A UML Approach to Build a Mobile Agent

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Abstract: Mobile Agents are one of the most promising technologies of distributed computing. Mobile Agents have certain properties, such as autonomy, mobility and most of all; they fit well in the low-bandwidth network environments. This paper mainly focuses on the information retrieval in a distributed computing environment using a Mobile Agent. This approach is materialized by a UML notation, which includes views to model organizational, lifecycle, interaction and mobility aspects of mobile agents' applications contributing to the analysis, design and implementation phases of their development. The PHP programming language is used for the implementation part using the PHP-YAZ and the Z39.50 protocol.

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1. Introduction

Today, networks have been expanding almost anywhere. The complexity of networks also is increasing in terms of the functionalities, services and number of users. It leads to huge challenges on network technology, particularly when vast amounts of data must be transported across the network with a high level of users' diversity demands on the provision of services, the quality of services, reliability and security.

Mobile agents are an approach to solve these and other problems of networked computing. Mobile Agents are now being regarded as an important technology to assist in helping to solve the problems of information overload and management. They represent the next evolution in integration since they can interoperate at many different levels; with the user at the desktop, with information and legacy systems in both local and distributed manners, and with other Mobile Agent-based systems. (Edwards, 1995).

Essentially, the Mobile Agent paradigm has evolved from two antecedents: client-server and remote evaluation paradigms. Traditionally, distributed applications have relied on the client-server paradigm in which client and server processes communicate either through message-passing or remote procedure calls (RPC). This communication form is synchronous, i.e., the client suspends itself after sending a request to the server, waiting for the results of the call. (Timon et.al., 2004) In the early nineties, Remote evaluation (REV) was proposed as an alternative paradigm. In REV, the client rather than invoking a remote procedure sends its own procedure code to a server, and requests the server to execute it and return the results. (Jazayeri and Gschwind, 2000). In RPC, data is transmitted between the client and server in both directions. In REV, a code is sent from the client to the server, and data is returned. In contrast, a Mobile Agent is a program (encapsulating code, data and execution context) sent by a client to a server. Unlike a procedure call, it does not have to return its results to the client. It could migrate to other servers, transmit information back to its origin, or go back to the client if appropriate. (Yingyue and Hairong, 2006)

The Mobile Agent consists of code, data, thread and authority of its owner. According to the movement pattern, Mobile Agents differ from applets (downloaded from the server to the client) as well as from Servlets (uploaded from the client to the server) in that Mobile Agents can have multiple hops, and they can be detached from the client (Home Node). A Mobile Agent autonomously visits places without interacting continuously with its originating place. This originating place gets involved only when the Mobile Agent is sent to the first visiting place, and when the Mobile Agent returns from the last visited place. (Jennings et.al., 1993) So, the unnecessary data transmission can be avoided by sending a program to the server and performing data manipulation at that server. Also, it can perform robustly even if the connection fails because it does not require a continuous connection between the server and the client.

There are several advantages of the Mobile Agent, the most important ones are seen in the possibility of reducing expensive global communication costs by moving the computation to the data and in the possibility to distribute complex computations onto several, possibly heterogeneous hosts. Mobile Agents can be useful for the development of different systems domains, such as electronic commerce, distributed information retrieval, workflow management and cooperation, personal assistance, remote device control and configuration, and advanced telecommunication services, among other ones. These kinds of applications clearly benefit from using Mobile Agents because they reduce the network load, overcome network latency, execute asynchronously and autonomously, are fault-tolerant, and also can sense their execution environment and react dynamically to changes. (Odell, 2003).

In this paper, an overview on the current state in the development of the Mobile Agent paradigm is presented in the second section. Also, a highlight on the concept and the advantages of the Mobile Agent paradigm will be examined in the third section. The Mobile Agent proposed model is presented in the fourth section accompanied by an example in the fifth section. Finally, the conclusion and the future work are presented in the last section.

2. Related Work

Recent years, Mobile Agents have been developed very fast and they attract many attentions of researchers in academia and industry. As natural consequence, a large number of Mobile Agent systems, both in academia and industry, were developed. Some of the best known are: Telescript, Aglet, Voyager, Concordia, Agent Tcl, TACOMA and MOA.

