executed.

[0042] Of course, all environment-dependent operations of algorithm **26** may be separately encapsulated so that the algorithm module code is environment independent and need not be modified when used in different environments. However, in appropriate situations, it may be desirable to encapsulate separately only some environment-dependent operations. Even so, encapsulation of the algorithm is still enhanced as the algorithm module code need not be modified when the separately encapsulated operations need to be changed.

[0043] Further, the environment-dependent operations of algorithm **26** may be encapsulated in multiple modules. Similarly, the algorithm operations of algorithm **26** may also be encapsulated in more than one module. Different modules may be executed on different computers in a network.

[0044] Additional functionality may also be implemented in any of the modules or objects. For example, an Environment object may deploy a Monitor object for monitoring the status of execution of a command object.

[0045] Other features, benefits and advantages of the present invention not expressly mentioned above can be understood from this description and the accompanying drawings by those skilled in the art.

[0046] Although only a few exemplary embodiments of this invention have been described above, those skilled in the art will readily appreciate that many modifications are possible therein without materially departing from the novel teachings and advantages of this invention.

[0047] The invention, rather, is intended to encompass all such modification within its scope, as defined by the claims.

What is claimed is:

1. A method of executing a computer algorithm, comprising:

   executing a first module encapsulating said computer algorithm except at least one communication operation of said algorithm;

   executing a second module encapsulating said at least one communication operation of said algorithm, such that said at least one communication operation is available to said first module.

2. The method of claim 1 wherein said at least one communication operation comprises at least one environment-dependent communication operation of said algorithm.

3. The method of claim 2, wherein said at least one environment-dependent communication operation comprises all environment-dependent communication operations of said algorithm.

4. The method of claim 1, further comprising executing a third module encapsulating another communication operation of said algorithm.

5. The method of claim 1, further comprising instantiating at least one data object for encapsulating data communicated between said first module and a communicating partner, each one of said at least one data object being an instance of a data class, said data communicated between said first module and said communicating partner being accessible by said first module.

6. The method of claim 5, wherein data from said first module is encapsulated in a first data object being an instance of a first data class, and data to said first module is encapsulated in a second data object being an instance of a second data class.

7. The method of claim 6, wherein said second module comprises a communication object, said communication object being an instance of a communication class.

8. The method of claim 7, wherein said first module comprises a command object, said command object being an instance of a command class.

9. The method of claim 8, wherein each one of said classes implements one of a plurality of protocols of a framework, such that instances of said classes are compatible with each other.

10. The method of claim 9, wherein said framework is a Java framework and each one of said plurality of protocols is respectively encapsulated in an interface.

11. The method of claim 10, wherein said command class implements a command interface, said command interface defining at least one method of executing, said method of executing taking an indicator of said communication object as a parameter, thereby an operation of said communication object is available to said command object.

12. The method of claim 11, wherein said communication class implements a communication interface, said communication interface defining at least one method of communication.

13. The method of claim 12, wherein said at least one method of communication comprises a method of communicating data from said first data object to said communicating partner.

14. The method of claim 13, wherein said at least one method of communication comprises a method of communicating data from said communicating partner to said second data object.

15. A computer readable medium storing thereon computer executable instruction code, said code when executed by a processor of a computer causes said processor to:

execute a first module encapsulating a computer algorithm except at least one communication operation of said algorithm;

execute a second module encapsulating said at least one communication operation of said algorithm, such that said at least one communication operation is available to said first module.

16. The computer readable medium of claim 15 wherein said at least one communication operation comprises at least one environment-dependent communication operation of said algorithm.

17. The computer readable medium of claim 16, wherein said at least one environment-dependent communication operation comprises all environment-dependent communication operations of said algorithm.

18. The computer readable medium of claim 15, wherein said processor is further caused to instantiate at least one data object for encapsulating data communicated between said first module and a communicating partner, each one of said at least one data object being an instance of a data class, said data communicated between said first module and said communicating partner being accessible by said first module.

19. The computer readable medium of claim 18, wherein data from said first module is encapsulated in a first data object being an instance of a first data class, and data to said first module is encapsulated in a second data object being an instance of a second data class.

20. The computer readable medium of claim 19, wherein said second module comprises a communication object, said communication object being an instance of a communication class.

