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## A Framework for V-Learning Service Platform for API Based Programming Learning and Design Refinement

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# A Framework for V-Learning Service Platform for API Based Programming Learning and Design Refinement

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**Abstract**—The evolution of 3D internet technologies has opened a whole new range of opportunities for enhanced learning, and has offered new support in programming learning fields. In this paper, we present a framework for the virtual-learning service platform over 3D virtual worlds. Our framework provides a set of fundamental services that can effectively help to reduce the learning curve in learning programming on a new specific platform and improve the targeted platform development work. The proposed framework is a generalization of our experience gained in developing of a fully immersive 3D e-learning system which has been tested and used for customer training.

**Keywords**—Virtual-Learning; API Based Programming; 3D Internet; Software Framework; Web Service

## I. INTRODUCTION

Programming based on a certain *Software Development Kit* (SDK) that enables creation of application for a specific platform is common and ubiquitous today. Traditional software platforms and frameworks deliver SDKs together with their software products so as to enable *Independent Software Vendors* (ISVs) to develop customized application and extended functions based on their products. e.g., .NET Framework SDK from Microsoft that contains libraries, samples, documentation and tools required to develop applications for Microsoft Windows and .NET Framework; *Java Development Kit* (JDK) from Oracle for the development of desktop, server and high-end embedded devices. Now with the evolution of Web 2.0 technologies, more and more Websites provide Web APIs that allow the combination of multiple services into new applications known as mashups to their users. For example, Facebook Platform provides a set of APIs and tools that enable 3rd party developers to integrate with the "open graph"—whether through applications on Facebook.com or external websites and devices. Google also offers a variety of APIs that are based on its popular consumer products for web developers.

This kind of software development can be referred to as *API Based Programming* (ABP). ABP can facilitate development of new specific applications by allowing designers and programmers to devote their time to meeting software requirements rather than dealing with the more standard low-level details of providing a working system. However, application developers need to spend additional time learning to use the APIs and getting familiar with the programming model. Although SDKs also frequently include sample codes and supporting technical notes or other

supporting documentation to help application developers to learn, because of the complexity of their APIs, the learning curve may still be very steep in some cases, e.g., 3D game programming based on game engines.

The design quality of APIs is absolutely crucial to the users' acceptance and further to the success of software products. From the platform developers' perspective, the concerns change to how to improve their products' competitiveness that may mean more lightweight components, shorter learning curve, and better customer experience, etc. Expectation and feedback of customers are the most important inputs for the improvement of the platform, and getting customers to put their thoughts by writing on a questionnaire or survey is one of the most well-established feedback techniques. However, the problem is that users may not have time or are unwilling to fill in these boring forms. Therefore, questionnaires and surveys are inefficient, laborious and time-consuming.

There is an actual need for a tool to help both in learning the targeted platform based programming and enhancing the quality of the targeted platform API design work. With the development of hardware and 3D technology, we see the wide adoption of 3D Internet technologies [1], more and more administrators recognize the potential for *Multi-User Virtual Environments* (MUVES) in education. Motivated by this trend in e-learning, this paper proposes a virtual-learning service framework in response to the problems outlined above. The framework enables quick learning for application developers and provides an easy approach to gain valuable user behavior data so as to refine their API design for platform developers.

We organize our paper as follows: we first review related work in Section II; then we present and discuss the framework for such a v-learning service platform, and demonstrate the key challenges for realizing the framework and the approaches for dealing with such challenges in Section III; we describe the typical usage scenarios in Section IV and give an example of our in-market experiments in Section IV; finally, we conclude this paper in Section VI.

## II. RELATED WORK

With regard to the requirements of flexible services integration and evolution, Services Oriented Architecture (SOA) [2-3] and Services Computing [4] were proposed. Furthermore, Web 2.0 technologies enable rich user interfaces and community based services. However, all the above

mentioned technologies and services and based on 2D Web. Now with debut of 3D virtual world, there come the opportunities of new types of services—3D Web services or virtual services [5]. In [5-6], the authors compared the interaction patterns for web services and virtual services and proposed an architecture for virtual services.

In the context of globalized communication, Web 3D, virtual reality and simulation techniques are becoming more promising through the possibility of creating collaborative spaces for simulation and training [7]. In [8], Steinkuehler presented an illustrative analysis of selected data and preliminary findings specific to learning within 3D virtual space for play. Annetta et al. discussed the crucial role avatars play in virtual classrooms in [9]. Given the successful cases in Second Life [10], we can see a good prospect of adoption 3D virtual worlds in education.