Generally, each Mobile Agent system has private characters. For example, they can have either strong mobility or weak mobility. However common requirements of these systems on infrastructure are their need to provide these agents with a migration capability, in order to communicate with each other and to interact with the hosts in network. Infrastructure must guarantee privacy and integrity for agents and the underlying computer system. Infrastructure also needs to have ability to prevent malicious agents attacking other agents or the computer systems. (van, 1999).

Since the mid-nineties, when the first tentative Mobile Agent-based methodologies and their modeling languages started to appear, there came into existence quite a large number of languages for analysis and design of Mobile Agent systems.

Bauer, Odell and colleagues designed the Mobile Agent-Oriented Modelling Language Mobile Agent UML (Odell et.al. 2005 and Wooldridge et.al. 2000) as an extension of UML. One of its main drawbacks, though, is the absence of precisely specified semantics for defining the different modeling elements, which can lead to misinterpretation of AUML models. AUML also needs to populate a set of diagrams. However, the meta-model defined for AUML class diagrams is just an explanation of the basic concepts, but it does not represent specification of the language used. AUML interaction diagrams are not specified in the terms of a meta-model at all. Another of AUML's drawbacks is the absence of modeling tools dedicated to it. It is necessary to challenge the AUML notation against industrial and real world applications to verify its completeness. This is a very difficult task, because it is hard to find proper real world industrial applications. Nevertheless, the AUML community is encouraging companies to participate in its efforts to develop a strong and useful Mobile Agent-based modeling language.

Wooldridge, Jennings and Kinney presented in (Caire and Leal, 2001) The GAIA methodology for Mobile Agent Oriented Analysis and Design. The requirements capture phase, independent of the paradigm used for analysis and design is not included in GAIA. GAIA is a general methodology that supports both the micro-level (Mobile Agent structure) and macro level (Mobile Agent society and organization structure) of Mobile Agent development; however, it is not a silver bullet approach, since it requires that inter-Mobile Agent relationships (organization) and Mobile Agent abilities are static at run time. The motivation behind GAIA is that object-oriented methodologies fail to represent the autonomous and problem solving nature of Mobile Agents; they also fail to model Mobile Agents' ways of performing interactions and forming organizations. Using GAIA, software designers can systematically develop an implementation-ready design based on system requirements.

GAIA is appropriate for the development of systems with the following main characteristics:

The organization structure of the system is static, in that inter Mobile Agent relationships do not change at run time.
The abilities of Mobile Agents and the services they provide are static, in that they do not change at run time.
The overall system contains a comparatively small number of different Mobile Agent types

Due to the above mentioned restrictions, GAIA is of less value in the open unpredictable domains; on the other hand it has been proven as a good approach for developing closed domain Mobile Agent systems.

Message (Methodology for Engineering Systems of Software Mobile Agents) (Cervenka, 2003) is an Mobile Agent oriented software engineering developed in particular for the needs of the telecommunications industry. It uses the same meta-model language as UML for description of its abstract syntax. However, message modeling language does not cover all aspects.

Tropos (Wagner, 2003) is a Mobile Agent-Oriented software development methodology which was founded on the concepts of goal-based requirements. However, Tropos models provide just a restricted view of the system. The Mobile Agent architecture, behavior and deployment are described insufficiently. Furthermore, improvements of the existing modeling concepts would also help to create semantically richer models, for example, better logical structuring of goals (constraints) or better definition of still fairly unclear concepts about plans, capabilities and resources.

Wagner (Chavez et.al. 1997) suggested a Mobile Agent-oriented approach to the conceptual modeling of organizations and organizational information systems. AOR proposes a conceptual framework for Mobile Agent-oriented modeling that is based on a set of 19 ontological principles, including those of entity-relationship (ER) modeling and a corresponding diagram language called AOR modeling language (AORML).

However, AOR allows more adequate models of organizations and organizational information systems than plain UML. But in its current form it has got several weaknesses:

a. The entire development path from analysis to implementation is not yet fully defined.
b. AORML does not currently include the concept of activities.
c. AORML does not include the concept of goals which is fundamental in several other approaches.
d. AORML does not allow modeling of the proactive behavior of Mobile Agents. This type of behavior, which is the focus of artificial intelligence approaches to Mobile Agents, is based on action planning and plan execution for achieving goals.