21. The computer readable medium of claim 20, wherein said first module comprises a command object, said command object being an instance of a command class.

22. The computer readable medium of claim 21, wherein each one of said classes implements one of a plurality of protocols of a framework, such that instances of said classes are compatible with each other.

23. The computer readable medium of claim 22, wherein said framework is a Java framework and each one of said plurality of protocols is respectively encapsulated in an interface.

24. A method of encapsulating a computer algorithm, comprising:

encapsulating, in a first module code, said computer algorithm except at least one communication operation of said computer algorithm;

encapsulating said at least one communication operation in a second module code;

so that one of said first and second module codes can be modified without changing the other one of said first and second module code.

25. The method of claim 24, wherein said at least one communication operation comprises all environment-dependent communication operations of said algorithm.

26. The method of claim 24, wherein each one of said first and second module codes implements a common protocol so that said first and second module codes are compatible.

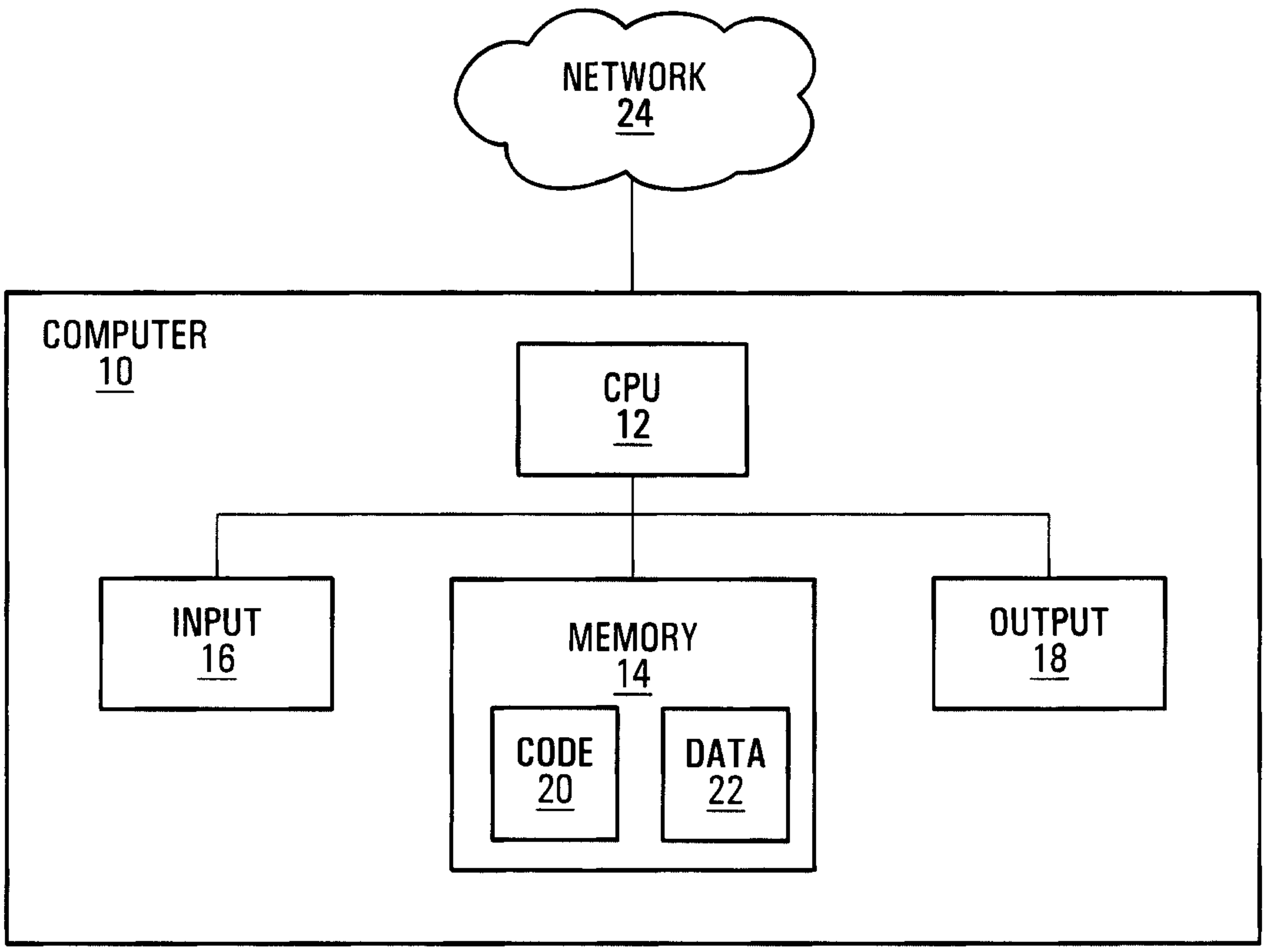

NETWORK
24
COMPUTER
10
CPU
12
INPUT
16
MEMORY
14
OUTPUT
18
CODE
20
DATA
22

Fig. 1

