Agent-Based Architecture of a Distributed Laboratory System

Hong Lin, University of Houston-Downtown, USA

ABSTRACT

We present a method for designing the architecture of an agent-based e-educational system. We demonstrate the effectiveness of our method by its application in the design of a computational grid built to be an environment for lab activities. An integrated lab package was developed to allow students to utilize the grid services and support the learning process. Our architectural design strategy ensures an outstanding feature of the system: It allows lab modules to be added into the system in an incremental fashion while ensuring the correctness of the system. Students are recruited in our research program to develop lab modules and build the grid. Initial use of the lab package indicates that it allows lab activities to be performed more efficiently and it enhances the learning effectiveness.

Keywords: architecture types; distributed systems; modeling languages; non-procedural languages; software architecture; structural modeling; technology infrastructure; very high-level languages; Web-based applications

INTRODUCTION

Agent-oriented design has become one of the most active areas in the field of software engineering. The agent concept provides a focal point for accountability and responsibility for coping with the complexity of software systems both during design and execution (Yu, 2001). Such a complex system typically cannot utilize the central control strategy, because it consists of loosely coupled self-contained functional units, each with its own mentality and behavior, because they are designed to deliver different services to different groups of clients. This brings unprecedented challenge to software engineering, because the design of such a system must ensure correct interaction among the functional units as well as correct implementation of each unit, probably running on different platforms. The emergence of intelligent agent conceptualization brings forth a modeling tool deemed to be effective in coping with the issues in developing large-scale distributed systems (Paquette, 2001). In this approach, a distributed system is modeled as a set of autonomous, cooperating agents that communicate intelligently with one another, and interact with human users at the right time with the right information.

A distributed learning system is a typical complex distributed system that involves
many dynamically interacting educational components, each with its own goals and needs for resources while engaged in complex coordination. It is very difficult to develop a system that could meet all the requirements for every level of educational hierarchy, since no single designer of such a complex system can have full knowledge and control of the system. In addition, these systems have to be scalable and accommodate networking, computing and software facilities that support a large number of simultaneous users concurrently working and communicating with one another (Vouk, Bitzer & Klevans, 1999). A special challenge in the design of an educational system is that it must be modular while having a distributed nature. Modularity is required so the system can be scaled to accommodate multiple course modules. In this article, we discuss the design of an online learning system that supports laboratory activities for computer science curriculum. The laboratory is performed in an educational grid. We use a multi-agent system (MAS) to design an infrastructure that allows for incremental development of lab modules.

We have studied the implementation of Collaborative Agent System Architecture (CASA) (Flores, Kremer & Norrie, 2001) with the chemical reaction model (CRM) (Banâtre, Fradet & Radenac, 2004, 2005a, 2005b). CASA can catch the interactive and dynamic nature of e-learning systems. Our research results are published in Lin (2005) and Lin and Yang (2006a). Following our existing work on the design methodology of MAS, we exploit this methodology in a project that aims at a grid for laboratory use in undergraduate education. The new method will provide a solution to current problems in the design of a comprehensive environment to support lab activities in teaching courses on parallel/distributed systems and networks. Although great efforts have been put in the development of software lab packages (for example, the Phil_2000 lab package for introductory computer science courses), most of the labs are still ad hoc activities. Without a central controlling model, available computing resources cannot be effectively utilized. In addition, teachers and students may be discouraged to explore the use of advanced labs to enhance learning effectiveness, because they often have to repeat the same scenarios inefficiently in different labs due to lack of an integrated lab package. The unified model in chemistry-inspired languages will enable formal specification of an evolving system and provide a framework for top-down design of the entire system (Banâtre, Fradet & Radenac, 2004; Lin & Yang, 2006a, 2006b). This design strategy will lead to an architecture that enables incorporating lab modules into the lab package in an incremental fashion.

The organization of this article is as follows. Next, we will give some background that initiated our research project. Then, we articulate the design goal, design ontology and architecture of the designed system. A showcase is described, and the implications of the lab package to the education are discussed afterwards. Then, we discuss some related works and compare our system to other e-learning systems in the literature. Finally, we give concluding remarks and discuss the future works.

**BACKGROUND**

With the fast innovation of computer and communication technologies, computer curriculum is being adapted to accommodate teaching modules that enhance teaching effectiveness by utilizing frontier technologies. Apart from traditional computer science curricula, information technology (IT) curricula strive to equip students with modern computer technologies defined by the current industrial desires. The Department of Computer and Mathematical Sciences (CMS) at the University of Houston-Downtown (UHD) is augmenting its computer science curriculum by an IT track. One of the most important parts of this project is designing labs that can be performed through the Internet. Our first step is implementing lab packages for our parallel computing and computer-networking courses in a grid that encompasses lab facilities centered at a Beowulf cluster. We will then extend our lab environment to include other computer science and mathematical courses.
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