In general, most of the existing Agent-oriented modeling languages share the common basic concepts coming from solid foundations of Mobile Agents theories, such as the concepts of Mobile Agent, role, or interaction. However, the current modeling languages differ in their approach to modeling these concepts. Several Mobile Agents modeling and specification paradigms used in various theories and software engineering approaches are reflected by the current modeling languages, including logic-based, knowledge-based, requirements-based, BDI-based (belief-desire-intention), UML-based etc. languages.

3. Results

The concept of agent comes from Artificial Intelligence and Distributed Artificial Intelligence where it is abstract of robot idea. Until now, there is no universal definition on what an agent is. A Mobile Agent is an agent with the ability to freely migrate between locations across networks. Therefore, a Mobile Agent is a combination of two distinct concepts: mobility and agent. The main idea of mobility in Mobile Agent is the move of self-contained program near to data source. This migration results significant reduction of traffic transmission over a network. (Van, 1999)

A Mobile Agent is a software with the feature of autonomy, social ability, learning, and most importantly, mobility. More specifically, a Mobile Agent is a process that can transport its state from one environment to another, with its data intact, and be capable of performing appropriately in the new environment. Mobile Agents decide when and where to move.

A Mobile Agent continuously perceives reasons and acts. While it is definitely possible to do these things in parallel. It starts with perception, followed by reasoning (including a possible update of the Mobile Agent’s memory) and ends with taking actions. This is called the Mobile Agent cycle. (Kim, 2000)

Different Mobile Agents have different lifetimes. At the one extreme, Mobile Agents can live ‘forever’ that remain running as long as a computer system is up; like Mobile Agents that provide a core system service. At the other end, Mobile Agents can execute a certain short task, Mobile Agents that only ‘live’ for a few seconds. It might also be the case that the certain Mobile Agent ‘hibernates’ for some time, with its state stored on disk, but without the Mobile Agent being active in the memory of the computer. A Mobile Agent continuously executes a fixed task, such as monitoring a data stream or, scheduling meetings. The user Mobile Agents come up and come down when the user logs on or logs off. (Dutt et.al., 2000)

A Mobile Agent has the unique ability to transport itself from one system in a network to another in the same network. When a Mobile Agent decides to move, it saves its own state, transports this saved state to the new host, and resumes execution from the saved state. Mobile Agents are active in that they can choose to migrate between computers at any time during their execution. This makes them a powerful tool for implementing distributed applications in computer networks. This ability allows it to move to a system containing an object with which it wants to interact and then take advantage of being in the same host or network as the object. Our interest in Mobile Agents is not motivated by the technology but rather by the benefits agents provide for the creating of distributed systems. There are a lot of benefits, or good reasons, for Mobile Agents. (Loukil et.al., 2006).

a. They reduce the network load.
b. They overcome network latency.
c. They encapsulate protocol.
d. They execute asynchronously and autonomously.
e. They adapt dynamically
f. They are heterogeneous.
g. They are robust and fault-tolerant.

After analyzing the problem domain and taking a deep understanding of Mobile Agents with static and dynamic aspects of the system, Mobile Agent behaviors can be classified to internal behaviors and External behaviors.

Internal behaviors consists of all the internal jobs and features of the Mobile Agent; like, goals, beliefs, plans and capabilities. External behaviors consist of all the outside communications, message exchanging among Mobile Agents in multi Mobile Agent systems and migration from host to host. (Appleby and Steward, 1994)

Mobile Agents can be constructed with a wide range of capabilities. One of the advantages of the Mobile Agent-based approach is that a complex processing function can be broken into several smaller, simpler ones. Since each individual Mobile Agent can be crafted to be an expert in solving a specific problem or performing a particular task, you can build systems that exhibit complex behaviors by using a collection of relatively simple Mobile Agents.

In summary, Mobile Agents reduce significantly network traffic and communication delays due to no need to transfer amount of intermediate data over the network. Hence network bandwidth is used more effective. Further, with autonomous character of agent, Mobile Agent can obtain greater degree of flexibility when it carries duties to execute at nodes that it visits. Mobile Agent can decide by itself where it will go and what it will do. This is very useful, especially in distributed applications because developers no need to define exactly all necessary requirements or role of client and server in design time.