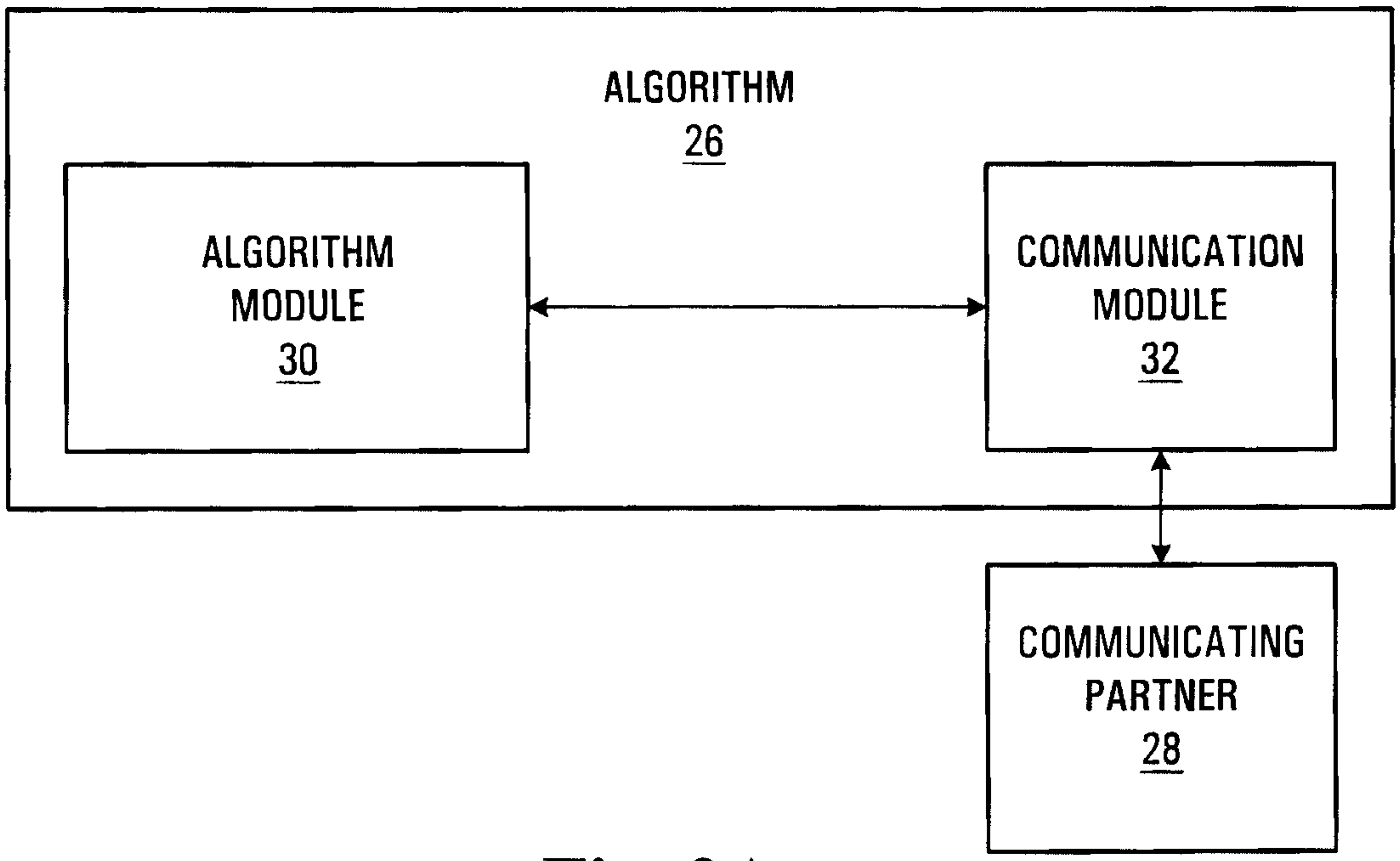

ALGORITHM
26
ALGORITHM MODULE
30
COMMUNICATION MODULE
32
COMMUNICATING PARTNER
28

Fig. 2A

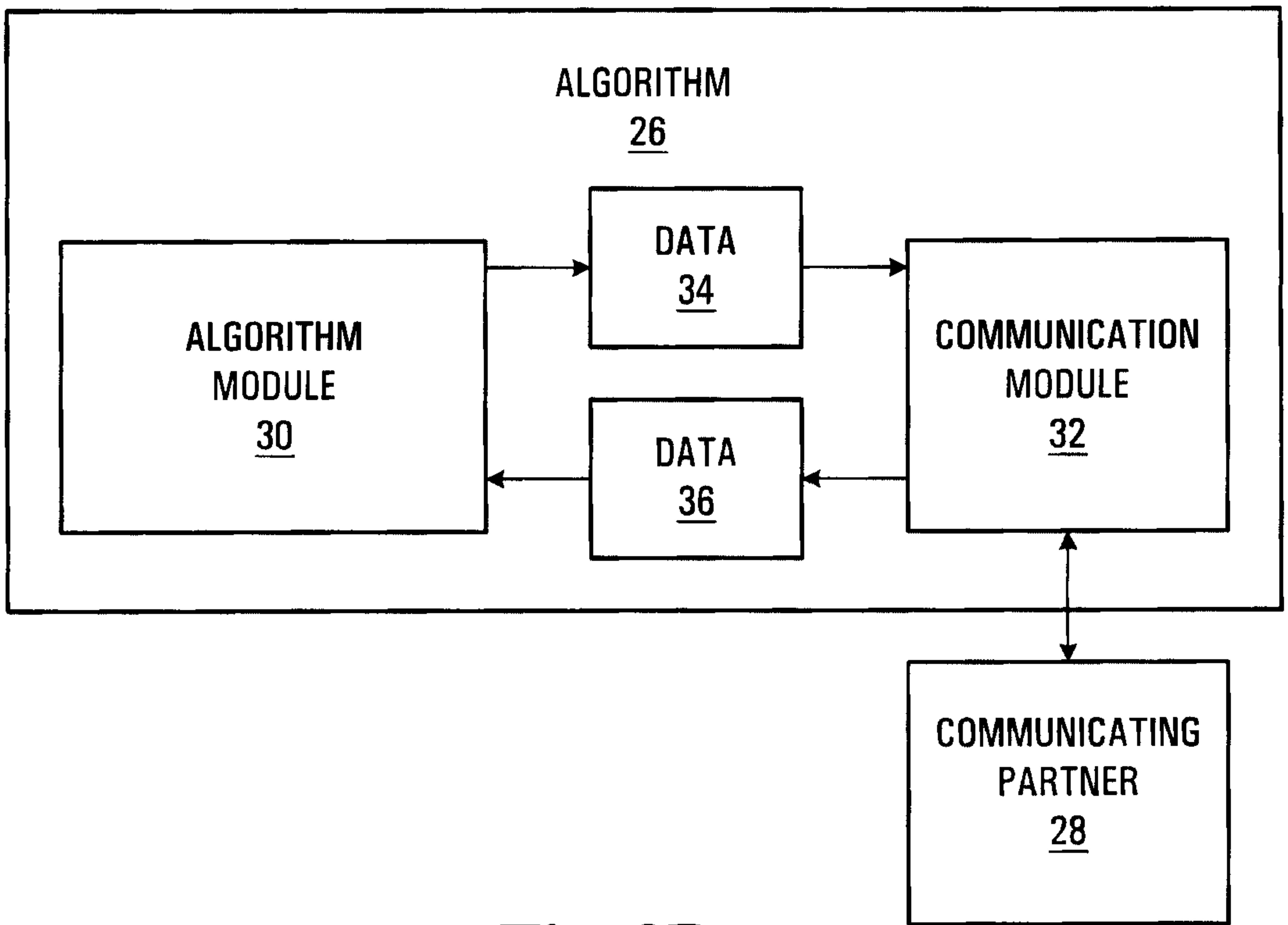

ALGORITHM
26
ALGORITHM MODULE
30
DATA
34
DATA
36
COMMUNICATION MODULE
32
COMMUNICATING PARTNER
28

Fig. 2B

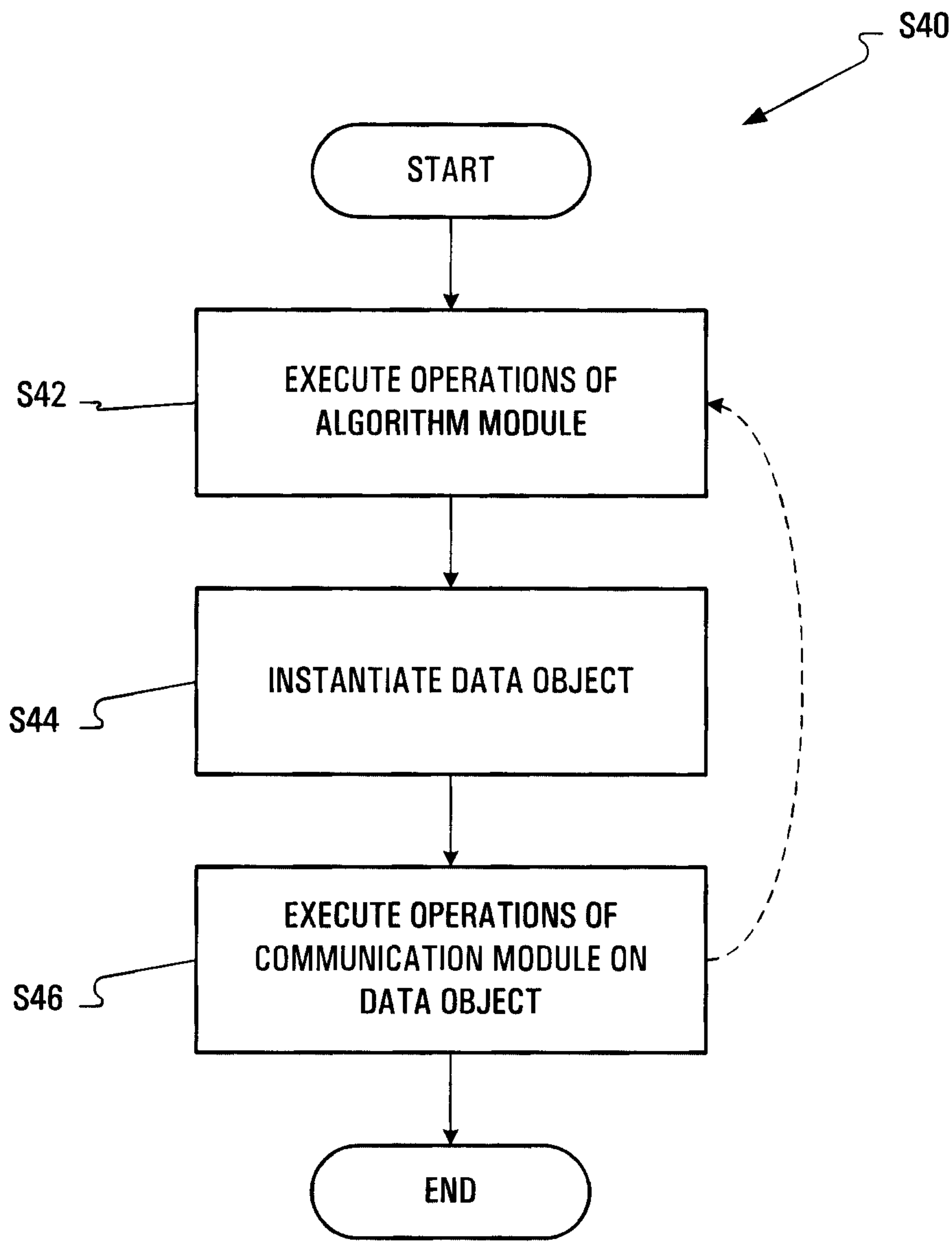

S40
START
S42
EXECUTE OPERATIONS OF ALGORITHM MODULE
S44
INSTANTIATE DATA OBJECT
S46
EXECUTE OPERATIONS OF COMMUNICATION MODULE ON DATA OBJECT
END