Worked-examples play an important role in learning and problem solving [11] and are relevant to the acquisition of initial cognitive completion skills [12], and hence play an important role in learning programming. Rahman and Boulay [13] presented two types of web-based interface supporting both the completion strategy [14] and the structure-emphasizing strategy [15]. We adopt these two strategies in our platform to help learning API based programming.

### III. FRAMEWORK FOR A V-LEARNING SERVICE PLATFORM

Our v-learning service platform is designed to provide a set of virtual services and Web services that can benefit application developers' learning experience and generate feedbacks for both application developers and API designers. In this section, we first discuss the rationale for a framework that can render such a platform, including its main objectives and the service system it supports. We then discuss the requirements for such a framework and depict its high-level architecture. Also, we discuss the key features and benefits of the framework.

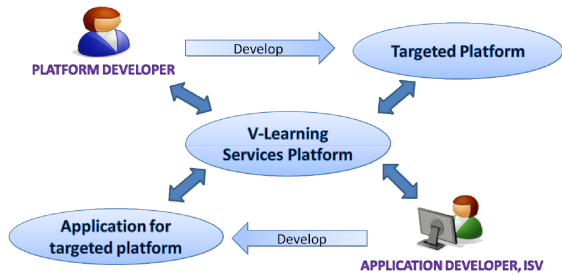


Figure 1. Relationships between individuals in v-learning service system.

The v-learning service system mainly consists of two types of role-players (see Figure. 1). First are the platform developers who create the platform, design the APIs provided by the platform and release SDKs that enable customized secondary development. Second are the application developers who receive SDKs from targeted platform developer and develop application for the platform. There may be a third type of role that designs and deploys the courseware for the application developers, though in some cases such work can also be done by the platform developer.

Our V-learning service platform overcomes a number of key challenges and provides the following functions:

- Provide an immersive virtual learning environment including some important components such as social engagement, real-time document creation, audio, brainstorming and so forth [16].
- Support linear scalability; that is, the computing resource can be scaled out smoothly as the number of users increases.
- Provide a set of presentation patterns and content templates that can enable quick construction and deployment of 3D courseware components.
- Provide a secured environment for the clients' private data; that is, a sufficient mechanism should be in place to protect application services from various forms of web attacks.
- Analyze the captured data to generate feedbacks so that the platform developers can better understand the needs of their customers and improve on their design, application developers can reduce their time spent in learning the platform.
- Provide easy way to integrate with existing 3rd software systems

The framework we propose is designed to fulfill these functions. Its high-level architecture is depicted in Figure 2.

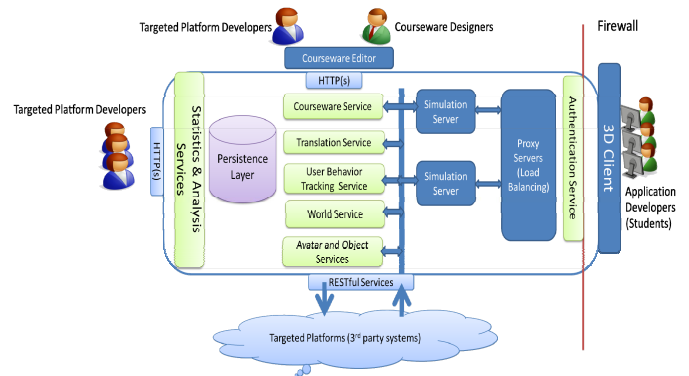


Figure 2. Framework for v-learning service platform.

The key functionalities of our V-learning platform are packaged as a suite of services. The main components and services are described as follows:

- Authentication Service, which is to authenticate users and enable single sign-on among platform services and external services.
- Proxy Servers, which provide transparent load balancing among several simulation servers.
- Simulation Servers, which are the main controller of the applications running in the platform, the script engine contained within the server can communicate with and combine all the services in the framework.
- Courseware Service, which allow rapidly create fully accessible v-learning without programming skills,

courseware designers can construct and deploy courseware components rapidly from anywhere in the world with just a web connection.

- Translation Service, which is used to translate data structures defined in courseware services and divide them into elements that can be directly understood by services running in other servers.
- User Behavior Tracking Service, which is responsible for logging user behavior data dynamically to database.
- Statistics Services, which can generate statistics and feedbacks from real users.
- Object Services, which maintain all the dynamic objects in the simulation servers, and Avatar Services which maintain all the avatar information for users.
- World Services, which maintain the topological relations between proxy servers and simulation servers and support dynamic load balancing.
- Third Party Systems. The framework support extensible external customized services for specialized application.