In addition, applications that use Mobile Agents will be more scalable because the mobility feature of a Mobile Agent results in moving to a suitable location in the network. Also, the Mobile Agent ability to adapt to the real-time modifications in heterogeneous environments also brings to advantages of Mobile Agent because heterogeneity is a typical characteristic of today's communication networks. (Van, 1999).

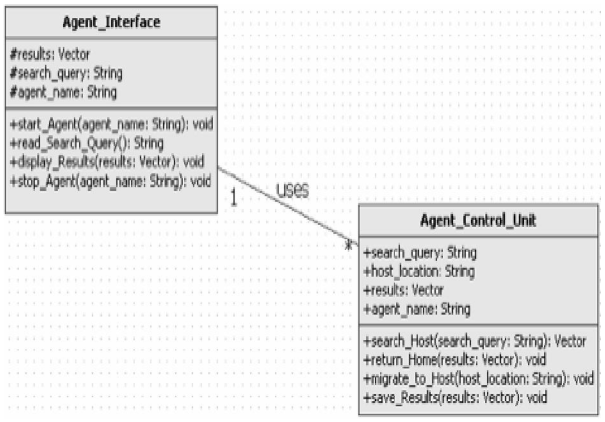
4. Mobile Agent proposed Model

The Unified Modeling Language (UML) is being recognized as a satisfactory medium to support Mobile Agent modeling. UML is the standard language for documenting systems in the object-oriented paradigm. Additionally, UML is an extensible language since it provides built-in mechanisms to introduce new elements for specific domains such as Mobile Agent-based modeling

The Mobile Agent model is described by a set of input events, a state set, a set of output events, an internal, external and confluent transition function, an output and time advance function. The internal transition function dictates state transitions due to internal events, the time of which is determined by the time advance function. The external transition function is triggered by external inputs which are defined as bags over simultaneously arriving input events. If an external and internal event coincides the behavior of a model is defined by the confluent transition function. Each model communicates with the external world through its input and output events, the latter of which it produces. Its state is described by a set of variables.

In the Mobile Agent model proposed, the system is divided to 2 objects; Agent Interface (AI) - Is the heart of the Mobile Agent. It is the source of the Mobile Agent's autonomy. It periodically activates the Mobile Agent's brain, and that activation might cause the Mobile Agent to do something. Agent Control Unit (ACU) - This is the brain of the Mobile Agent. It allows the Mobile Agent to reason, to decide if and what actions to be taken. Agent Memory Unit (AMU) - The memory (AMU) provides the brain (ACU) with historic information and basic knowledge the memory (MU) have been separated from the brain (ACU) to distinguish between a component that does the thinking, and a component that stores information. The memory (AMU) allows the brain (ACU) to store current information for future reference; it provides the Mobile Agent with state.

The Unified Modeling Language (UML) was used for modeling the proposed Mobile Agent model. The Class Diagram was used to model the Internal and some external behaviors of the Mobile Agent Proposed in an abstract way; as shown in the following figure.



Agent_Interface
#results: Vector
#search_query: String
#agent_name: String
+start_Agent(agent_name: String): void
+read_Search_Query(): String
+display_Results(results: Vector): void
+stop_Agent(agent_name: String): void
1
uses
*
Agent_Control_Unit
+search_query: String
+host_location: String
+results: Vector
+agent_name: String
+search_Host(search_query: String): Vector
+return_Home(results: Vector): void
+migrate_to_Host(host_location: String): void
+save_Results(results: Vector): void

Figure (1): Mobile Agent Proposed - Class Diagram

Mobile Agent_Interface class:

a. read_Search_Query: This method is for reading the search criteria from the user through the GUI of the Searcher Mobile Agent.
b. display_Results: This method is for displaying the results found.
c. start_Mobile Agent: This method is for starting the Searcher Mobile Agent
d. stop_Mobile Agent: This method is for stopping the Searcher Mobile Agent after accomplishing the task.

Mobile Agent_Control Class:

a. search_Host: This method is for searching the host for results.
b. return_Home: This method is for returning back to the home node initiated the search with the results found in its journey.
c. migrate_to_Host: This method is for locating the host and traveling to it.
d. Save_Results: This method is for saving the results got in the repository the Mobile Agent have to be displayed afterwards.