Fig. 3

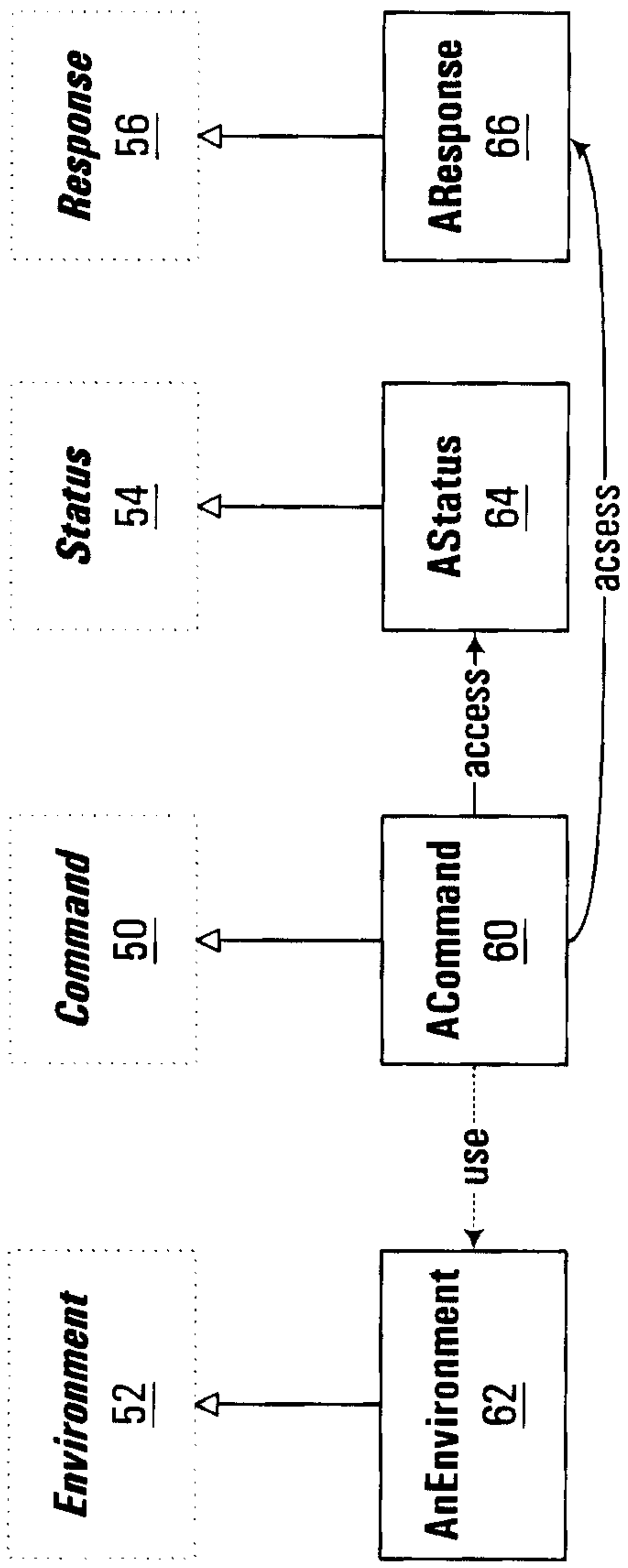

Environment
52
Command
50
Status
54
Response
56
AnEnvironment
62
ACommand
60
AStatus
64
AResponse
66
use
access
acsess

