ABSTRACT

This article introduces a practical software architecture called CUBES, which focuses on system integration and evolvement for online virtual universities. The key of CUBES is a supporting platform that helps to integrate and evolve heterogeneous educational applications developed by different organizations. Both standardized educational applications that follow popular e-learning standards, such as SCORM and CELTS, and unstandardized ones can be integrated into CUBES with ease. A regularly used virtual university based on CUBES that includes educational applications covering the entire spectrum of the learning and management process is introduced to examine the usability of CUBES. The authors hope that new architectures, tools, and methods are explored to reduce the effort in building and evolving virtual universities.

Keywords: data integration; distance education; software architecture; virtual university; Web-based applications

INTRODUCTION

Motivation

During the last decade, numerous Web-based learning systems, such as Blackboard (2004) and WebCT (2004) have been developed to provide learning environments for virtual universities. Most of these systems intend to implement a series of software modules by themselves to support the entire online learning and management process. However, many practical systems, especially those used in universities for distance learning, are developed in a collaborative manner. Some modules come from corporations or other organizations; others have to be developed by universities to meet special requirements. In addition, these modules must evolve constantly.
Therefore, how to integrate these heterogeneous software modules into a seamless learning environment becomes a big challenge. One possible solution is the standardization of the system architecture. In recent years, many efforts have been put into this area; for example, IEEE’s LTSA (IEEE LTSC, 2001), IMS’s ongoing Abstract Framework (IMS, 2003), CMU’s service-oriented LSA (CMU, 2001), MIT’s OKI (OKI, 2004), and SCORM (ADL, 2001). These standardized architectures reduce the efforts of integration and evolution but are still insufficient due to the following reasons:

- To define a widely accepted and practical architecture proves a hard work. IEEE’s LTSA, although widely accepted, is a high-level conceptual architecture and insufficient in practical implementation. Some others, such as MIT’s OKI, IMS’s Abstract Framework, and CMU’s LSA, intend to define the architecture in more details. But they are not widely accepted and differ from each other in many aspects. SCORM is probably the most popular e-learning standard nowadays but only covers part of the system architecture.

- To thoroughly define each module in the system architecture is even more difficult. For example, the goal of IMS’s Abstract Framework is to define the required applications, services, and components in the learning environment. However, it seems a long way before accomplishment and much longer before it is widely accepted.

- Standards hardly can cover newly developed modules, such as real-time interactive virtual classrooms and adaptive learning tools.

- Some legacy modules conflicting with standards have to be integrated. It may not be a short time before standardized modules replace all of them.

It is clear that integration and evolution must be based on popular e-learning standards, but only these standards are not enough. In a practical virtual university, efforts have to be made to address the problems that standards do not care.

A New Software Architecture

CUBES is a new software architecture for virtual universities. It is the result of years of working in a practical virtual university project (Tsinghua, 2003).

In this project, problems of integration and evolution mentioned previously are serious:

- Several e-learning standards — SCORM and CELTS (CELTSC, 2003), a Chinese localized version of selected standards from IEEE, AICC, ISO, and so forth — need to follow;

- Educational applications that developed into eight groups from different universities must be integrated into one virtual university;

- Some legacy applications need to be integrated into this virtual university;

- Evolvement of these applications is probably frequent, as they will be used in different universities and modified according to the feedback.

We believe that an appropriate software architecture based on popular e-learning standards is promising to solve these problems. CUBES is the result of our efforts toward this direction.

In the following sections, CUBES is introduced in detail. The composition of CUBES, functions of important components, communications between these components, and design principles are dis-
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