During the modeling of the Mobile Agent using existing notations it is noticed that modeling agent mobility with activity diagram or any other diagram does not give you the overall view about agent moving and execution path. It was proposed using the Sequence Diagram. Mobility is based on representing the change of the state of object that moves from one location to another. Agent moves by sending stereotyped message to the node where it wants to go. This representation gives overall view of nodes and agent mobility path. The Mobile Agent is represented with stereotype <<agent>>. At the beginning of the diagram, agent is located at the home node. After that, agent moves from this location to node1, and that is represented with a message and stereotype <<move>>.

The UML sequence diagram was used to model Mobile Agent plans and actions, where it was possible to:

(i) Associate goals and roles with plans.
(ii) Model Mobile Agents moving from a host to another.
(iii) Describe messages.

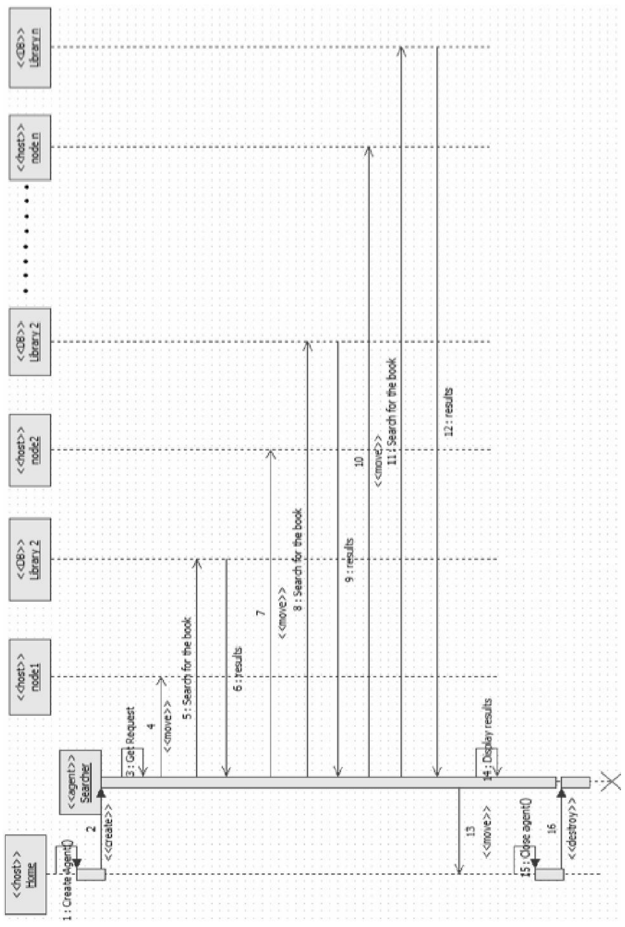


Figure (2): Mobile Agent Proposed - Sequence Diagram

5. Case Study – Book Search Mobile Agent:

The case study includes three library servers; the Congress Library, the British Library and the Bell Labs Library.