Fig. 4

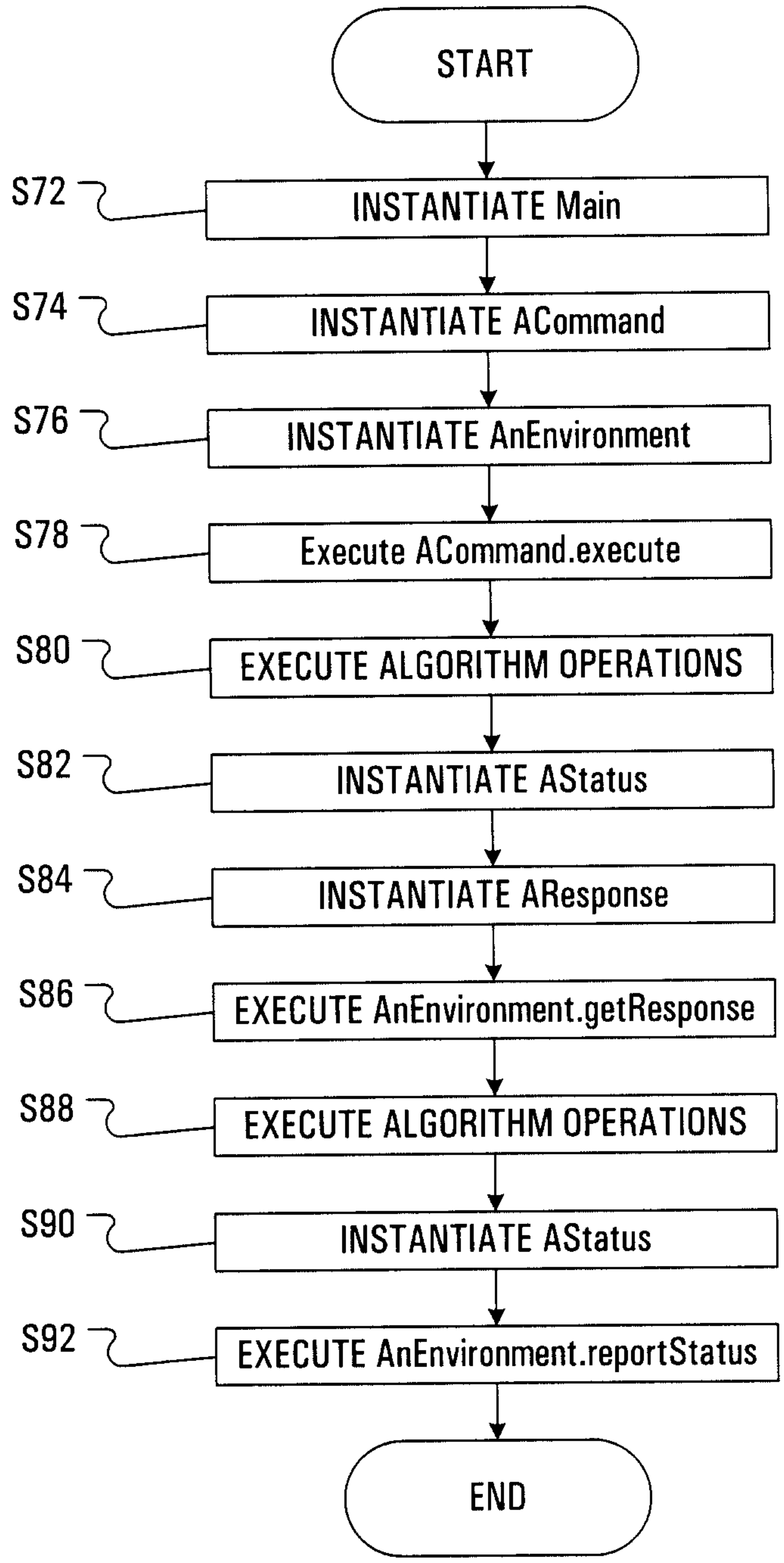
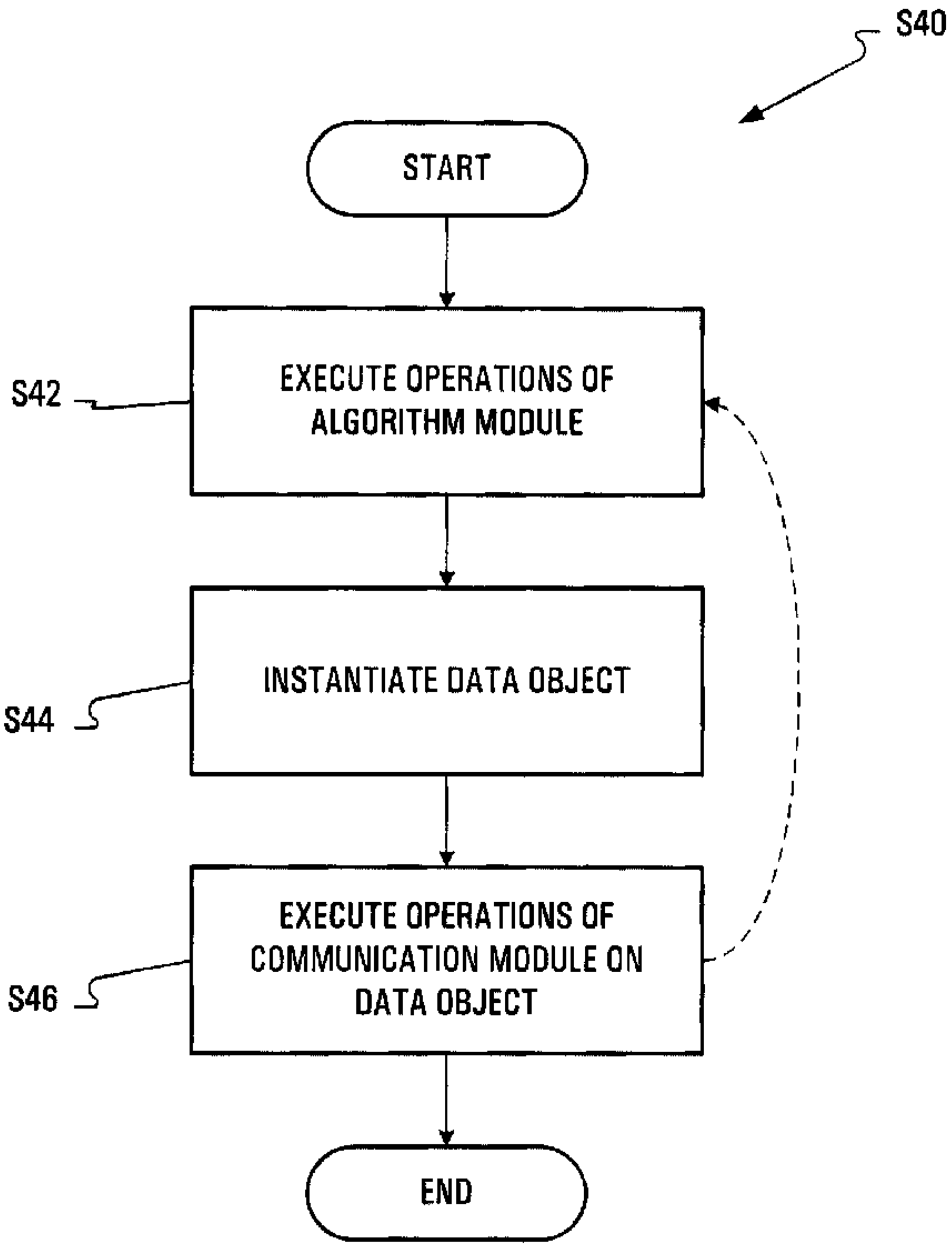

START
S72
INSTANTIATE Main
S74
INSTANTIATE ACommand
S76
INSTANTIATE AnEnvironment
S78
Execute ACommand.execute
S80
EXECUTE ALGORITHM OPERATIONS
S82
INSTANTIATE AStatus
S84
INSTANTIATE AResponse
S86
EXECUTE AnEnvironment.getResponse
S88
EXECUTE ALGORITHM OPERATIONS
S90
INSTANTIATE AStatus
S92
EXECUTE AnEnvironment.reportStatus
END

Fig. 5


S40
START
EXECUTE OPERATIONS OF ALGORITHM MODULE
S42
INSTANTIATE DATA OBJECT
S44
EXECUTE OPERATIONS OF COMMUNICATION MODULE ON DATA OBJECT
S46
END