The framework has a number of unique characteristics:

- The system provides a highly efficient infrastructure for supporting hundreds of applications and a large number of clients.
- The system provides a set of services for courseware designer to define, build and deploy courseware together with 3D components in a easy and flexible way.
- The system provides a vivid and interesting learning environment, which can enhance the learning efficiency and effectiveness of the users.
- The system provides a set of scalable services for API designers to collect feedback information from real users, subsequently organize and analyze the collected data.
- The system is designed based on SOA principles that package functionality as a suite of interoperable services that can be used within multiple separate systems from several business domains.

Compared with the traditional 2D systems, the 3D virtual world system has some special features:

- 3D system provides a more powerful rendering form. Almost all the media formats in real world such as animation, videos, audios, images, texts and 3D scenes can be well integrated into the system.
- 3D system is the simulation of the real world, vivid scenes such as virtual classrooms, boards and projectors can bring the viewer an immersed sense.
- Shared space and real-time visibility provided by the 3D system can facilitate communication and collaboration between users.
- 3D technologies can produce better compatibility. For some 3D programming learning, the best environment is a 3D scene; for the traditional 2D programming, learning the task can also be well completed in a 3D scene.

## IV. TYPICAL USAGE SCENARIOS

In this section, we describe the typical usage scenarios of the v-learning platform. To clearly describe our approaches, we divide the section into three parts. The first part describes how to design and deploy courseware; the second part describes how to help learning the API of the target system (which is the learning process and learning pattern); the third part describes how to perform user behavior analysis and API design refinement.

### A. Courseware Construction and Deployment

#### 1) Learning Design and Construction

Before the actual learning begins, the learning objectives, learning materials and well-designed learning process must be constructed first. *Sharable Content Object Reference Model (SCORM)* [17][18][19] has produced a collection of standards and specifications for web-based e-learning. It also defines how these lower-level sharable, learning resources are aggregated and organized into higher-level units of instruction. Now SCORM has been widely adopted in commercial, educational, government, and international projects [20].

As defined in *Content Aggregation Model (CAM)* [17], asset is the basic building block of a learning resource. Assets are an electronic representation of media, such as text, images, sound, assessment objects or any other piece of data that can be rendered by a web client and presented to a learner.

In traditional web services, the services are presented to end users through 2D interfaces such as web page, screen of mobile phone devices, etc. While in virtual services, the services will be provided to end users in virtual worlds, and provide immersive 3D experiences [6]. Our platform provides a set of fundamental virtual services that can render the data described below:

- In-world white board, which are rendered in virtual worlds and present learning objects in the form of texture.
- Multimedia. Instruction design is the practice of arranging media to help learners and teachers transfer knowledge most effectively. The platform provides a set of APIs to control multimedia including audio and video.
- Web Pages. Web pages in virtual world can support a wide range of assets including HTML fragment, JavaScript function, various types of Image, and so forth.
- Runtime Services, which are NPCs (Non-player Characters), avatars, v-learning facilitation agents or 3D objects that automatically respond to users' actions in virtual worlds.

We have built lots of templates and props to help improve the efficiency of courseware construction for non-professionals, who only need to define bindings to combine their contents with predefined templates and props. They can also write their own scripts and add new models to the system to implement more complex functionalities.

#### 2) Courseware Deployment

All the materials of the courseware can be defined in a Courseware Profile Document (CPD) which is encoded into

XML format and then deployed to the framework through the courseware service. The structure of CPD document is depicted in Figure 3.

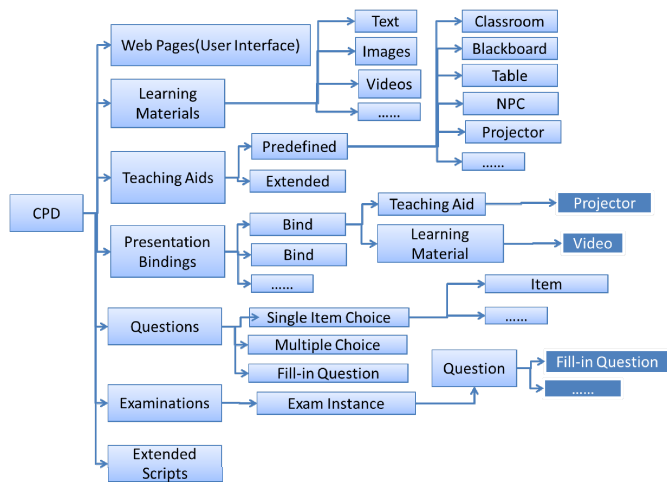


Figure 3. Structure of Courseware Profile Document.