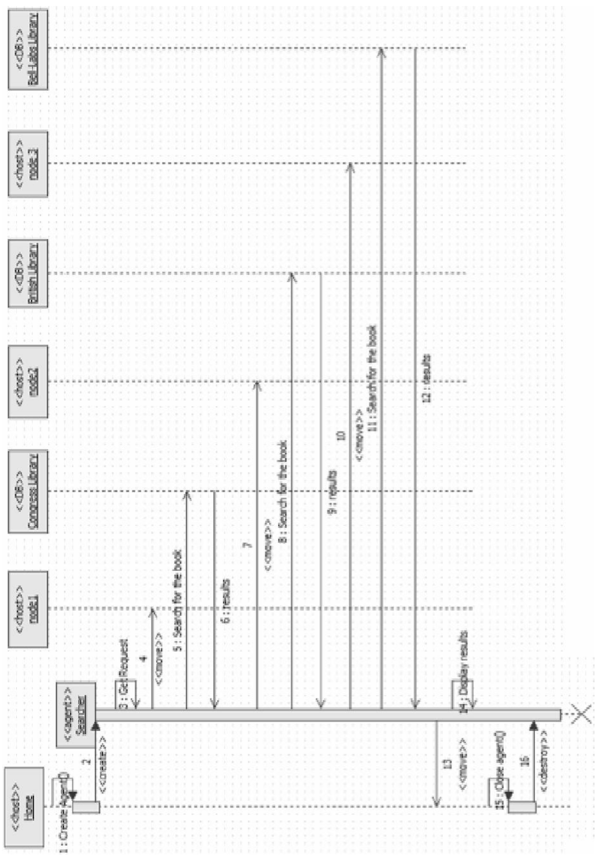


Figure (3): Case Study – Sequence Diagram

5.1. A Typical Scenario for the Information Retrieval Mobile Agent presented:

The Search Mobile Agent is created at the Home node. The Input parameter is the book name to search for; the user inputs his demand through the GUI where it is going to be placed as a search_query. The Search Mobile Agent then migrates from the Home node to the first library server and searches it. If the book is found it will save the result in the Mobile Agent Repository; found or not and the book details. After that; whether the Search Mobile Agent found the book or not; it will continue on its journey; locates the second library server, searches it then saves the result in the Mobile Agent Repository; and so on. After all the servers are done, the Mobile Agent will return back to the user if he is online then displays the result. If the user is not online the Mobile Agent will wait for the user till he logs in.

5.2. Implementation:

The proposed model was implemented by the PHP programming language, using the YAZ technique. YAZ is a C/C++ library for information retrieval applications using the Z39.50/SRU protocols for information retrieval. The Z39.50 is a client-server protocol for searching and retrieving information from remote computer databases. It supports a number of actions, including search, retrieval, sort, and browse. (Wikipedia, 2010)

The hosts used for the presented model are: the Congress Library, Bell Labs libarary and the British Library; listed in the following line:

```
   $host=      array("z3950.bell-labs.com/books",
  "z3950.loc.gov:7090/voyager",
                      "Z3950cat.bl.uk:9909/BLAC");
```

Figure (4): Libraries Server Address, the ports, the databases to look in saved in an array (host)

It represents the Library Server Address, the port and the database to look in for all three hosts; that will be saved in the host array.

In order to use the searching technique in PHP-YAZ, the following code was presented for the Searching part of the Agent_Conrtol_Unit Class.

```
  for ($i = 0; $i <3; $i++)
           {  //to connect to the hosts listed in the
              //  host array.
             $id[] = yaz_connect($host[$i]);
             //specifies the preferred record syntax
            //for retrieval
             yaz_syntax($id[$i], "usmarc");
             //Specifies a range of records to
             //retrieve.
             yaz_range($id[$i], 1, 10);
             //prepares for a search on the given
            //connection.
           yaz_search($id[$i],"rpn",$search_query);
          }
```

Figure (5): Agent_Control_Unit Class Searching Part.

6. Conclusion and Future work

This Paper presented an approach to model an information retrieval Mobile Agent in a distributed computing system. This approach is materialized by a UML notation. The model presented intended to have general applicability and intelligibility independent of a particular methodology or toolkit and to focus on the essential concepts required to model the internal and external behaviors of the Mobile Agent.

Due to the existence of many divergent Mobile Agents modeling approaches none of them have achieved general acceptance and use in wider community of software engineers. On the other hand, the Unified Modeling Language (UML) is more and more widely accepted as a standard notation for object oriented software modeling. Also, it is more user-friendly, what is very important especially in projects where there have to be consultants with customer who does not have engineering skills. Unified modeling language was introduced as a language for specification, visualization and documenting of software systems overcoming the mentioned drawbacks.

Finally, there is no fixed method that is the end for all application development. Once got past all the method aspects of a modeling language, the user will be left with various types of diagrams that will help in the software development process.

There are some future avenues to enhance the Mobile Agent model proposed. The problem dealt with assumes that a single Mobile Agent executes a task. A task can be finished in a shorter time by multiple Mobile Agents rather than a single Mobile Agent. They can cooperate to solve complex situations from their individual capabilities, by interacting among them in order to communicate messages, knowledge, goals, plans, etc. Another possible extension of theory development of a Mobile Agent with Deadlines. One other important major issue need the concern is security due to the existence of many open and unresolved problems.

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