The user interfaces in the virtual world are web pages defined in CPD. Web page is the main interaction style, they can be located anywhere over the Internet and will be downloaded if needed.

There are a number of predefined teaching aids within the v-learning platform. These teaching aids are template models of 3D object such as classrooms, blackboards, projects etc. Predefined teaching aids can be used to help rapidly building a virtual learning world for people without 3D modeling knowledge. User can also create their own 3D models for their application and import them into the world. The presentation binding elements in CPD can bind teaching aids together with other elements, i.e., learning materials that are also defined in the CPD and can be referenced in other elements. The translation service can then generate scripts for the binds automatically, in this way people with no script programming skills can also construct a vivid virtual learning world.

Like learning materials, questions are referenced in examination elements after they are defined. The examination instance will be translated to an examination paper that can be used in learning process after the CPD has been deployed.

Scripts convey all the business logic and combine all the elements together. Some scripts can be generated automatically by the platform and they are to provide basic functionalities. Users can write their own scripts for more complex features.

User can combine all the elements described above in the courseware editor and package them to deploy via the courseware service.

## B. Learning Process and Patterns

### 1) V-learning Patterns

Our v-learning service platform supports a number of learning patterns (see Table 1). These patterns were also suggested in [6].

TABLE 1 V-LEARNING PATTERNS

Learning Patterns	Description
Tutorials	the users can get help from kiosk or other utilities, this may be a user manual, a fragment of audio or API document
Co-creation	the users can work together to create 3D objects, this pattern is ubiquitous in serious games and game learning
Collaboration	the students work through the assignment until all group members successfully understand and complete it
Role playing	"Role playing is the best way to develop the skills of initiative, communication, problem-solving, self-awareness, and working cooperatively in teams" [xxx]. (role playing in education Adam Blatner, M.D.
Classroom emulation	students can benefit from the sense of massive learning environment at any time, any where
Learning by doing	this is one of the most useful patterns in the v-learning service platform for software development training, Learning by doing means users can immediately view the results caused by their operation
Quizzing	object or agents may ask questions and user answer to it. This is another useful pattern in the v-learning service platform
Simulation	the user can experience those that in real world are impossible or hard to go through

### 2) API Based Programming Learning Strategy

Various kinds of patterns can be adopted to assist programming learning, but Learning By Doing (LBD) is the most efficient way [21]. Two things are implied in LBD: first, the user needs to write down their code and comments which inspire a spirit of practice; second, the user can immediately view the results of their input.

We employ the Web-based worked-examples interface [13] to help users practicing and learning programming. There are two types of interfaces, for structure-emphasizing strategy and completion strategy, respectively.

#### a) Structure-emphasizing Strategy

The first type of interface, which supports a structure-emphasizing strategy, presents users with a worked-example. This example consists of a programming problem and a solution together with a list of plan names. Plans are modules and generic program snippets that represent stereotypes in a program.

The underlying plan contents are initially invisible. Clicking on the title pane or buttons with the plan name reveals its contents. A prompt dialog box immediately appears next to the title pane presently explored to start a self-explanation exercise. The interface provides a text area for user input. No feedback is given to users' explanations. However, after a specified period of time or some predefined events, the interface presents complete descriptions for each plan structure to allow students to reflect on their previously explanations. Examiner can also get this information from database to check the mastery of students.

#### b) Completion Strategy

The second type of interface, which supports completion strategy, is designed to encourage students to complete partial

code pertaining to a number of instances of plan structures in the example solution. The strategy requires students to study the partial code provided in the completion assignment; otherwise they cannot correctly solve the task.

The interface provides students with a text box in which they have to insert suitable code to complete the program. The framework then delivers the completed code to the running environment, which is held by 3rd party companies and described as targeted platforms in Figure 1, and gains the running result from the targeted platform. The running results are then presented to students on the correctness of answers.

### C. User Behavior Analyze and API Design Refinement

In order to analyze user behavior data, first the system needs to provide a practicable way to record user operation. Westerman described three different ways [22] in which user information can be obtained.

The first way, videotaping or a human recorder, is not always feasible. The video recording must then be analyzed, and the human recorder has known limitations. Timing information cannot be directly obtained and the created logs that are resource intensive because they are videos.

The second method, instrumentation, is the augmentation of an interface such that it records the user's actions. This approach can only be used if the system studied includes logging or can be modified to include logging. This is however not a general solution, as information collected in this way is limited to software that can be instrumented. For example, commercial applications such as Microsoft Word and many games cannot be instrumented to record user behavior.

The third method is to include an unobtrusive application that exists in the background, which can be used generically across all applications, and that records user behavior and timestamps it.

The v-learning service platform adopts the latter two methods. The scripts can handle various kinds of user keyboard and mouse actions and record them to persistence layer via the user behavior tracking service.

In virtual worlds, user operation can be grouped into two categories—operation in UI, e.g., clicking on a button to open the interface that display the user manual; and operation in virtual world, e.g., clicking on in-world 3D objects with which information, job aids and tools are associated. There are some predefined user action checkpoints supported by default, such as the time a user spends on each question, the time used on each examination, the time used in seeking user manual or API documentation, the usage times of “backspace” and “delete” key in each input unit, mistakes in API usage quiz, spelling mistakes, and syntax error in parameters.

The platform supports a set of keyboard and mouse events, ISVs can write their own scripts to handle these inputs for specialized concerns and customized purpose.

## V. CASE STUDY OF V-LEARNING SERVICE PLATFORM

In this section, we will take the API learning for the Immersive Web (IW) Platform as an example. The IW platform, which provides a solution for the development of online 3D virtual world applications that can be accessed simultaneously by multiple users provide a set of APIs for ISVs to develop 3D internet applications. The problem to be solved is that the platform is developed for ISVs which may probably not expertise in 3D application development; thus there is need for effective training methods to help ISVs to learn the APIs and programming models rapidly. Another problem is that the platform developers need to evaluate their API design, e.g., if the APIs are easy to use and if there are sufficient APIs to cover common 3D application fields. A learning sample was developed using the v-learning service platform to solve the problems described above.

After the design work and construction of the courseware, the CPD file is deployed to the servers. Users can then see the available applications from the portal in the 3D client once they have logged into the platform (see Figure 4).

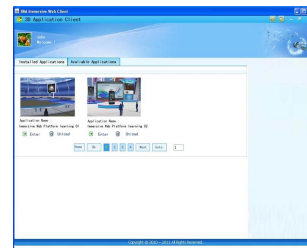


Figure 4. The portal showing the available applications.

Take one of the scenes for example, we can see a few classrooms built based on platform predefined templates in Figure 5 and teaching aids (blackboards showing information about the IW platform) in Figure 6.



Figure 5. The classrooms built from the predefined templates.



Figure 6. The portal of v-learning service platform.

Users can take exams and small quiz in their learning process. Figure 7 shows one example of the completion strategy quiz, user need to fill in the blank in the line with runnable codes.



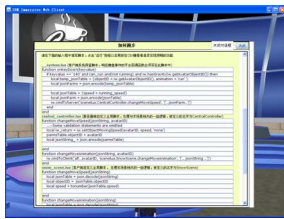


Figure 7. Completion strategy examination.

The user can immediately view the results of the running code in the virtual world, e.g., to create an object using the IW API (see in Figure 8).



Figure 8. Create an object and view the result immediately.

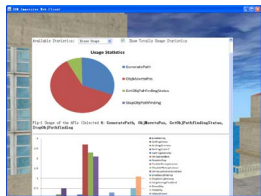


Figure 9. Statistics generated from user behavior records.

User behavior tracking data is recorded simultaneously to databases and can be used to generate statistics later. Figure 9 shows one of the statistics generated from the user input behavior. These data can be further analyzed for evidence of API design assessment and refinement.

## VI. CONCLUSIONS

Today, it is very common for Independent Software Vendors (ISVs) to carry on secondary development based on 3rd party platform. This paper presents a framework for a virtual-learning service platform that solves the following two problems: (i) the problem of shortening the learning curve in learning development on new platforms; and (ii) the problem of effectively gaining user behavior tracking data and feedback from real users for platform developers. This paper also provides an example that further describes the effectiveness of our methodology.

The future work can be carried out on how to improve the efficiency of courseware construction for non-professionals, how to provide more valuable statistics for platform developers, and how to better integrate with other existing computer-aided learning systems.

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